

## European Survey for Chemists

## Employment and Careers of European Chemists (ESEC2)

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**Abstract:** Employment conditions and career opportunities are in the focus of the new Employment Survey for European Chemists (ESEC2). Conditions and opportunities are individually analysed for all countries with a statistically significant number of responses. The results provide important clues for careers in these countries and in Europe as a whole. The importance of employer sectors varies very much between European countries. A chapter of this report is devoted to career planning of students and new graduates. This is the first general evaluation of the survey. It provides many details about the chemistry workforce in Europe and its development.

## 1. Background


The on-line questionnaire of the 2nd Employment Survey for European Chemists (ESEC2) was open for everybody in March 2017. The questionnaire was developed and the survey executed by the European Chemistry Network Association (ECTN) and the European Chemical Society (EuChemS), formerly known as European Association for Chemical and Molecular Sciences. The participating National Chemical Societies (member societies of EuChemS) cover more than 99% of the EuChemS membership.


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ESEC2 is based on the experience of the first European employment survey (ESEC1) for chemists and chemical engineers, which was carried out in 2013. The report on ESEC1 is freely accessible.<sup>[1]</sup> Both the questionnaire and the technology have been much reworked. The questionnaire of ESEC1 was offered in 24 European languages. It turned out that a number of chemists preferred to respond in English instead of their native language. For this reason, the ESEC2 questionnaire was developed in English, and the National Chemical Societies got the choice to translate it into their local language(s). Only the Norwegian Chemical Society took advantage of this possibility.

The American Chemical Society (ACS) has many more years of experience than EuChemS in organising employment and salary surveys (most recent salary survey).<sup>[2]</sup> As ACS and EuChemS surveys have similar objectives, the two societies agreed to harmonise their respective questionnaires as a first step towards a future cooperation in this field. The harmonisation already started by jointly discussing the ESEC2 questionnaire.

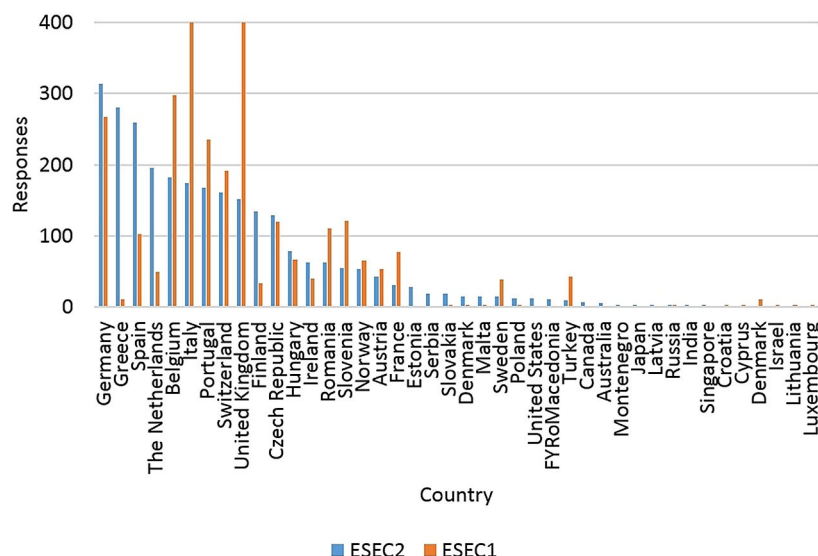
The ESEC2 questionnaire was organised in sections. Each Section was composed of questions and their possible answers by tick-boxes or pull-down menus. Free-text entries were only permitted on the concluding page of the questionnaire. Several questions were mandatory. Conditional questions appeared only in particular cases. As an example, the question concerning current M.Sc. education appeared only if the respondent on a previous page stated that they were following Master or equivalent graduate level studies. Conditional pages helped to reduce the time needed to complete the questionnaire.

This report compares results of ESEC1<sup>[1]</sup> and ESEC2, and it relates the results for the European chemistry workforce with other national<sup>[3]</sup> and global surveys.<sup>[4–6]</sup>

## 2. Survey: Participation, Questionnaire, Evaluation

A total of 2754 chemists and chemical engineers responded to ESEC2. As in the case of the report of ESEC1, this report does not differentiate between chemists and chemical engineers, and their responses have been evaluated jointly. For convenience, in this Editorial this joint group of chemists and chemical engineers will simply be referred to as “chemists”. No irregular responses were identified in ESEC2, most probably because of the improved technology used for the on-line questionnaire. All responses were stored in anonymous form.

Compared to ESEC1, less responses were received for ESEC2. This was mainly caused by distinctly lower participation from



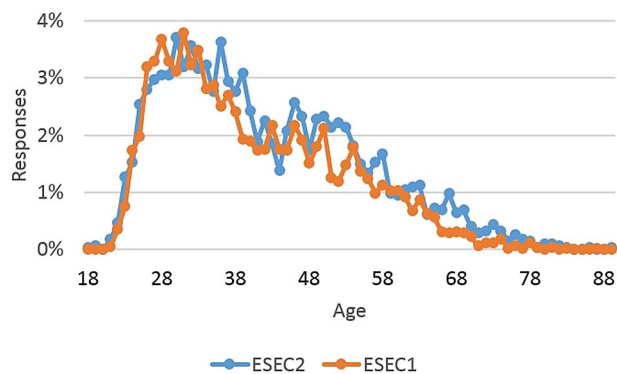
**Figure 1.** Comparison of the numbers of responses from current working or studying countries for ESEC2 (blue bars) and ESEC1 (red bars). The sequence of countries corresponds to the number of responses in ESEC2. Responses from Italy and United Kingdom to ESEC1 are out of scale (Italy: 986, UK: 887).

Italy and the United Kingdom (Figure 1). Other countries submitted more responses, hence participation from different European countries was much more uniform than in ESEC1. It was already mentioned that for ESEC1 "results of a cross evaluation might be dominated by the large share of respondents from Italy and the UK. ... This called for an evaluation of individual countries together with the joint evaluation of all European responses".<sup>[1]</sup> This country-specific evaluation clearly revealed differences in traditions and/or conditions between various European countries. For statistical reasons only countries with more than 100 responses were evaluated individually. The same approach was again chosen for evaluating the ESEC2 data. Czech Republic is the last of 11 countries in Figure 1 with more than 100 responses.

Some figures are based on the evaluation of all responses, other figures depict the situation for a particular group of respondents. It is stated in the legend of the Figure, if it refers to a particular group. Nothing is stated in the legend in cases where the Figure covers all responses. The number of responses, both in case of all responses or of a particular group, may vary slightly between figures as not all respondents filled in all the questions.

As in case of the first survey, the ESEC2 questionnaire had six general sections (Personal/Education/Employment/Job/Training/Salary). M.Sc. students, postdocs, Habilitation students (postdoctoral qualification, fellow) and industry employees were asked dedicated questions in special sections. The participation of industry employees accounted for 38% of the responses. This group covered manufacturing industry, non-manufacturing industry, self-employed chemists, and publishing houses. The distinct reduction in industry participation was partly caused by the smaller number of responses from the UK, which in ESEC1 had a dominating industry participation (61%).

As for the ESEC1, the age of the respondents exhibits a distinct maximum around 30 years of age (Figure 2). This coinci-



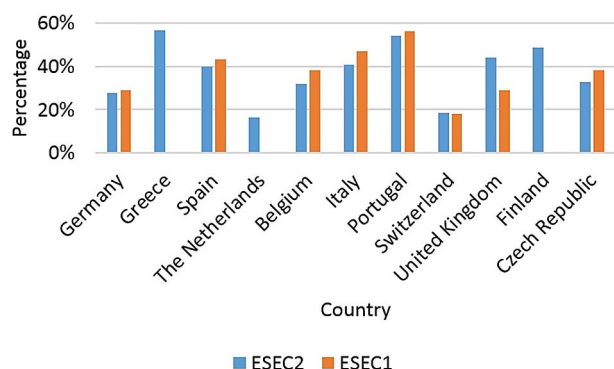
**Figure 2.** Comparison of the age distribution of respondents for ESEC2 (blue line) and ESEC1 (red line).

dence is an indication that some results of cross evaluations may not depend on varying participation from different European countries while other are very dependent, like the industry participation discussed above. Further examples will be found below. 1734 responses (63% of all answers) came from chemists who graduated within the last 15 years.

The youngest respondent was aged 18 and the most experienced one was 89 years old. Pensioners submitted 4% of all responses, students 4% as well. Only 4% of all respondents were not employed or were seeking employment.

The overwhelming contribution (80% of all responses) came from colleagues having either a full-time or a part-time job. 2% of all respondents are self-employed, 5% accepted postdoc or fellowship positions.

The total share of women in the survey was 41%, compared to 39% in ESEC1. Comparison of the two values gives an indication for the degree of reliability of the obtained values. These values coincide with recent data from Eurostat:<sup>[7]</sup> From the 17 million scientists and engineers in the EU, 40% are women and 60% men. But while women currently hold the

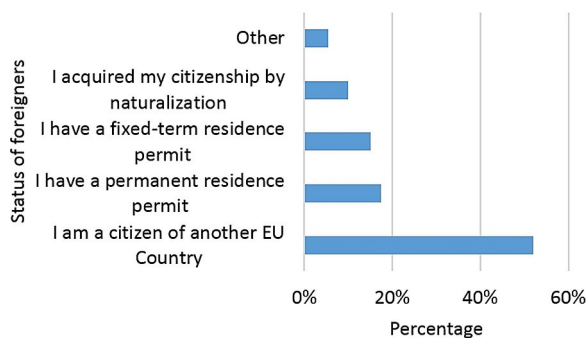


**Figure 3.** Share of women in the chemistry workforce of the 11 most responding countries and comparison of ESEC2 (blue bars) and ESEC1 (red bars). Greece, The Netherlands and Finland did not submit sufficiently many responses in ESEC1 to be individually evaluated.

majority of jobs in science and technology in service activities, they only account for 28.4% in manufacturing.<sup>[7]</sup>

The significant differences in the participation of women in the chemistry workforce between countries remain (Figure 3). 69% of the chemists are married, 97% of the partners live in the same country. Of married chemists with partners living in the same country, 46% have children below 18 years. 33% of married chemists with partners living in a different country have children below 18 years. 5% of not married chemists have children below 18 years.

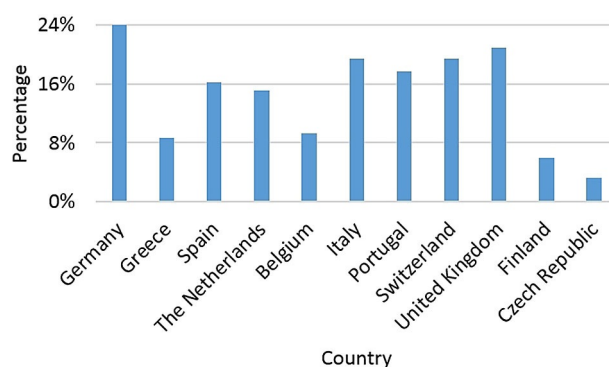
83% of all ESEC2 respondents live in their native country with almost no difference between females and males. In a corresponding ACS survey,<sup>[8]</sup> 85.7% of the respondents are U.S. natives. The majority of the ESEC2 respondents who do not live in their native country are citizen of another EU country (Figure 4).



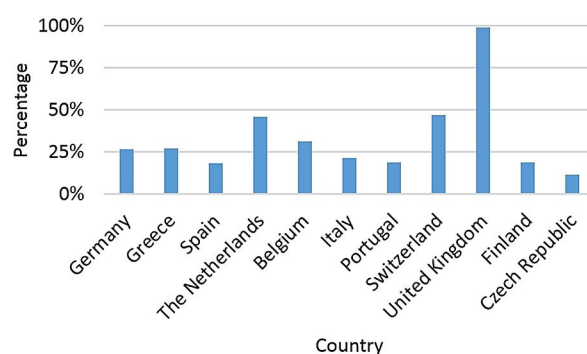
**Figure 4.** Status of foreigners among all respondents of ESEC2.

The percentage of responses from chemists in the 11 most responding countries, who do not work or study in their native country, varies between 24% (Germany) and 3% (Czech Republic) (Figure 5).

With on average almost 20% of foreigners working in the 11 most responding countries, it is not a surprise that many workers use English at work (Figure 6). Apart from the UK, almost 50% of the chemists in The Netherlands and in Switzerland speak English at work. In countries with more than one local language, in our responses Spanish and Catalan have almost



**Figure 5.** Responses from chemists in the 11 most responding countries, who do not work or study in their native country.



**Figure 6.** Share of chemists in the 11 most responding countries, who speak English at work.

the same share in Spain, German dominates by a factor of 4 over French in Switzerland. The share of French in the Belgian chemistry workforce in the ESEC2 responses is 1%.

### 3. Education

The following graduation levels have been surveyed:

- Post-secondary level (begins at the end of full-time compulsory education), (General and vocational; lab assistant, technician)
- Short-cycle tertiary level (link between vocational education and tertiary education at colleges, universities and polytechnics)
- Bachelor or equivalent graduate level
- Doctoral or equivalent graduate level
- Habilitation (Dr. habil., Dr. sc., or similar)
- Other qualification

Like in ESEC1, the dominating qualification in the chemistry workforce in Europe according to ESEC2 is Ph.D. (47%) (Figure 7). A M.Sc. degree is held by 34% of the respondents, followed by holders of a B.Sc. degree and of a Habilitation degree (8% each). All kinds of post-secondary, short-cycle tertiary or other qualifications did not get sufficiently many responses to be evaluated further. For comparison, the percentage of ACS members in 2015 with Ph.D. has risen to 66%,

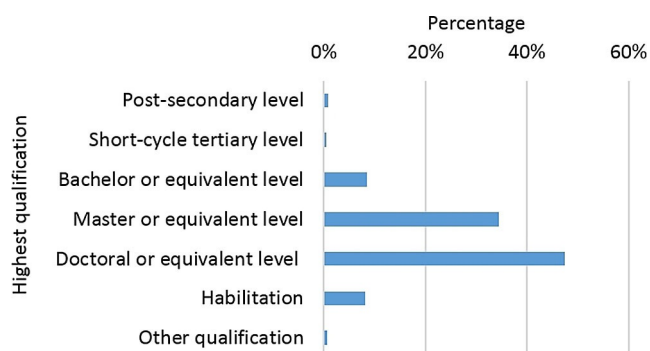


Figure 7. Highest qualifications acquired by respondents of all ages.

whereas the shares declined for holders of M.Sc. (16%) and B.Sc. (17%) degrees.<sup>[9]</sup>

Shares of graduation levels differ very much between the 11 most responding countries (Figure 8). Only graduates of the last 15 years are included in order to provide a good impression of the current situation. When discussing Figure 8, it has to be taken into account that all these countries have very different traditions in their educational systems and as a result in their job markets. As stated in the Eurydice Report 2017 on Modernisation of Higher Education in Europe: Academic Staff-2017: "The degree of difference in academic staff categories from one country to another is a striking feature of the European higher education landscape".<sup>[10]</sup> This explains in particular the large variation in the share of jobs for B.Sc. holders. On the other hand, Habilitation degrees are uncommon in some countries, in other countries they have very divergent meanings. For these reasons, most reliable is the comparison of the shares of M.Sc. and Ph.D. holders as these degrees play very similar roles in the different countries (Figure 9). But also under these conditions, variations between countries are surprisingly

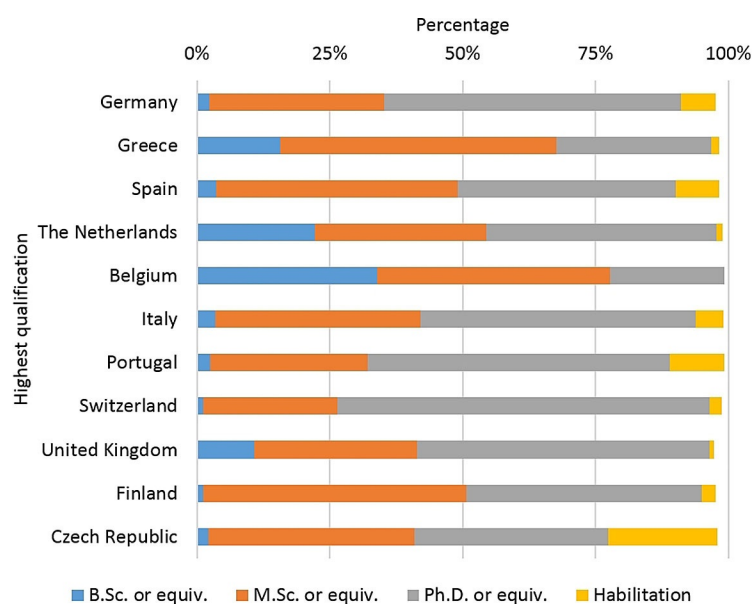


Figure 8. Main qualifications levels of the graduates of the last 15 years in the 11 most responding countries.

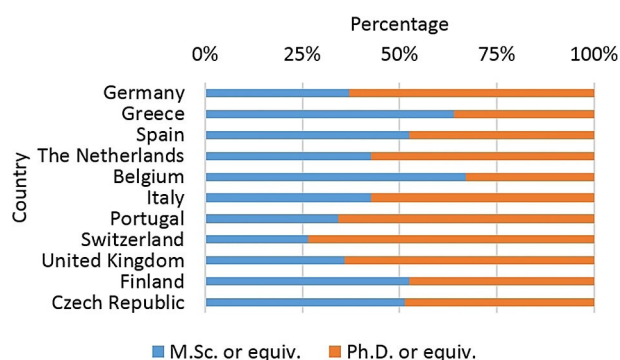


Figure 9. Relation between holders of M.Sc. and Ph.D. degrees among the graduates of the last 15 years in the 11 most responding countries.

large. The most divergent values are 73% Ph.D. holders in the chemistry workforce in Switzerland, compared to merely 33% Ph.D. holders in Belgium.

In addition to the graduation level, the chemical sub-discipline chosen for the highest qualification is of importance for careers of graduates. Figure 10 relates the chemical sub-disciplines chosen by graduates of the last 15 years to the preferences of those who graduated before 2002. The dominating role of Organic Chemistry before 2002 is clearly depicted, as is the distinct loss in this dominance in recent time. In contrast, Medicinal/Pharmaceutical Chemistry shows the largest relative increase in its share.

Preferences for chemical sub-discipline chosen for the highest qualification by graduates of the last 15 years vary significantly between countries. This is illustrated in Figure 11 for the 7 dominating chemical sub-disciplines in the 11 most responding countries. Organic chemistry dominates in Switzerland, The Netherlands and Spain, whereas it is much weaker in Belgium and Portugal. Physical chemistry dominates only in Germany. Analytical chemistry is dominating in Greece, Chemical engineering in Belgium.

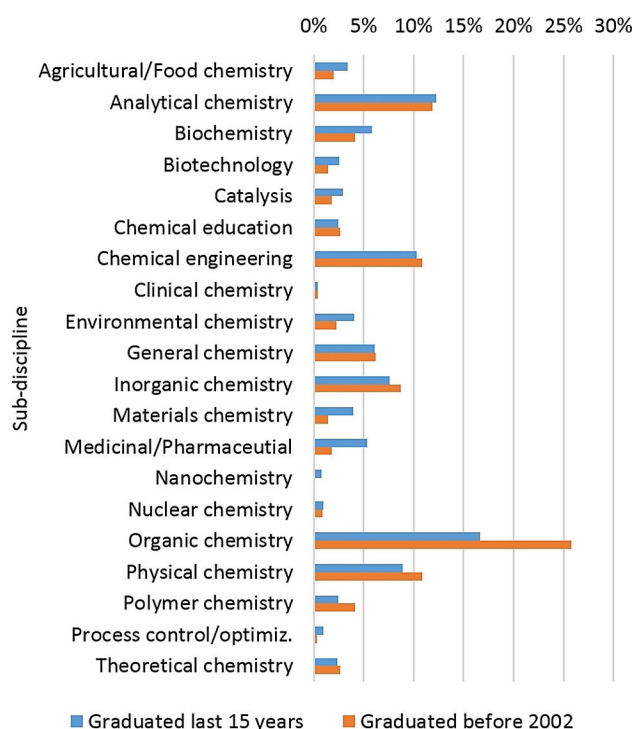
Different chemical sub-disciplines have different favourite qualification levels (Figure 12). Almost 70% of the respondents, who graduated in Physical Chemistry during last 15 years, hold a Ph.D. In Agricultural/Food Chemistry in contrast, more than 60% of the graduates of the same period hold a M.Sc. degree.

#### 4. Career planning

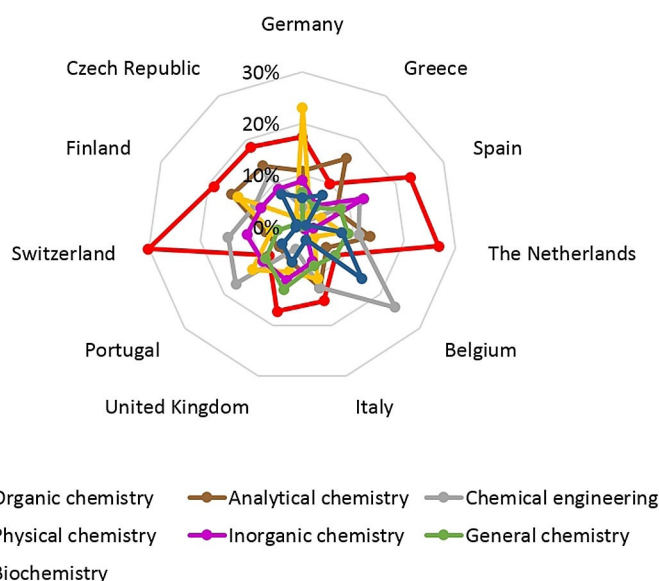
Specific questions were presented to current M.Sc. and Ph.D. students, to Habilitation students and research fellows, to current postdocs and prior postdocs. Habilitation students and research fellows are jointly evaluated and called Habilitation students. 33% of all respondents have completed a postdoctorate or Habilitation position. Due to a technical problem, no responses from current Ph.D. students could be collected.

Current M.Sc. students were asked to what extent they have already thought about their future career





**Figure 10.** Chemical sub-disciplines chosen for the highest qualification by graduates of the last 15 years (blue bars) and by those who graduated before 2002 (red bars).



**Figure 11.** Chemical sub-disciplines chosen in various countries for the highest qualification by graduates of the last 15 years. Shown are the seven dominating sub-disciplines. The data are normalized to 100% for each country in order to ensure comparability.

plans. Almost 50% of the respondents admitted that they did either not or only to a small extent/to some extent think in advance about their future career (Figure 13). This is surprising as career guidance services are available to all students in higher education institutions throughout their course of study in the vast majority of education systems.<sup>[11]</sup> As to current Habilitation students, almost half of them thought only to some extent

about their further career. The other part responded to the same question that they thought not at all or only to a small extent about their further career. Exact data are not displayed here as the number of responses from current Habilitation students is too small to be evaluated quantitatively.

As to their future plans after completing their current degree, at least half of all respondents intend to stay in the EU or EFTA permanently (Figure 14). In the case of Habilitation students, this value even reaches more than 80%. On average, 15% of all respondents plan to work in the EU outside their home country for some years and return back to their home country afterwards. Another 15% do not know yet what they are going to do after completion of their current degree. Around 10% of current postdocs want to return home right away after finishing their current contract.

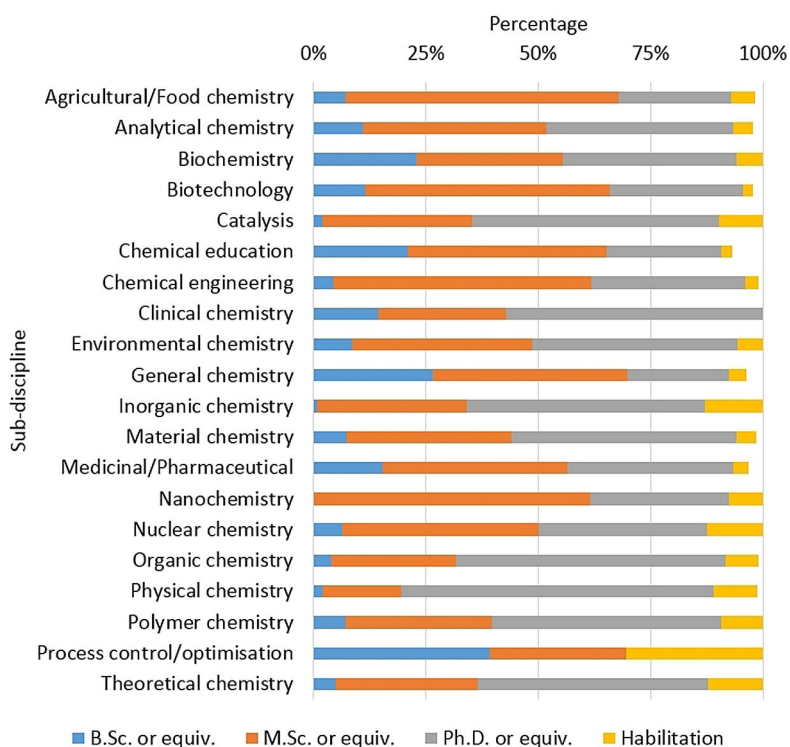
Both prior and current postdocs were asked why they did a postdoc (Figure 15). The most frequent motivation (more than 40%) wanted to deepen their skills in a particular area. Two interesting differences are seen between the answers of prior and current postdocs. The aim of deepening particular skills is more pronounced in the case of prior postdocs, whereas many more current postdocs experienced difficulties finding another job and chose a postdoc position as a career bridge.

Postdocs have also been asked what would be their most preferred career, assuming they had the choice. A clear dominance is stated for university faculty with emphasis on research or development (Figure 16). Two interesting differences between prior and current postdocs become visible: Around twice as many current postdocs than prior postdocs prefer a governmental or research institute, whereas twice as many prior postdocs prefer an established firm. This difference may reflect the economic situation in several countries during recent years.

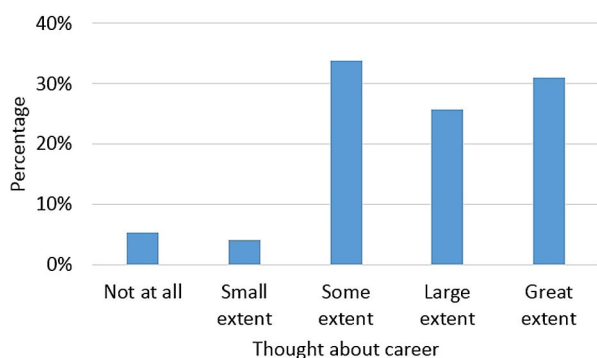
A similar survey was done in 2013 among Ph.D. students at 39 research-intensive universities in the USA.<sup>[5]</sup> The results in<sup>[5]</sup> Figure S1 differ very much from the results in Figure 16: The most attractive career for a U.S. Ph.D. without a postdoc plan is an established firm (63%), for Ph.D. students with a postdoc plan it is university faculty with an emphasis on research and development (51%).

A comparison of the most preferred career of prior postdocs with the actual situation on the current job market shows the enormous difference between the intentions of prior postdocs to be employed as university faculty and the total number of jobs there (Figure 17). The latter is only half the size of the former, and the latter indicates the total number of faculty jobs but not the number of vacancies. The dominating orientation towards a career as university faculty until the highest degree was achieved and the small chances of getting such a job afterwards is found around the globe and is criticised (e.g., [12]).

Sometimes it is assumed that the strong desire for a career as university faculty is supported and promoted by the current university staff. For this reason, we asked all postdocs and Ha-



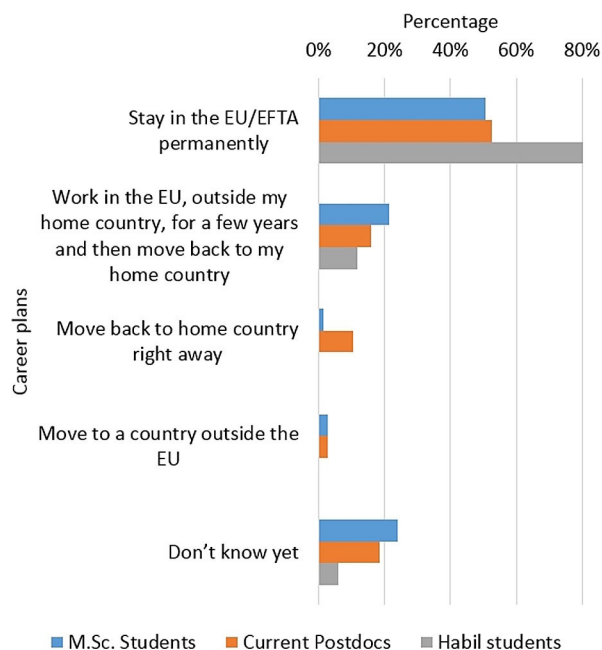
**Figure 12.** Comparison of the highest qualification levels of graduates of the last 15 years in the different chemical sub-disciplines. Differences from 100% indicate that not all respondents answered this question.



**Figure 13.** Responses by current M.Sc. students to the question: "To what extent have you already thought about your future career plans?"

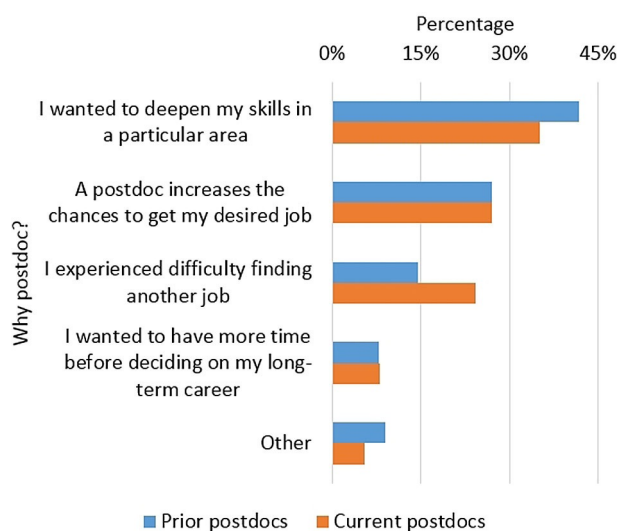
bilitation students "In your lab/department, to what extent have postdocs been encouraged or discouraged to pursue a career as university faculty with an emphasis on research or development?" On average, 40% say they have been encouraged, the same percentage states they have been neither encouraged nor discouraged, whereas around 20% of the graduates feel they have been discouraged (Figure 18).

Postdocs and Habilitation students are facing crucial decisions at the end of their current education segment. They were asked whether they think they have enough information about the various career options. Responses by current postdocs are shown in Figure 19 as this group should best reflect the actual situation. The top information status is reported for university careers, but even here, only less than 60% of the postdocs think they have enough information. The information

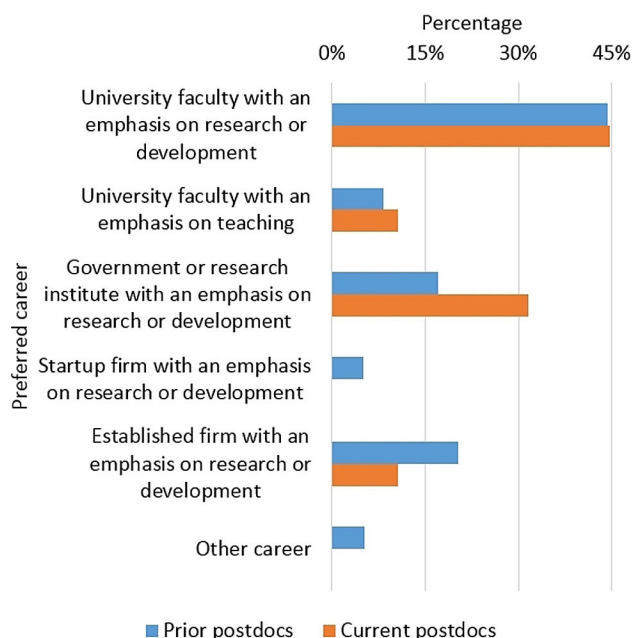


**Figure 14.** Future career plans of current M.Sc. students (blue bar), current postdocs (red bar) and Habilitation students (grey bars).

status on all career options outside university is below 30%, which cannot be considered as sufficient. More than 75% of all current postdocs wish to have more information about careers in any kind of industry. More than one third of all current postdocs even report severe lack of information about start-up companies and about non-research careers outside the tradi-



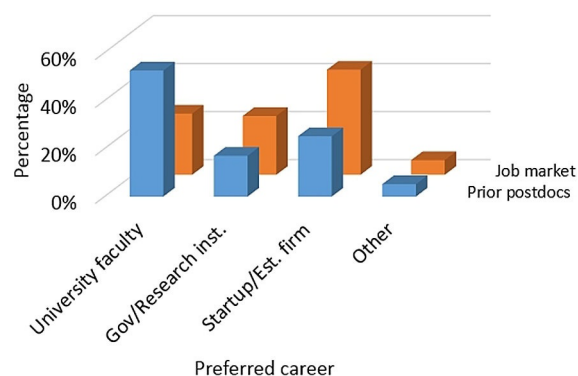
**Figure 15.** Factors dominating the decision to do a postdoc, comparison between prior postdocs (blue bar) and current postdocs (red bar).



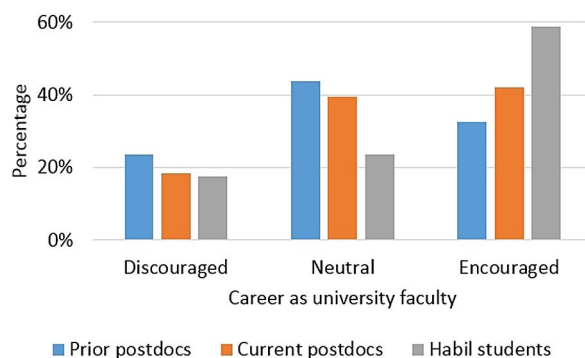
**Figure 16.** Preferred careers of prior postdocs (blue bar) and current postdocs (red bar) in case they had the choice.

tional fields of chemistry. It is stated in the Eurydice Report 2017 on Modernisation of Higher Education in Europe: Academic Staff-2017: "Top-level authorities rarely develop mid or long-term national strategies for human resource planning in higher education".<sup>[10]</sup>

No significant change in the information status can be observed when postdocs and Habilitation students of different ages are compared (Figure 20). Promises of careers outside traditional areas of chemistry have been discussed for years,<sup>[13]</sup> but educational institutions apparently did not find ways to provide this information.



**Figure 17.** Preferred careers of prior postdocs (blue bar) compared to the real job market (red bar).



**Figure 18.** Responses whether graduates have been discouraged or encouraged to pursue a career as university faculty with an emphasis on research or development.

## 5. First Job

Among the ESEC2 respondents, 71% of the graduates of the last 15 years found their first job immediately after graduation. In order to detect tendencies, we compared types of contracts for first jobs and types of contracts for current jobs. This was done for the graduates of the last 15 years as well as for all respondents (Figure 21). First job contracts remained more or less unaltered between respondents of all ages (blue bars) and the graduates of the last 15 years (red bars). In contrast, significant changes can be observed when first and current job contracts (grey bars) are compared for the graduates of the last 15 years. The share of permanent contracts has roughly doubled for this group, whereas all other types of contracts declined correspondingly.

According to an ACS survey in 2014,<sup>[8]</sup> the percentage of new grads who found full-time, permanent positions was 29.6%, whereas the share of graduates taking on part-time or temporary work was 18.8%. Comparison between these ACS data and those in Figure 21 is restricted as Figure 21 includes both full-time and part-time contracts and not only responses by graduates of 2014.

For ESEC2, 12% of the graduates of the last 15 years did find their first job within six months after graduation, whereas 16% needed more than six months. This value is identical to

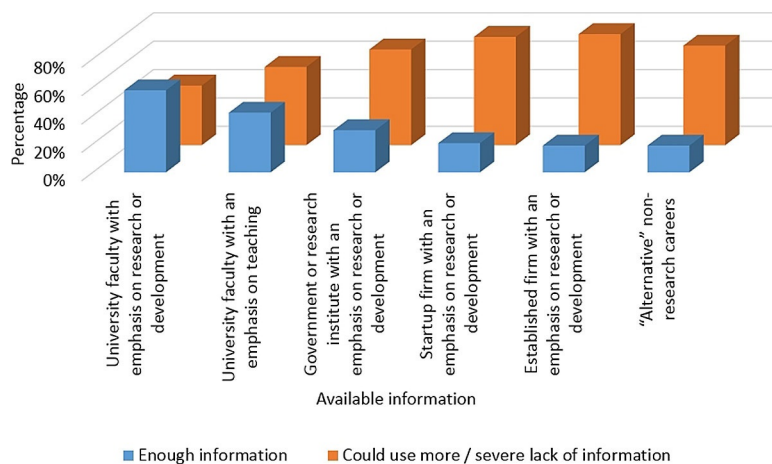


Figure 19. Responses by current postdocs on the availability of information about various career options.

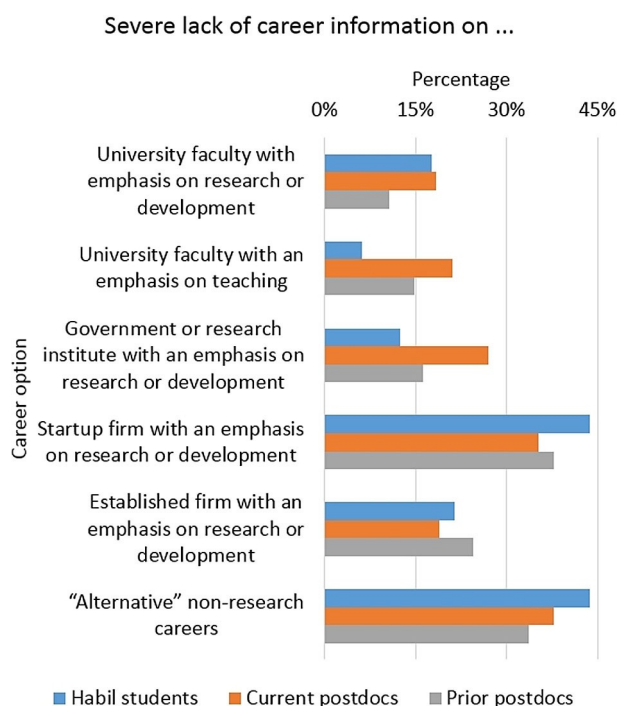


Figure 20. Postdocs and Habilitation students of different ages continue to experience severe lack of information on various career options.

ACS reports that 16% of young graduates do not have employment six months after entering the job market.<sup>[14]</sup> We also evaluated the number of months needed by those graduates of the last 15 years, who did not find their job immediately (Figure 22). The highest number available from the pull-down menu was 99 months. Some respondents simply clicked this. Obviously, many of the respondents thought in years rather than months and selected 6, 12 or 24 months in the pull-down menu. The median time needed by all respondents is 8 months if the first job was not found immediately.

For the 11 most responding countries, we separately evaluated the number of months needed by the graduates of the

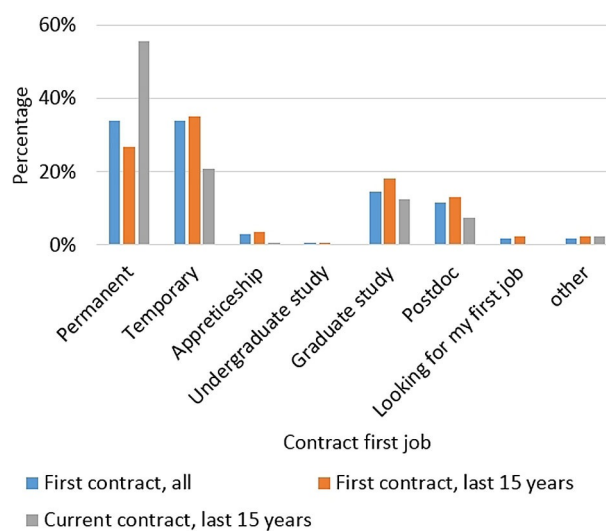


Figure 21. Job contracts for the first jobs of all respondents (blue bars), first jobs of the graduates of the last 15 years (red bars) and current job contracts of the graduates of the last 15 years (grey bars).

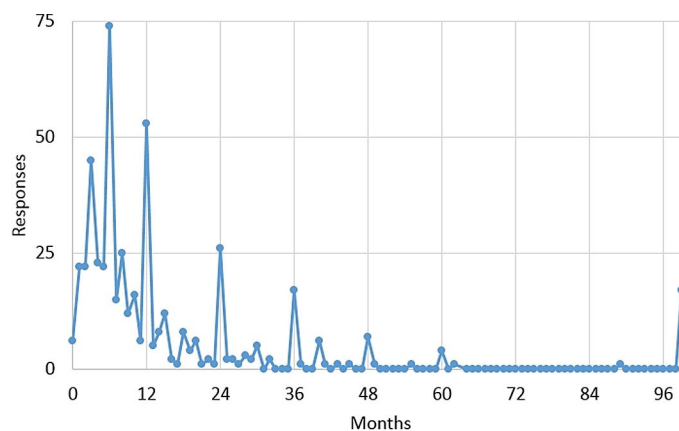
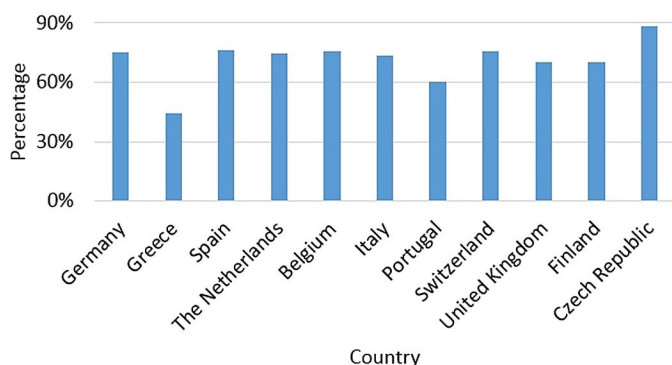


Figure 22. Months needed to find the first job by graduates of the last 15 years, who did not get their first job immediately.

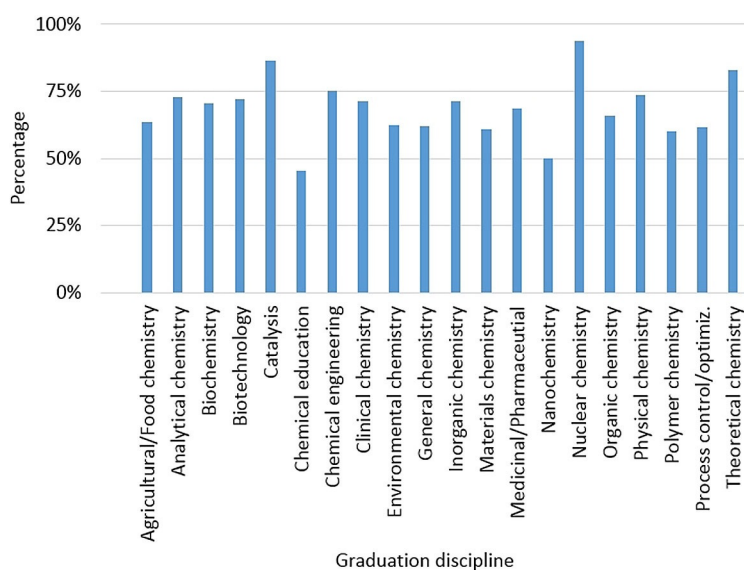


last 15 years to find the first job immediately (Figure 23). Only three significant deviations from the average value of 71% are seen. Still particularly bad is the situation in Greece, less so in Portugal. An outstanding positive deviation is found for the Czech Republic, where 88% report that they found their first job immediately after graduation.



**Figure 23.** Share of graduates of the last 15 years in the 11 most responding countries who found their first job immediately.

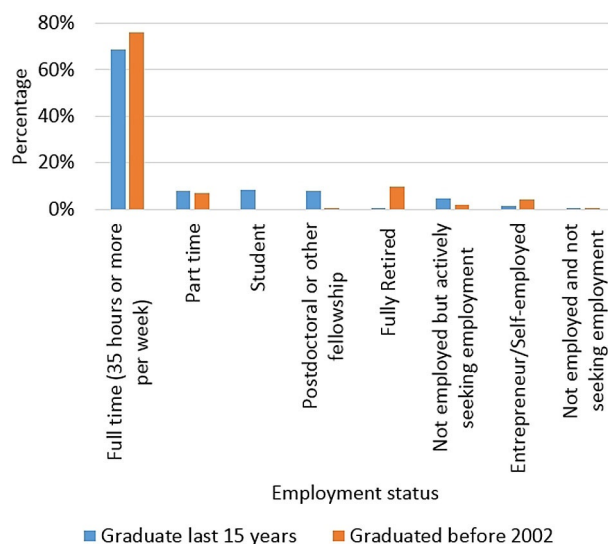
Chances of finding the first job immediately after graduation may depend on the graduation discipline. The results for the graduates of the last 15 years are shown in Figure 24. A distinct minimum is found for chemical education. The best chances are reported by graduates in nuclear chemistry. Possible relations between these findings and the situation on the job market will be discussed in the next chapter.



**Figure 24.** The role of graduation discipline on the share of graduates of the last 15 years who found their first job immediately.

## 6. Current Job, Requested Qualification, Satisfaction

The vast majority of chemists work full time (35 hours or more per week, Figure 25). No significant difference is observed between those who graduated prior to 2002 and those who graduated afterwards. It must be taken into account that among the graduates of the last 15 years we still have students and research fellows, who do not count as full-time employees.



**Figure 25.** Comparison of the employment status of chemists who graduated within the last 15 years (blue bars) and those who graduated prior to 2002 (red bars).

As to the real weekly working hours, all respondents report 41 hours (median). There is no difference in the median value for females and males. The 11 most responding countries could be evaluated separately. Except Switzerland and Germany, the result was 40 hours per week. For Switzerland 45 hours per week was reported, for Germany 42 hours per week.

Whereas no difference for females and males was found for the median weekly working hours, a distinct difference was seen for the primary employment status (full time or part time) as of March 1st, 2017. Among the male respondents, 73% work full time and 6% work part time. Among the female respondents, 69% work full time and 10% work part time. This corresponds well with a study of 1200 US graduates that, outside academia, female scientist tend to work slightly fewer hours than do their male counterparts.<sup>[15]</sup> That paper did not examine scientists' family status.

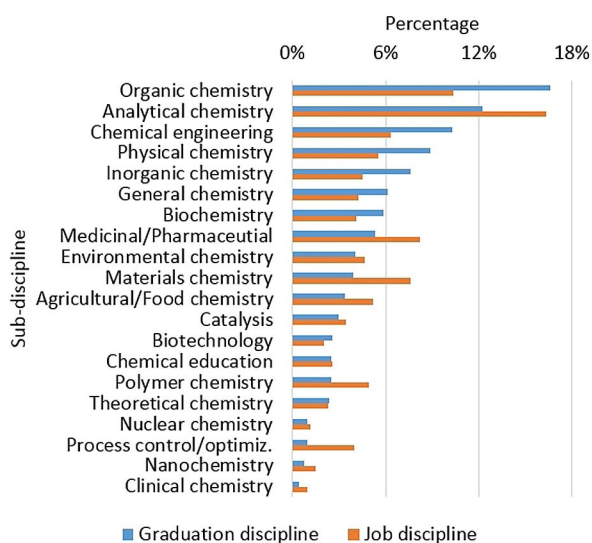
Some of our colleagues work very many years for the same employer (blue line, Figure 26). On the other hand, it seems that an increasing number of respondents is already changing employers after a



**Figure 26.** Comparison how many years all respondents worked for their current employer (blue line) and how many years passed since graduation (red line).

short time. This would be a wrong conclusion as we have many more younger respondents than aged ones. In order to clarify the real situation we overlaid the graph for the years worked for the current employer and the graph for years passed since graduation (red line). The two curves fit surprisingly well without any prior normalisation of the data or similar mathematical treatment. The close correlation of the two curves (years worked for the current employer and years since graduation) indicates that chemists are satisfied with their jobs and do not change often.

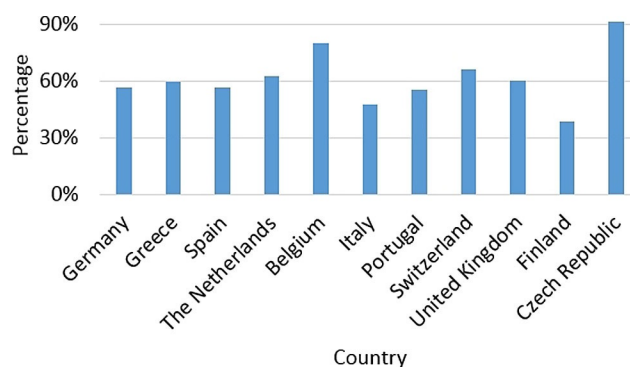
Very interesting is the comparison of the graduation discipline of recent graduates with their current job. The respondents were asked: "Which chemical discipline is dominant in your current professional activity?" The large discrepancy between hard skills acquired by education (Figure 10) and those required in the job is obvious from Figure 27. Most outstanding examples are Organic chemistry with almost twice as many offers for graduation (blue bar) than available jobs (red bar), whereas in Analytical chemistry the number of jobs (red bar) is



**Figure 27.** Comparison of the chemical sub-disciplines chosen for the highest qualification by graduates of the last 15 years (blue bars) and the job discipline in the real working world (red bars).

distinctly higher than the number of graduates completing their qualification in this field (blue bar). The good availability of jobs in Analytical chemistry has been evident for several years and is observed in the USA as well: "Industry's demand for analytical chemists is growing, but some worry whether the academic pipeline can keep pace".<sup>[16]</sup> In general, one can see that graduation in traditional areas of chemistry exceeds the number of jobs offered in these sub-disciplines, whereas education in younger subdisciplines such as Materials chemistry or Process control and optimization needs to be strengthened. Some educational institutions might develop their focus in order to enable their graduates to compete successfully on the globalized job market.

Industry employees involved in hiring personnel were asked whether they experience difficulties in hiring qualified people. Responses are very different for different countries (Figure 28). In Finland, less than 40% of the recruiters report difficulties. The other extreme is the Czech Republic, where 91% of the recruiters complain about a lack of qualified candidates. The data in Figure 28 comprise both quantitative considerations (currently fewer jobs for chemists) as well as qualitative aspects (applicants with skills other than those demanded, cf. Figure 27).



**Figure 28.** Response by industry employees involved in hiring people on difficulties to find qualified applicants. The ordinate scale indicates the percentage of recruiters in the particular country who report difficulties in hiring qualified personnel.

Job functions for graduates in chemistry are very diverse, for example, Education, must not be confused with graduation disciplines, e.g., Chemical education, or education sectors, e.g., Higher education. Research and development is dominant by far (44% of all respondents, Figure 29). Education is second (16%). None of the other job functions has a share of more than 6%.

It was expected that job functions might be somewhat different for graduates of different subdisciplines. To address this question we investigated the relation between the 11 dominating job functions and the graduation disciplines of the job owners (Figure 30). Research is the dominating job function for graduates of all subdisciplines except Chemical education, with a focus on education: 42% of all graduates in Chemical education report Education as their job function. Graduates of the two subdisciplines Environmental chemistry and Agricultur-

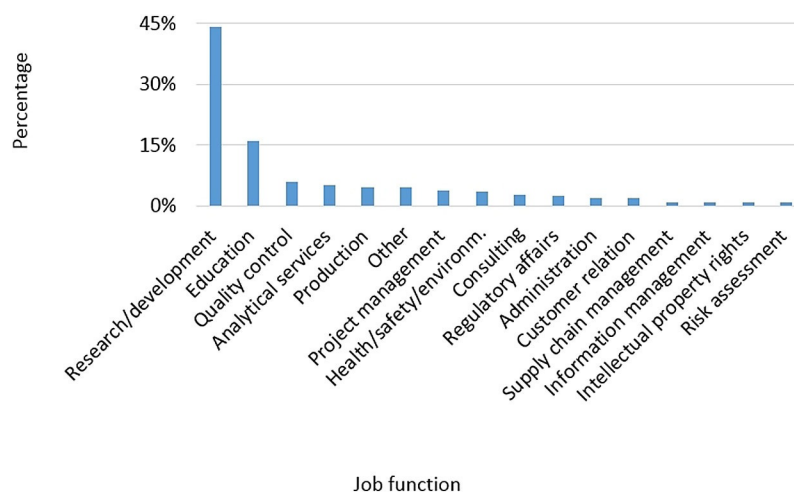


Figure 29. Job functions reported by all respondents.

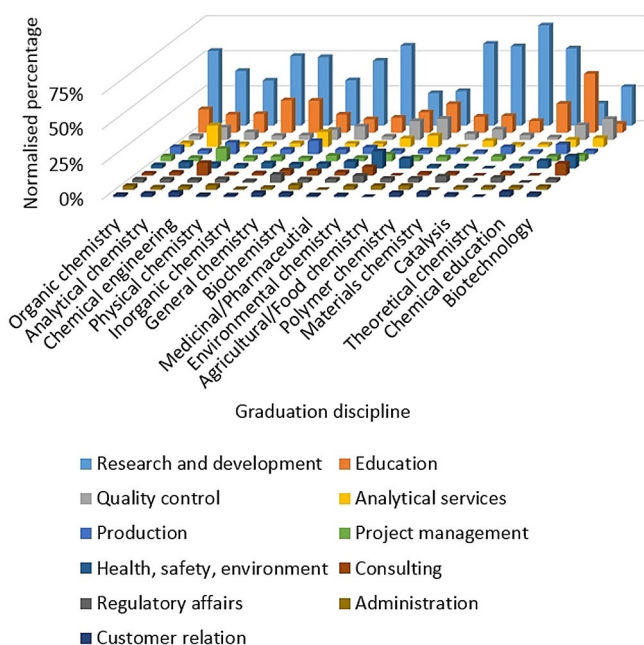


Figure 30. Importance of the most frequent job functions for graduates of different graduation disciplines. To permit comparison between graduation disciplines, the number of responses for each graduation discipline was normalised to 100%. Responses by all graduates are evaluated. Please note the different meaning of “chemical education” as graduation discipline and “education” as job function.

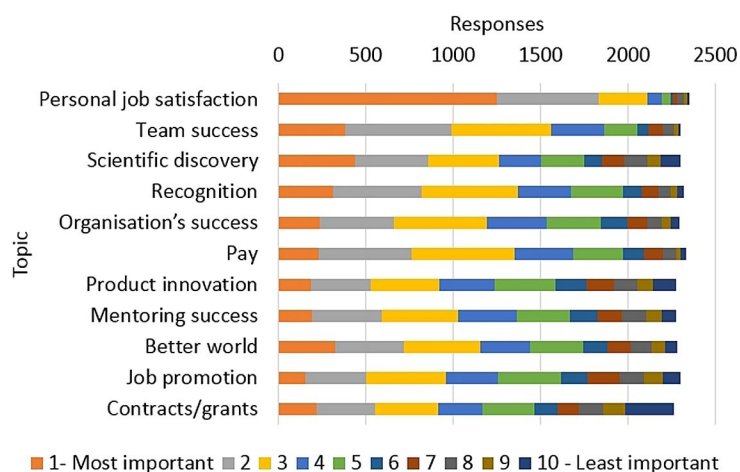
al/Food chemistry are less frequently working in research and development than graduates of the other branches. The job function Education plays a role for graduates of all subdisciplines, in particular for graduates in Physical chemistry and Inorganic chemistry. This might partly be caused by the smaller number of jobs within these graduation disciplines (Figure 27).

Satisfaction in the job is of great importance. In ESEC2, this area was surveyed in more detail than in ESEC1. Respondents were asked to value 11 topics for their importance to job success: personal job satisfaction, team success, scientific discovery, recognition, organisation’s success, pay, product innova-

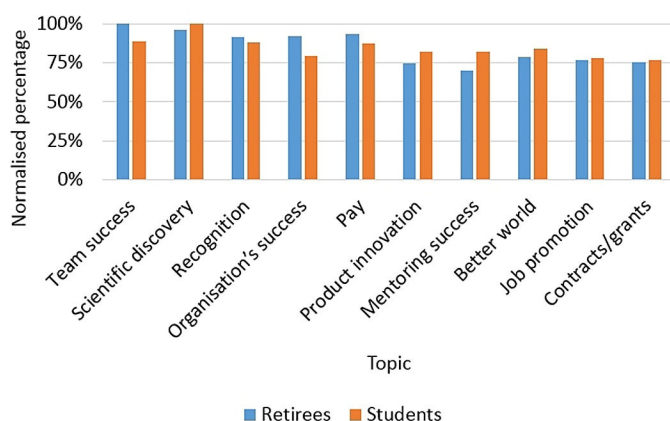
tion, mentoring success, better world, job promotion, contracts/grants. Each of these topics should be assigned a score between 1 (most important) and 10 (least important). The frequency of scores, that is, how often a particular score was chosen, varies much between topics (Figure 31). To evaluate the results in Figure 31 in a very easy manner, one may just look at the dominating positive scores (values 1–4), that is, the size of the red-grey-yellow-blue columns. The largest column is found for Personal job satisfaction (top row in Figure 31), followed by Team success, Recognition and Pay. The smallest column is observed for Contracts/grants. It should be noted that even this smallest positive column comprises more than 50% of the responses. Only slightly longer than Contracts/grants are Product innovation, Job promotion, Mentoring success.

It was interesting to evaluate how the scoring changes over time and over the professional life of the respondents. For this reason, we evaluated students and retirees separately. To attain this goal, we reduced the scores for each of the above topics to a single number. This was achieved by multiplying the score frequencies with the corresponding score weight (score 1—most important: weight 10; score 10—least important: weight 1). These integrated scores were systematically higher in the case of students compared to retirees. In order to enable a reasonable comparison, the integrated scores have been normalised to 100% for each of the two groups separately and displayed as stacked bars (Figure 32). As retirees and students are often not employed, the topic Personal job satisfaction was not included in Figure 32. For retirees (blue bars), topics Team success, Scientific discovery and Pay are scored higher. Students rank highest Scientific discovery, Team success, Recognition and Pay.

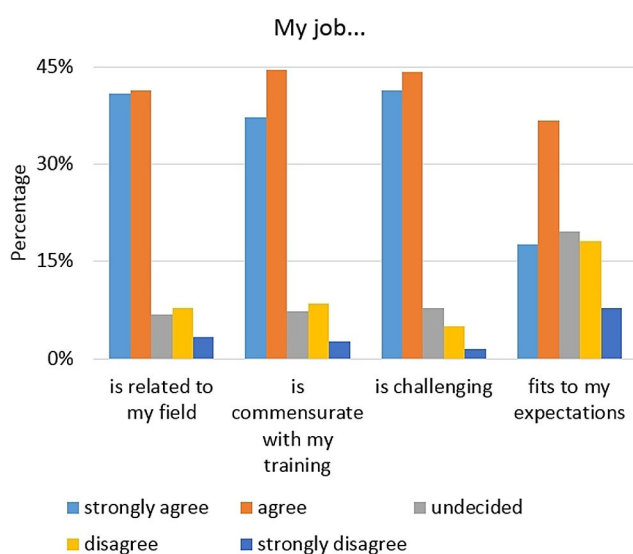
Chemists are very satisfied with their current job. More than 80% strongly agree or agree that their current job is related to their field (Figure 33). The same holds true for the statement that their job is commensurate with their training. Even 85% define their job as challenging (strongly agree or agree). Still 55% find their job fits to their expectations (strongly agree



**Figure 31.** Definition of job success by all ESEC2 respondents. 11 topics have been scored. Scores range from 1 (most important) to 10 (least important). The frequency of score assignment is depicted. The total number of responses per topic vary as not all respondents scored all topics.



**Figure 32.** Definition of job success by retirees (blue bars) and students (red bars). Scores per topics have been integrated and normalised to 100% for retirees and students separately.



**Figure 33.** Current job and satisfaction (all respondents).

and agree). On the other hand, more than 25 % disagree or strongly disagree here. Our data do not yet permit to identify the reason for this distinctly less positive result that their job fits to their expectations.

## 7. Employers for Chemists

Of all chemists employed in industry, 63% work in large companies (more than 250 employees and a turnover of more than 50 Mio EUR/year). Small and medium enterprises with less than 250 employees and a turnover of less than 50 Mio EUR/year employ 35% of the ESEC2 respondents. The remaining 2% report industry associations or platforms as employer. Of all companies, 59% make business worldwide. 18% of the companies have their focus on the EU, 14% consider the national market as most important for them, 9% are oriented towards local or regional activities. By far most of the companies (77%) have R&D departments. In 2016, the sector Chemicals showed a global R&D growths rate of 2.3%. The growths rate of this sector in the EU amounted to 6.7%. As to the R&D intensity (R&D as percentage of net sales), the chemicals sector belongs to the medium-high R&D intensity sectors.<sup>[17]</sup>

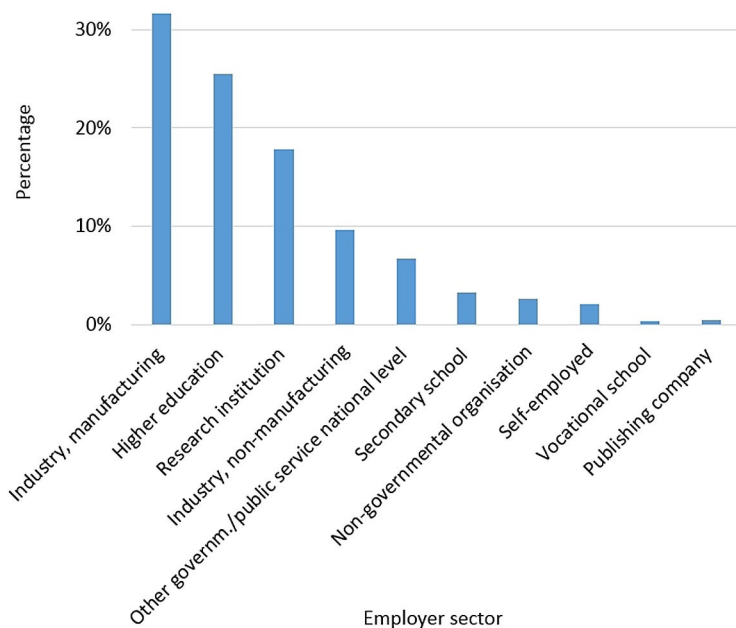
### 7a. Employer Sectors

The manufacturing industry remains the dominating employer for chemists in Europe, who filled in the survey and lived in the top-responding countries (32%, Figure 34). Higher education (26%) and Research institutions (18%) changed places compared to ESEC1. Altogether, industry (manufacturing industry, non-manufacturing industry, Publishing companies and Self-employment) provides 44% of all jobs for chemists. Research facilities (Higher education 26%, Research institutions 18%) offer 44% of the jobs as well. For estimating the total number of jobs in research, it has to be taken into account that 39% of all industry employees report R&D as their dominating work function (see further below, Figure 38). This means that nowadays the majority of all jobs for chemists in Europe are dominated by research.

Due to the diverse history in industrial development, employer sectors play different roles in different European countries. We evaluated responses by graduates of the last 15 years for the 11 most responding countries. This group of respondents should best reflect the actual situation in their working/studying countries. Indeed, manufacturing industry plays the dominating role in most countries (Figure 35). In some countries (Spain, Portugal, United Kingdom, Czech Republic), Higher education and/or Research institutions provide more jobs than manufacturing industry. In case of Portugal and the Czech Republic, manufacturing plus non-manufacturing industry together offer less jobs than Higher education or Research institutions.

It might be interesting to know, which employer sectors are preferred by graduates of which subdisciplines or vice versa





**Figure 34.** Importance of various employer sectors for the job market of European chemists.

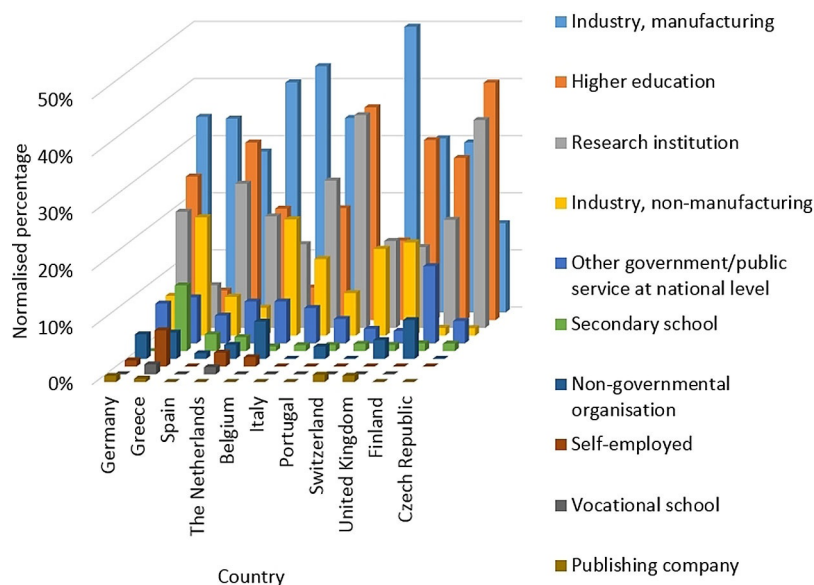
(Figure 36). Graduates of organic chemistry, analytical chemistry and chemical engineering, the top graduation disciplines (cf. Figure 27), have high shares in all employer sectors. The dominating role of graduates in chemical education in Secondary schools is not surprising. Analytical chemists occupy the highest share in Other government/public service at national level. The share of chemical engineers in Non-manufacturing industry is higher than their share in Manufacturing industry. It should be remembered that the data in Figure 36 are normalised to 100% within every employer sector, hence Figure 36 must not be used to compare shares between different employer sectors.

## 7b. Industrial Sectors

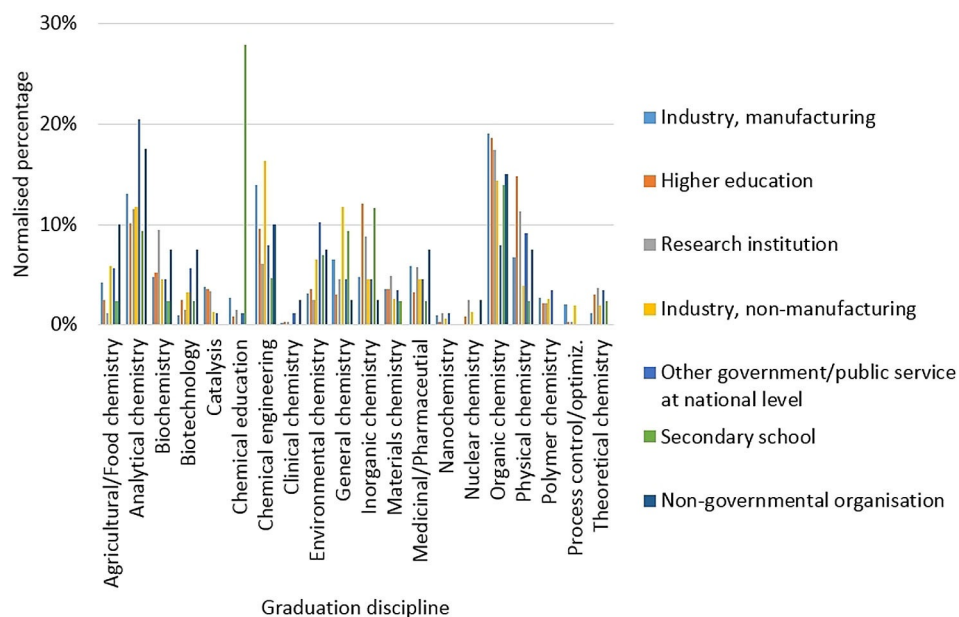
In the subsequent analysis of the importance of industrial sectors for the job market of chemists we only included industry employees. The industrial sector Chemicals provides 37% of all industry job for chemists (Figure 37), followed by Healthcare industry (26%) and Food industry (10%). These are European average values. Shares of industrial sectors in individual countries are very diverse. For statistical reasons, this evaluation was restricted to the seven dominating industrial sectors, which cover 88% of all jobs for chemists in industry, and the 11 most responding countries. The results are shown in Figure 38.

The industrial sector Chemicals is the dominating sector for chemists in all evaluated countries except Greece. The highest share for the sector Chemicals is found for The Netherlands (54%), followed by the Czech Republic (47%) and Switzerland (44%). In Greece, the sector Chemicals provides merely 18% of the jobs for chemists there. The dominating sectors for chemists in Greece is Healthcare industries (42%), followed by Food industry (25%). Healthcare industries is usually the second important sector after Chemicals except in Portugal, where the Food industry (16%) offers more jobs than Healthcare industry (12%). The combination of Chemicals, Healthcare industry and Food industry as dominating industrial sectors for the employment of chemists holds true for most countries except Germany (Information and communication technologies on rank 3), United Kingdom and Finland with Biotechnology on rank three.

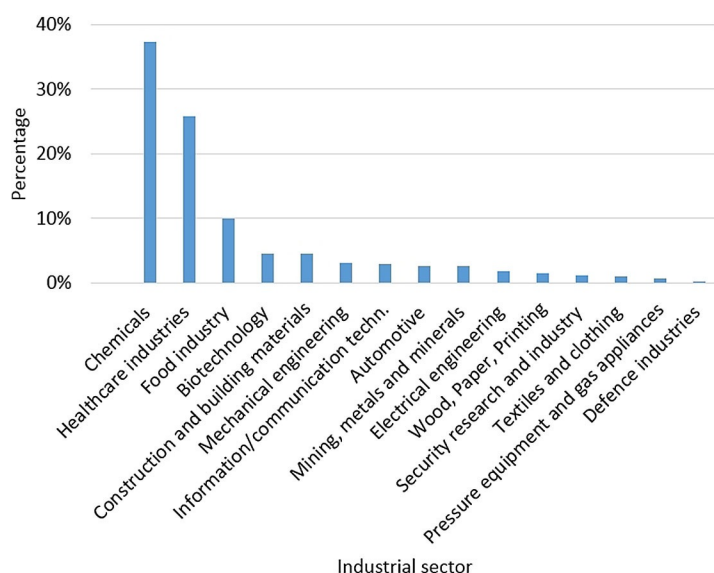
Applied research, development, design is the dominating work function of chemists in industry (28%). As Figure 39 shows, R&D in industry also covers Management or administra-



**Figure 35.** Role of different employer sectors in the 11 most responding countries. Results are based on the responses from graduates of the last 15 years. Responses for every country are normalised to 100% in order to permit comparison between countries.



**Figure 36.** Role of different graduation disciplines in the seven dominating employer sectors (cf. Figure 34). Results are based on the responses from graduates of the last 15 years. Responses for every employer sector are normalised to 100% in order to permit comparison between graduation disciplines.



**Figure 37.** Importance of various industrial sectors for the job market of European chemists. Results are based on the responses from industry employees.

tion (7%) and Basic research (4%). This means, 39% of all chemists working in industry report R&D as their work function. The second important work function for chemists in industry is Production and quality control (16%).

## 8. Continuing Education: Participation, Topics, Skills

The European Commission published in 2017 a “renewed EU agenda for higher education”.<sup>[18]</sup> On page 3 of this agenda it is stated that “... Europe’s higher education systems face challenges, including: A mismatch between the skills Europe needs

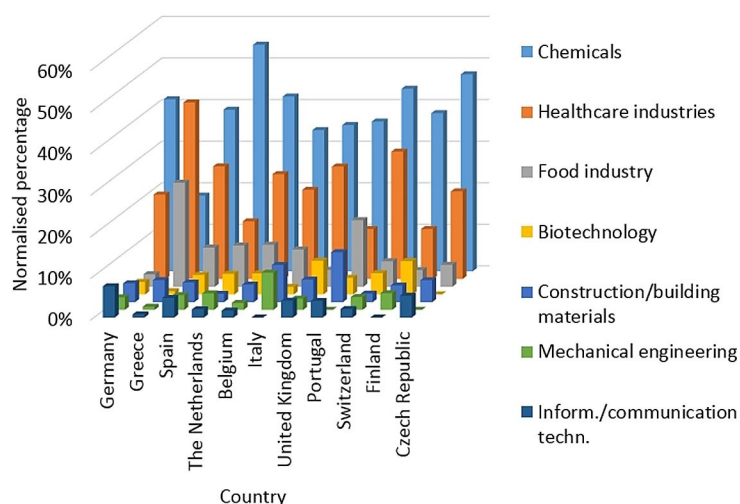
and the skills it has ...”. We surveyed the current situation for chemistry graduates by looking at their participation in continuing learning activities. Participation of chemistry graduates of the last 15 might provide some clues about the existence of such mismatches in tertiary education in chemistry.

Events of continuing education have been attended by 36% of all respondents and by 33% of the graduates of the last 15 years. Among the most responding countries, apart from two exceptions, the values vary between 30% for Spain and Portugal and 36% for The Netherlands (Figure 40). The two exceptions are Switzerland (24%) and United Kingdom (20%).

For a more detailed analysis, we evaluated the number of months of participation in continuing learning. The sequence of countries in Figure 41 was chosen according to the total number of responses from these countries (cf. Figure 1). Within each country, the responses are arranged in sequence from largest to least participation in continuing education.

In the pull-down menu for this question, the number of months could be selected between 1 and 99. Five respondents among the graduates of the last 15 years chose the maximum value 99. It would mean they spent more than half of the time since graduation for continuing learning. The common range of answers in Figure 41 is located below 60 months. The median value for time spent for continuing education by graduates of the last 15 years is six months.

The graph in Figure 41 consists of a series of decaying peaks. This shape is more or less identical to the corresponding Figure in the ESEC1 report,<sup>[1]</sup> regardless of the different parameters on the ordinate (ESEC2: number of months, ESEC1: attended events) and the few differences in the list of the



**Figure 38.** Role of the seven dominating industrial sectors (cf. Figure 37) in the 11 most responding countries. Results are based on the responses from industry employees. Responses for every country are normalised to 100% in order to permit comparison between industry sectors.

most responding countries between ESEC1 and ESEC2. This confirms the previous observation that the majority of chemists after graduation refrains from any participation in continuing education, regardless of the working country (Figure 41) or the graduation level (Figure 42).

Clear differences for participation in continuing education are seen between employer sectors (Figure 43). Employees of Non-governmental organisations participate least (28%), followed by Research institutions (30%). Highest participation values are reported by employees of Secondary schools (61%) and self-employed chemists (58%).

In the subsequent part of this chapter, we will look for topics studied and skills acquired in continuing education. This

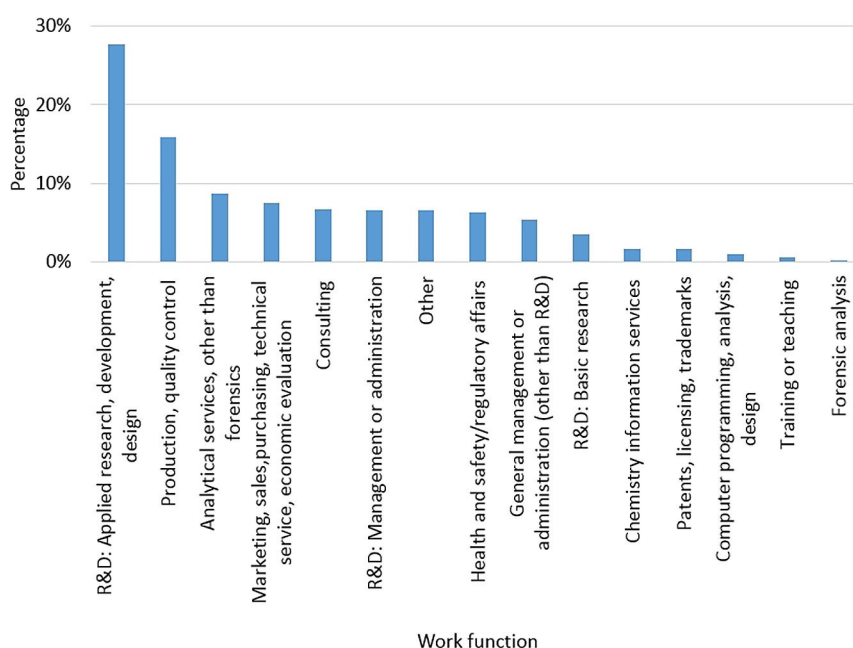
evaluation is based on responses by chemists, who participated in at least one event. As to topics, chemists attend all disciplines of continuing education. By far dominating are chemistry courses, which account for 24% of all attendees in continuing education (Figure 44, red line). This preference is the same as it was in ESEC1. Business/management remains the second most important topic (14%), followed by Education (11%).

The graduates of the last 15 years have also been asked, which of the above discussed topics would have been helpful additional qualifications to find a new job. The submitted ranking (Figure 44, blue line) differs for some topics significantly from the topics attended in continuing education. Business, management as well as Informatics are assumed to be particularly helpful in finding a new job. In contrast, additional courses in Chemistry as well as Education are not considered to be of importance for finding a new job. Very interesting is the large number of responses stating that none of the topics

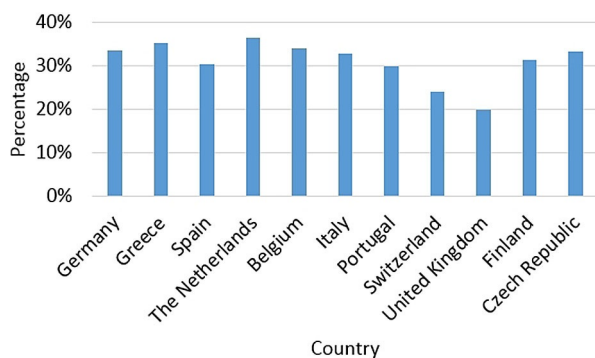
was believed to be helpful in finding a new job.

As to the skills, we have grouped them into seven broad categories in order to make the comparison of the various offers easier:

- Hard skills (including legislative, regulatory knowledge (environmental/safety/labour/contracting), language, e-skills),
- Marketing skills (including technical knowledge, product knowledge, product development),
- Social Skills (including team working skills, social perceptiveness (listening/understanding), communication, networking, intercultural),



**Figure 39.** Shares of work functions reported by respondents working in industry.

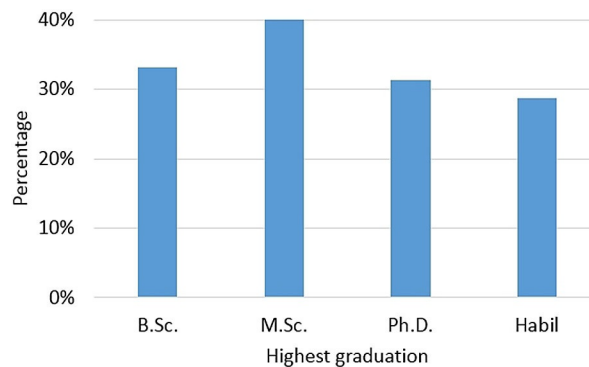


**Figure 40.** Percentage of respondents of the most responding countries participating in continuing education. Results are based on responses from graduates of the last 15 years.

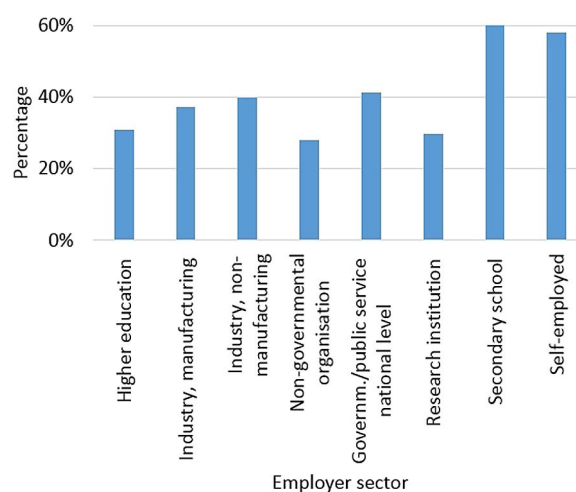
- Problem-solving Skills (including analytical skills, Interdisciplinary, initiative, multi-skilling, creativity),
- Self-management (planning, stress and time management, flexibility, multi-tasking),
- Management skills (strategic & visionary, coaching and team building, change management, project management, process optimizing, quality management, people skills crucial for collegial management style),
- Entrepreneurial skills (including supplier and customer relationship/ understanding, business understanding, trend setting/ trend spotting).

Hard skills are the dominating group of skills acquired by graduates of the last 15 years. As Figure 45 shows, the difference in attendance among the top five skill groups is not very large. It declines from 22% for Hard skills to 15% for Management skills. Much less requested have been Marketing skills and Entrepreneurial skills, both at 6%.

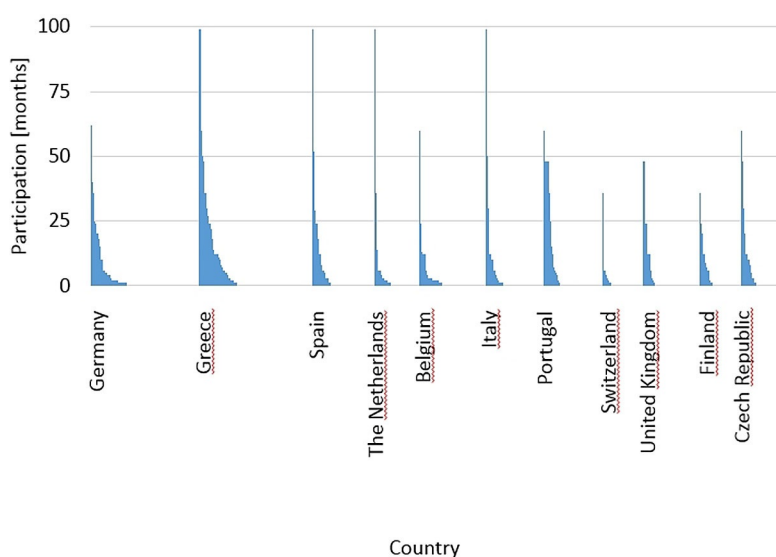
In another question, we asked separately, whether or not the respondents received dedicated training on entrepreneur-



**Figure 42.** Participation in continuing education by graduates of the most responding levels. Results are based on respondents of all ages.

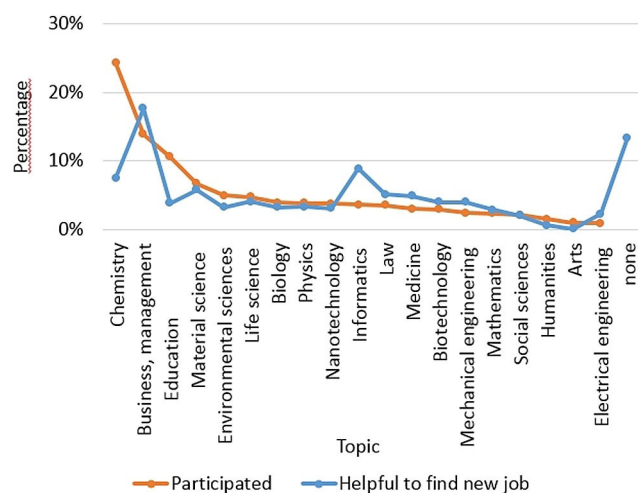


**Figure 43.** Participation in continuing education by employees of the most responding employer sectors. Results are based on all respondents of all ages.

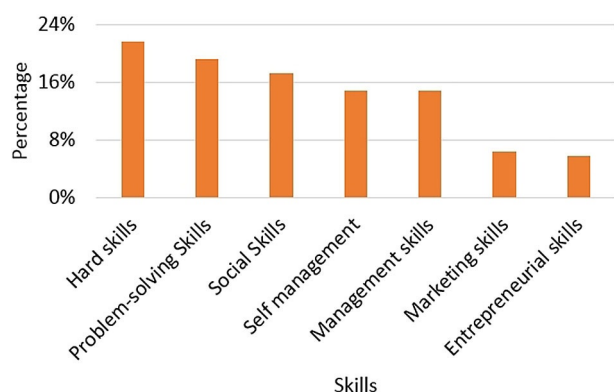


**Figure 41.** Participation in continuing education by employees of the 11 most responding countries. Results in months are based on responses from graduates of the last 15 years.





**Figure 44.** Participation in fields of continuing education (red line) and ranking of additional qualifications assumed to be helpful to find a new job (blue line). Results are based on the responses from graduates of the last 15 years.



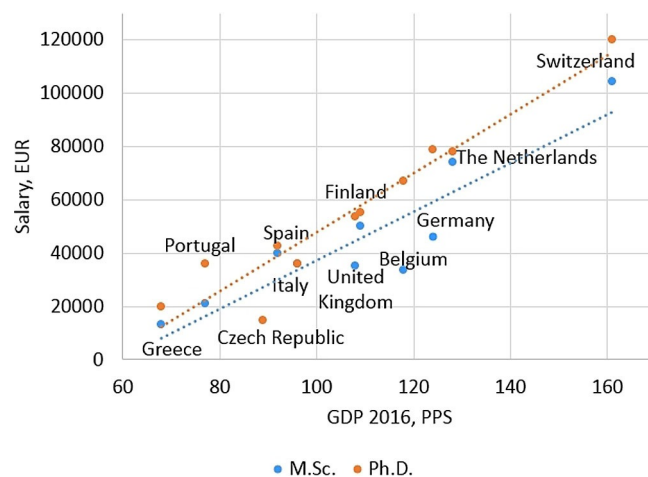
**Figure 45.** Skills acquired by attending events of continuing education. Results are based on the responses from graduates of the last 15 years.

al skills. Only 28% of those who responded to this question received training on entrepreneurial skills. Of them, 26% received this training during their university studies.

## 9. Salaries

The wide span in annual salary within the EU was already discussed in the ESEC1 report.<sup>[1]</sup> For this reason, we focus here on the median salaries for the 11 most responding countries and did not calculate any EU average value. Some of these countries have established systems of bonuses, which are paid in addition to the base salary. In order to achieve a more realistic comparison we added bonuses to the base annual salary for 2016 where possible. These base annual salaries plus bonuses have then been related to the Gross Domestic Products (GDP) of the corresponding country for the year 2016, the same year as the reported salary. GDP values were taken from Eurostat.<sup>[19]</sup> They are given in Purchasing Power Standards (PPS) with EU28=100. Values for M.Sc. graduates in the Czech Republic

have been omitted because of the low number of responses in this category. Best-fit straight lines were calculated for M.Sc. and Ph.D. graduates separately. The scattering around both lines in Figure 46 is lower for Ph.D. graduates due to the larger number of responses for this graduation level. The scattering is largest for the Czech Republic, the country with the lowest number of responses in this group.



**Figure 46.** Median salaries plus bonuses 2016 for M.Sc. and Ph.D. graduates in the 11 most responding countries.

Independent data to compare with the results shown in Figure 46 are available for chemistry managers in Germany. The annual salary for this group is given as 62 485 EUR.<sup>[20]</sup> This amount fits very well into the range reported for Germany in Figure 46. Of interest is also a comparison with salaries for chemists in the USA. The average salary for all sectors in 2016 is given as 97 850 USD.<sup>[21]</sup> At the time when ESEC2 data were collected, this corresponded to 92 353 EUR. Together with a GDP of 145 PPS for the USA,<sup>[16]</sup> these data also fit quite well into Figure 46.

ESEC2 respondents were asked whether, over the past three years, they have accepted a position or compensation package that was less than the previous position in order to maintain employment. 15% reported they had accepted such a position or package, 5% are not sure about it.

In addition to salaries of employed chemists, we surveyed the income situation for retired chemists and students. The number of responses by retired chemists and students was much lower than from employed chemists, hence only a few countries could be analysed (Figure 47).

A comparison of Figures 46 and 47 shows that the reported income of students depends not very much on the GDP of the particular country, in clear contrast to the income of retired and of employed chemists.

## 10. Free-text entries

At the end of the questionnaire, a free-text field was offered to submit anything the respondents wanted to let us know. This

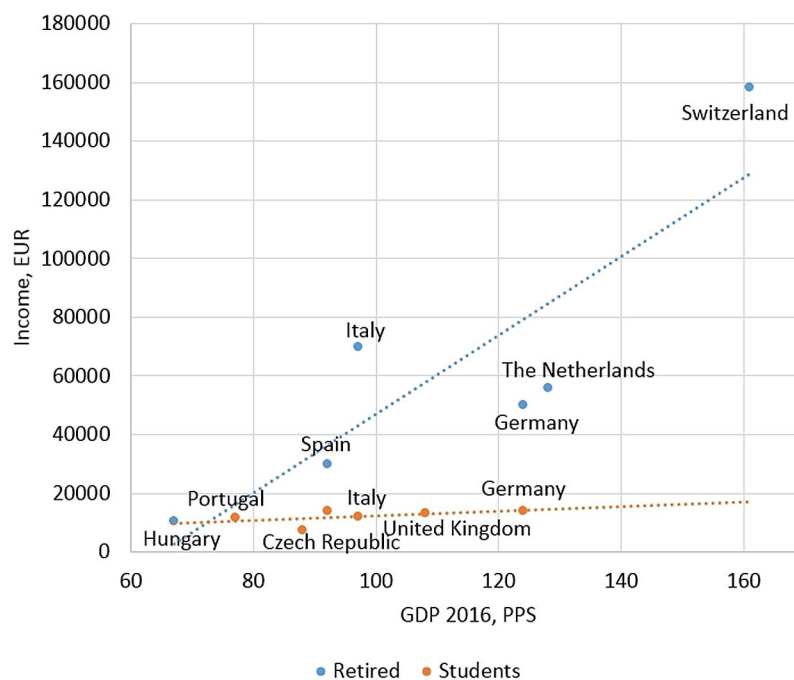


Figure 47. Income of students and retired chemists in 2016.

invitation was well accepted. Dedicated personal information was submitted by 338 respondents. The free-text entries were grouped into eight clusters (Figure 48). Almost half of the en-

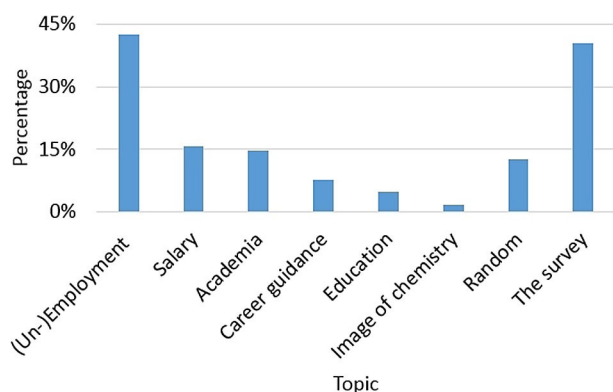


Figure 48. Provisional clustering of the free-text responses.

tries dealt with severe problems related to problems in the job or to unemployment. Within this cluster, the outstanding issue concerns married mothers with small children trying to find a job without splitting the family. The cluster about salaries and contracts as well as the cluster about academic issues (conditions of employment in academia and in research institutions) are of roughly the same size. These clusters are under ongoing evaluation. A large cluster holds technical remarks about the survey and about the questionnaire. These entries are of particular value for an improved questionnaire for the next survey. This survey is expected to take place in 2020 as joint event with the American Chemical Society.

## Acknowledgements

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**Keywords:** career · chemist · education · employment · Europe · salary

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