# Appendix 2

# ITEACH – Training

The iTeach project, supported by the European Union's Lifelong Learning Programme, aimed to quantify and improve the effectiveness of chemical engineering companies. It was carried out within the framework of an international collaboration involving six partners: United Kingdom (Newcastle University), France (University of Lorraine), Republic of Macedonia (International Balkan University), Portugal (University of Porto), Slovakia (Slovak Technical University), and Germany (TU Dortmund), involved in higher education in chemical engineering.

In addition to these six European partners, this project has mobilized different actors involved in education such as learners, graduates, and employers in the targeted sectors of activity.

This project led to the development of two frameworks, quantifying the effectiveness of a chemical or process engineering training and a course or a current teaching unit. These two frameworks are detailed below and details, various progress reports and project results remain available online[1]. What the main part of this work shows is a fairly high degree of uniformity at the European level of training.

## A2.1. Evaluation of a training course

The framework for evaluating the effectiveness of chemical engineering training was developed based on the results of data collection described in detail by Glassey

1 Project available at: https://research.ncl.ac.uk/iteacheu/.

Process Engineering Renewal 1: Background and Training,
First Edition. Éric Schaer and Jean-Claude André.

*et al.* (2017), a literature review (Anderson and Krathwohl 2001; Bachy *et al.* 2001) and Sorensen (2013), whose results are available online[2], as well as on discussions with all stakeholders involved in the educational process, namely students, graduates, academics, and employers.

The first analysis identified many parameters that could be taken into account for such a framework. A method based on decision matrices identified the most important ones, eliminated some redundant aspects and grouped the parameters into seven global indicators reflecting the specificity of Process Engineering training, as shown in Figure A2.1. The resulting framework for the evaluation of training is therefore based on the coherence of learning outcomes, pedagogical quality, relations with research and industry, the attractiveness of the institution, the employability of graduates, and its revision or quality management processes. This framework is also based on quantitative data that can be measured and evaluated.

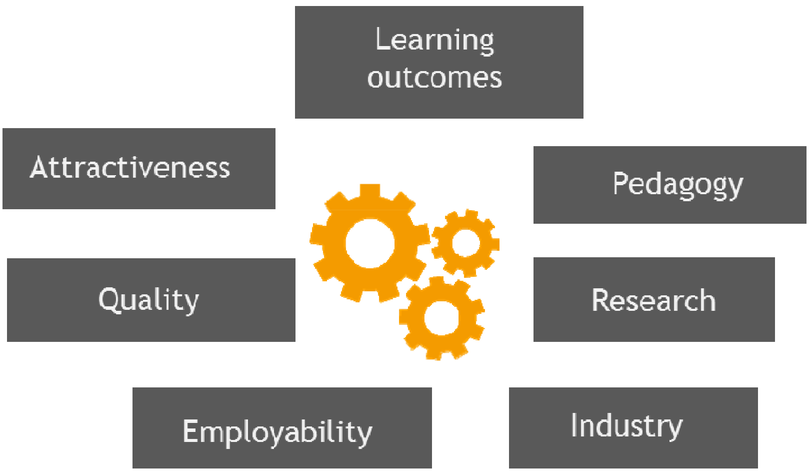



**Figure A2.1.** *Indicators for the evaluation of chemical engineering training*

These global indicators are quantified on the basis of parameters, whose mean values, threshold values, standard deviations and weights have been defined by the actors involved in the project. This quantification and definition work have been developed on the basis of the literature, the recommendations of the European Chemical Engineering Federation[3] and numerous internal discussions within the

2 https://research.ncl.ac.uk/iteacheu/deliverables/.

3 https://efce.info/Bologna_Recommendation.html.

consortium. The fundamental assumption is that of a normal distribution of observations, whose variables are described by the central (mean) and dispersion (standard deviation) parameters. This hypothesis is supported by the consistency observed in the programs offered by various providers in Europe and around the world (see (Glassey *et al.* 2017) for details on learning outcomes and the importance of various aspects of the program). However, the authors acknowledge that divergent conceptions and "revolutionary" curricula do not necessarily correspond to this model, and may not be properly evaluated by the framework thus developed. However, the latter constitutes a basis for discussion, albeit a reductionist one, allowing for comparisons and debates.

Taking the example of the pedagogy indicator, a given number of ECTS[4] for different teaching methods (traditional courses, tutorials, practical work, projects, problem-based learning, or any other non-traditional teaching) is proposed. Some average values have been put forward, although most accreditation bodies remain very cautious about prescribing a number of credits for specific teaching methodologies, and no particular teaching methodology has so far clearly proved more effective than another.

The objective of the project was not to focus on a particular teaching methodology. All of them have interests, depending on the subject taught, the number of students, the way it is implemented, etc. It therefore seems obvious that certain degrees of freedom must be proposed: it is unlikely that a training course will go from very effective to unacceptable value if the number of ECTS for a given pedagogy (in this example) changes only slightly. In this case, a Gaussian approach is used to quantify the parameter related to this data:

$$e = \exp\left(-\left(\frac{v-\mu}{\sigma}\right)^2\right)$$

with:

– $e$ is the efficiency of the measured parameter;

– $v$ its value (here the number of ECTS for a given teaching method);

– $\mu$ the average value (defined in this case by the project members, although this can be modified);

– $\sigma$ the standard deviation.

4 https://ec.europa.eu/education/ects/users-guide/docs/ects-users-guide_en.pdf.

The exponential is not divided here by the standard deviation (unlike the classical Gaussian law, where the integral is equal to one), so that the maximum value remains equal to one.

In the example given, the variations in efficiency are presented in Figure A2.2, with an average value of 100 and a standard deviation of 50.

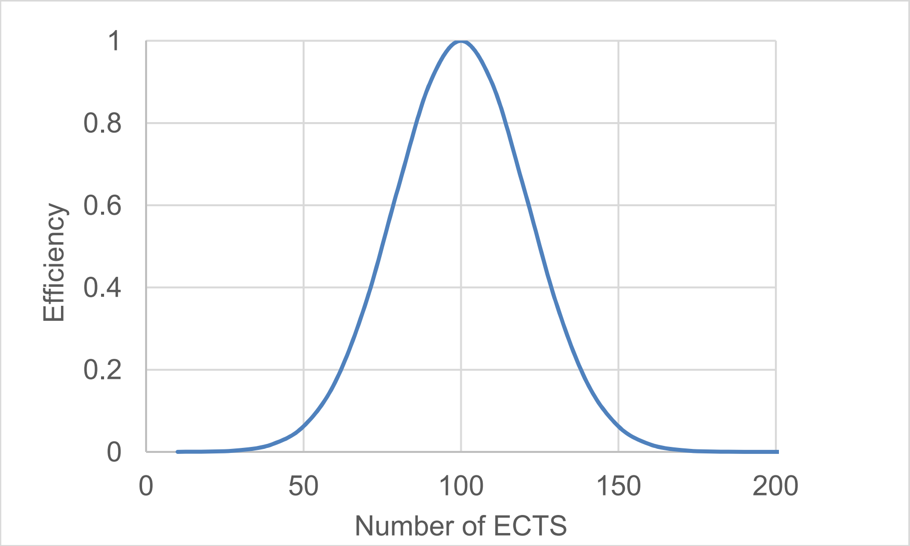



**Figure A2.2.** *Efficiency factor defined by the relationship (1)*

Finally, the proposed parameter can be multiplied by a factor, taking into account its relative importance in the overall quantification of the indicator. These factors were also discussed and approved by the consortium.

Although this quantification can be considered strict, so that only the precise value indicated by the consortium gives the highest score and any deviation in any direction decreases the value of the parameter, a sensitivity analysis shows that the effect of a single parameter on the overall indicator is limited.

In the case of the pedagogy indicator, for example, an increase of 10 ECTS in a teaching methodology followed by a decrease of 10 ECTS in any other teaching methodology indicated in Table A2.1 modifies the values of the parameter by 10%, but has only a 1% impact on the overall pedagogy-related indicator.

The figures given in the following sections should therefore not be considered as mandatory rules to be respected, but as a measure of the diversity of teaching methods that can be offered in any chemical engineering training center.

Some other parameters, such as the use of feedback questionnaires in pedagogy (see Table A2.1), can simply be defined in a binary way, the answers being yes or no. In this case, a value (predefined by the consortium according to the importance of the evaluated parameter) is simply added or not, depending on the presence of such a parameter.

Details of the overall indicators, including the quantification of each parameter, are then presented in the following sections.

### A2.1.1. *Pedagogy*

In this case the pedagogy indicator, the proposed parameters are detailed in Table A2.1.

For this indicator, the first point concerns the variety of teaching methodologies. It is clear that no one pedagogical method should be mandatory for another. The importance remains in the interactivity and diversity of the teaching methods used, in the reflections on their effectiveness, their relationship with the learner's culture, and their flexible adaptations in relation to learners' evolutions, industrial, social, and scientific expectations.

The use of feedback questionnaires, the evaluation of different aspects of teacher-learner interactions, and their use for improvement are also considered. The number of teaching hours for an ECTS (although it is supposed to be uniform, the surveys have shown significant differences, so that this parameter is also taken into account), the number of teaching hours per year, the learners' residence time (or the number of students not progressing within the time allowed), teacher training, including the staff/student ratio, as in many ranking surveys (Bekhradnia 2015), are also taken into account. The mean values and standard deviations of each parameter were proposed, based on the consortium's discussions and the few commonly accepted values for these parameters. The maximum score proposed for pedagogy is therefore 300.

| | Parameter | Average value (μ) | Standard deviation (s) | Score |
|---|---|---|---|---|
| Education | | | | |
| ECTS of traditional courses | | 100 | 30 | 10*e |
| ECTS of tutorials | | 50 | 30 | 10*e |
| ECTS of practical work in labs | | 50 | 30 | 10*e |
| ECTS of learning by resolution of problems | | 50 | 30 | 10*e |
| ECTS of active teaching | | 50 | 30 | 10*e |
| | | | | *Maximum score for teaching: 50* |
| Use of feedback questionnaires (assessing the following aspects) | | | | *If yes: 5, if no: 0* |
| Education | | y | n | 5/0 |
| Enthusiasm | | y | n | 5/0 |
| Organization (including educational documents) | | y | n | 5/0 |
| Group interactions | | y | n | 5/0 |
| Individual reports | | y | n | 5/0 |
| Breadth | | y | n | 5/0 |
| Examinations | | y | n | 5/0 |
| Assignments | | y | n | 5/0 |
| Overall | | y | n | 5/0 |
| Use of questionnaire responses? | | y | n | 15/0 |
| | | | | *Maximum score for questionnaires feedback: 60* |

| | | | |
|---|---|---|---|
| Number of teaching hours per ECTS (an ECTS also includes individual work) | 10 | 5 | 30*e |
| Total number of teaching hours per year | 800 | 50 | 30*e |
| | | | *Maximum score for teaching time: 60* |
| Percentage of students not progressing within set timelines | 0 | 10 | 60*e |
| | | | *Maximum score for repetitions: 60* |
| Availability of teachers | | | |
| On-site office | y | n | 10/0 |
| E-mail address | y | n | 10/0 |
| Percentage of time dedicated to teaching | 50 | 10 | 10*e |
| Number of learners per teacher | 5 | 5 | 10*e |
| Percentage of permanent teachers | 100 | 10 | 10*e |
| Continuing education to pedagogy | y | n | 10/0 |
| Academic tutors | y | n | 10/0 |
| | | | *Maximum score for availability pedagogical: 70* |
| | | | Total: 300 |

**Table A2.1.** *Details of the parameters for the pedagogy indicator*

### A2.1.2. *Learning outcomes*

Some ECTS relating to learning outcomes have been defined by the European Chemical Engineering Federation[5]. These figures are suggested as minimum values to achieve the required training objectives in chemical engineering. In the same way, degrees of freedom make it possible to reflect the specificities of each training center. The consortium does not propose any maximum value because, since the maximum value of ECTS in a training course is limited to 300, if some ECTS significantly exceeded the recommended value in one field, they would not meet the requirements imposed in others. It has been proposed that efficiency should remain at its maximum around the recommended ECTS values and decrease outside this range, as for a Gaussian distribution.

Skills and competencies are currently assessed binary as present or absent. This part could be developed further, taking for example the number of ECTS devoted to the development of each of these skills. Undergraduate and graduate internships are taken into account, as well as the accreditation of the institution by any relevant (inter)national body. The details of the parameters assessed in this indicator are presented in Table A2.2, and again, the maximum score proposed for the training objectives is 300.

### A2.1.3. *Attractiveness*

The attractiveness of a course of study can significantly affect the size of the cohort of students and the quality of candidates, and thus have an indirect impact on the quality of the overall course of study. As the parameters are relatively difficult to assess quantitatively, the framework here is based on more qualitative values for this indicator.

Details of the parameters included in this indicator are presented in Table A2.3. Quantitative measures include the number of students applying for training in relation to the number of places available per year, accommodation options, and their costs, as well as tuition fees. The general attractiveness of the city, the national, and international rankings of the training; the existence of a communication unit; its achievements; and the potential implications of the students are also taken into account, although these are more difficult to quantify. The average salary after graduation could also be included in the attractiveness indicator, but it was decided to take it into account in the employment indicator.

5 https://efce.info/Bologna_Recommendation.html.

| Training objectives | Minimum ECTS value | Standard deviation | Score |
|---|---|---|---|
| Basic sciences | 45 | 15 | 20*e |
| Mathematics | | | |
| Physical | | | |
| Chemistry | | | |
| Information technology | | | |
| Numerical methods | | | |
| Basics of chemical engineering | 35 | 15 | 20*e |
| Mass and energy balances | | | |
| Thermodynamics | | | |
| Fluid mechanics | | | |
| Mass and energy transfers | | | |
| Chemical reaction engineering | | | |
| Separations | | | |
| Biomolecular and biological engineering | | | |
| Chemical engineering applications | 15 | 10 | 20*e |
| Process and product engineering | | | |
| Health, safety and environment | | | |
| Analytical techniques | | | |

| | | | |
|---|---|---|---|
| Non-technical disciplines/skills | 10 | 5 | 20*e |
| Management and social sciences | | | |
| Languages | | | |
| Undergraduate internship | 15 | 5 | 20*e |
| In-depth study of scientific subjects | 15 | 5 | 20*e |
| Advanced courses, further training in chemical engineering | 40 | 15 | 20*e |
| Advanced process engineering | | | |
| Product engineering | | | |
| Biotechnological processes | | | |
| Process management | | | |
| Second cycle internship | 30 | 5 | 20*e |
| | Total: 205 | *Maximum score for consistency: 160* | |
| Accreditation (CTI, IChemE, etc.) | y | n | 20/0 |
| ECTS for active training | | | Number ECTS/10 |
| Definition of the syllabus in terms of objectives of training | y | n | 10/0 |

| | | | |
|---|---|---|---|
| ECTS of internships or external training | 30 | 5 | 20*e |
| | | | *Maximum score for authorization: 60* |
| Competencies | | | |
| Ability to gather information | y | n | 10/0 |
| Ability to analyze information | y | n | 10/0 |
| Self-learning ability | y | n | 10/0 |
| Ability to identify and formulate a problem | y | n | 10/0 |
| Ability to solve a problem | y | n | 10/0 |
| Ability to work in a team environment | y | n | 10/0 |
| Capacity to be communicated | y | n | 10/0 |
| Interdisciplinary approach | y | n | 10/0 |
| | | | *Maximum score for skills: 80* |
| | | | Total: 300 |

**Table A2.2.** *Detailed parameters for the target indicator of training*

| Attractiveness | Average value | Standard deviation | Score |
|---|---|---|---|
| Number of candidates v/number of places available | | | The number v if less than 30; 30 if larger |
| Tuition fees/average salary | | | 10-v (0 if negative) |

| | | | |
|---|---|---|---|
| Accommodation options | y | n | 10/0 |
| Size (number of inhabitants v) of the city | | | v*1.10-5 (10 if larger) |
| Monthly housing costs/average salary | | | 5*(2-v) (0 if negative) |
| Existence of a communication unit (at least at the university level) | y | n | 10 |
| Number of employees in the communication unit | | | v (if less than 10) |
| Achievements | | | |
| Information (website, leaflets, electronic letters, etc.) | y | n | 30/0 |
| Forums, company days, etc. | y | n | 10/0 |
| Learner participation | | | |
| In the activities of the communication unit | y | n | 10/0 |
| In attractiveness | y | n | 10/0 |
| In associations | y | n | 10/0 |
| In the communication | y | n | 10/0 |
| Percentage v of foreign students | | | v/10 (10 maximum) |
| Number of international trade agreements | | | v/10 (10 maximum) |
| English courses | y | n | 10/0 |
| National ranking | | | (100-v)/10 if positive |

| | | | |
|---|---|---|---|
| International ranking | | | (500-v)/50 if positive |
| Existence and influence of an Alumni association | y | N | 10/0 |
| Average score v of the integrants | $\mu$ | $\sigma$ | $50*(v-\mu)/\sigma$ |
| Social diversity | 20 | 20 | 10*e |
| Ratio of men to women (%) | 50 | 20 | 10*e |
| | | | Total: 300 |

**Table A2.3.** *Details of the parameters for the indicator relating to the attractiveness objectives*

### A2.1.4. *Relationship with research*

The importance of research-driven and tertiary education has been widely discussed in the literature (see for example Jenkins and Healey 2005). The number of research internships, hours taught by researchers and innovation projects contributes to this indicator (see Table A2.4). The high weighting of students who have obtained a double degree also takes into account the international dimension of the training. The quality and quantity of research activities also contribute to effective interactions between teaching and research and to the attractiveness of a teaching department.

The number of students undertaking a PhD after graduation should represent a balance between the continuation of studies and the industrial relevance of the training.

### A2.1.5. *Industry relations*

The industrial relevance of degrees, particularly in professional disciplines such as chemical engineering, is essential, as indicated by many accreditation bodies (IChemE, ABET). This indicator takes into account industrial internships, the number of teaching hours provided by industrialists, projects carried out in collaboration with industry, the existence and number of students completing an apprenticeship diploma, the influence of industry on the board of directors, the existence of industrial open days, the number of students setting up their own companies, the diversity of hiring sectors or the different (first) positions, as shown in Table A2.5.

### A2.1.6. *Employability*

Again, in professional disciplines such as chemical engineering, it is essential that graduates acquire the necessary knowledge and skills sought by industry (Gillet 2000). The time required for graduates to find their first job, the starting wage level, and the unemployment rate six months after graduation are traditionally used as parameters indicative of the industrial relevance of the training. The variety of geographical hiring areas may also reflect the international recognition and quality of a training center. The number of additional training after graduation, if excessive, indicates training gaps or discrepancies between training and industrial requirements. Some parameters, such as levels of responsibility, average salary, or percentage of full employment after 10 years after graduation, are also important, although more difficult to assess. Alumni associations can help to quantify these parameters. Table A2.6 contains detailed information on all the parameters included in the employment indicator.

| Relations with research | Average value (μ) | Standard deviation () | Score |
|---|---|---|---|
| ECTS of research internship | 30 | | v (if less than 30) |
| Advanced courses (in ECTS) given by researchers | | | v (if less than 10) |
| Visits to research laboratories | | | v (if less than 10) |
| Number of teaching hours (ECTS) given by research staff | | | v<br>(if less than 30) |
| ECTS of innovation project | | | v (if less than 30) |
| Percentage of research staff/teachers | 100 | | v/10 |
| Number of patents per year | | | v (if less than 10) |
| Research in collaboration with industry | | | v (if less than 10) |

| | | | |
|---|---|---|---|
| Startup creation in the last 10 years | | | v (if less than 10) |
| Volume of research contracts/average salary | | | v/100 (if less than 10) |
| Number of double degrees | | | |
| National | | | v (if less than 10) |
| International | | | v (if less than 10) |
| Percentage of students with a double degree | 100 | | v |
| Percentage of graduates pursuing thesis work | 10 | 10 | 20*e |
| | | | Total: 300 |

**Table A2.4.** *Details of the parameters for the relationship indicator with research*

| Relations with industry | Average value | Standard deviation | Score |
|---|---|---|---|
| ECTS for industrial internships | 30 | 0 | v (if less than 30) |
| Industrial stakes | y | n | 20/0 |
| Number of industrial conferences (on average on training) | 10 | 0 | v (if less than 10) |
| Visits to industrial sites | 10 | 0 | v (if less than 10) |
| Number of courses (ECTS) given by industrialists | 10 | 0 | v (if less than 10) |
| ECTS of projects carried out in collaboration with industry | 20 | | v (if less than 20) |
| Apprenticeship training | y | n | 10/0 |
| Percentage of students in apprenticeship | 10 | 0 | v (if less than 10) |

| | | | |
|---|---|---|---|
| Percentage of learners who start their own company (maximum 5 years after graduation) | 10 | 0 | v (if less than 10) |
| Number of industrialists on the Board of Directors | 10 | 0 | v (if less than 10) |
| Number of industrial chairs | 10 | 0 | v (if less than 10) |
| Existence of company days | y | n | 10/0 |
| Number of industrial sectors represented | 10 | 0 | v (if less than 10) |
| Junior enterprise | y | n | 10/0 |
| Hiring sectors | | | |
| Base chemicals | y | n | 10 |
| Specialty chemicals | y | n | 10 |
| Energy | y | n | 10 |
| Engineering | y | n | 10 |
| Pharmacy | y | n | 10 |
| Agri-food industry | y | n | 10 |
| Environment | y | n | 10 |
| Hiring functions | | | |
| Production | y | n | 10 |
| Research | y | n | 10 |
| Engineering | y | n | 10 |
| Technical assistance | y | n | 10 |
| HSE and quality | y | n | 10 |
| | | | Total: 300 |

**Table A2.5.** *Details of the parameters for the relationship indicator with industry*

| Employment | Average value | Standard deviation | Score |
|---|---|---|---|
| Average hiring salary of graduates/national average salary | 3 | 0.5 | 10*v (if less than 30) |
| Job search time (months) | 0 | 2 | 30*e |
| 6-month unemployment rate | 0 | 100 | 60*e |
| Influence of the *alumni* association on hiring | y | n | 10/0 |
| Percentage of additional training after graduation | 10 | 10 | 10*e |
| Percentage of additional research training after graduation | 10 | 10 | 10*e |
| Average salary at 10 years/national average salary | 10 | 1 | v (if less than 10) |
| Percentage of full employment at 10 years | 100 | 0 | v/10 |
| Level of responsibility at 10 years | | | The sum of the following figures shall not exceed 100 |
| Project Manager | 10 | | v |
| Head of department | 10 | | v |
| Expert | 10 | | v |
| Sales Manager | 10 | | v |
| Plant manager | 10 | | v |
| Senior manager | 10 | | v |
| Research Director | 10 | | v |
| Corporate Director | 10 | | v |
| Director of Human Resources | 10 | | v |
| University Professor | 10 | | v |
| Geographical areas of hiring | | | The sum of the following figures shall not exceed 30 |
| Outside the country of training | 10 | | v |
| In Europe | 10 | | v |
| In the rest of the world | 10 | | v |
| | | | Total: 300 |

**Table A2.6.** *Details of the parameters for the employability indicator*

### A2.1.7. *Quality approach*

Finally, quality assurance is an important indicator to ensure continuity and improvement in the quality and effectiveness of the overall program/training. The parameters considered in this indicator generally relate to quality assurance procedures.

Higher education institutions are regularly subject to national procedures and accreditation procedures. These include various curriculum/training review processes, the composition of the development board, and the regular use of teaching evaluation procedures, as shown in Table A2.7.

| Quality | Average value | Standard deviation | Score |
|---|---|---|---|
| Existence of a professional development council | y | n | 20/0 |
| Composition of the Development Board | | | |
| 5 | y | n | 10/0 |
| Number of sectors represented | 10 | | v (if less than 10) |
| External academics (to the institution) | y | n | 10/0 |
| Internal academics | y | n | 10/0 |
| Learners | y | n | 10/0 |
| Researchers | y | n | 10/0 |
| Alumni | y | n | 10/0 |
| Frequency of meetings (annual) | 4 | | 2.5*v |
| Prospective reflection | y | n | 10/0 |
| Frequency of program revisions (per year) | 1 | | 10*v (if less than 10) |
| Local decision-making capacity | y | n | 20/0 |
| Evaluation of lessons learned | | | |

| | | | |
|---|---|---|---|
| Frequency of evaluations (per year) | 2 | | 10*v (if less than 20) |
| Assessment of pedagogical skills | y | n | 10/0 |
| Evaluation of teaching materials | y | n | 10/0 |
| Assessment of scientific and technical aspects | y | n | 10/0 |
| Competency assessment | y | n | 10/0 |
| Analysis of learner feedback | y | n | 10/0 |
| Regular training of teaching staff | y | n | 20/0 |
| Existence of a pedagogical committee | y | n | 20/0 |
| Existence of a board of directors | y | n | 10/0 |
| Industrialists | y | n | 10/0 |
| Academic | y | n | 10/0 |
| Students | y | n | 10/0 |
| Local elected officials | y | n | 10/0 |
| | | | Total: 300 |

**Table A2.7.** *Details of the parameters for the quality indicator*

### A2.1.8. *Conclusion*

In order to be able to compare training courses at the international level, the final grade is divided by the cost of the training, taking into account staff salaries, infrastructure, maintenance, and all overhead costs per year and per student. To take into account differences between countries, this cost is divided by the average national salary. The framework thus developed was applied to the evaluation of an anonymous chemical engineering training center in Europe. The overall scores for each indicator were then calculated, based on an overall value of 300, and were therefore not associated with average cost or salary.

The radar graph of such an assessment is presented in Figure A2.3, which gives an indication of the department's strengths, such as the relationship with industry and employment after graduation, and areas for improvement such as the relationship with research or attractiveness. These figures acknowledge the complexity and preserve the richness of the information collected.

For a given chemical engineering teaching center, such representation may constitute avenues for continuous improvement, but the interest could also be to compare different chemical engineering training centers, on a European scale, to continue to progress together, sharing good practices, and guide students in their choice of an international department.

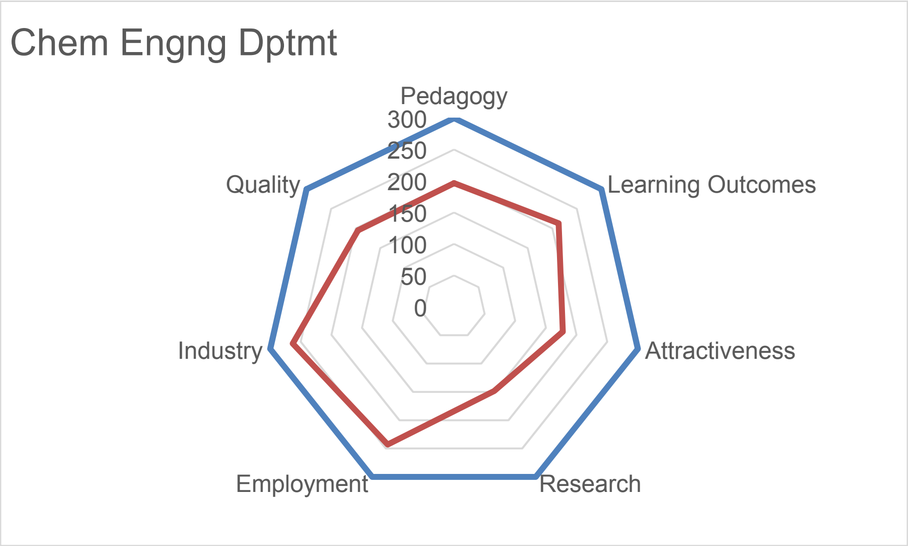



**Figure A2.3.** *Assessment of chemical engineering education. For a color version of this figure, see www.iste.co.uk/schaer/process1.zip*

The difficulty in evaluating an entire training program using this framework is the evaluation of each of the parameters, some of which are difficult to measure or quantify. For more external parameters, the school's website, interactions with the board of directors, and the alumni association are essential to carry out such an evaluation.

## A2.2. Evaluation of a teaching unit

Six (other!) indicators have also been developed and proposed as part of the iTeach project for the evaluation of a teaching unit. This evaluation is carried out by the population concerned by the teaching unit: students, graduates, teachers (including those who teach the course), and industrialists in the sectors where graduate students are employed. Some metrics are evaluated by questionnaires, by the description of the teaching unit, and by evaluations.

### A2.2.1. Strategic nature of the teaching unit

This indicator deals with the importance of a teaching unit for overall chemical engineering training. Does this teaching unit provide the knowledge and skills required for a (future) chemical engineering engineer? Is it adapted to what graduates are expected to apply in a professional situation? This indicator is assessed by graduates (weight 1), academics/teachers (weight 2), and employers (also weight 2). Its evaluation is based on the same questionnaire for each focus group, using Likert scale responses: 5: strongly agree; 4: agree; 3: neutral; 2: disagree; 1: strongly disagree.

– Is this teaching unit (course) necessary for the profession of future graduates?

– Does it meet all the needs expected of a course of this nature at this level?

– Is it aligned with the actual activities of a professional graduate in this discipline?

– Does it include a forward-looking approach, introducing new concepts and taking into account the future needs of the market?

– Is the curriculum consistent with other competing universities?

– Does this teaching unit (course) contribute to the attractiveness of the training program for future graduates?

After the answers to the questionnaires of the different stakeholders and the quantification of the results according to the Likert scale, the value of indicator 1 can be calculated according to the relationship (G stands for graduates, A for academics, and E for employers):

$$I_1 = \left(\frac{1}{5}\right)G + \left(\frac{2}{5}\right)A + \left(\frac{2}{5}\right)E$$

### A2.2.2. *Relevance of the proposed training*

This indicator deals with the content of the teaching unit. Does it allow an engineer to reach a sufficient level, does it cover everything he should? It is also evaluated by means of questionnaires that can be completed *a priori* and completed by students (weight 1), graduates (weight 1), academics (weight 2), and employers (weight 1). The Likert scale is also used, with answers as follows: 5: strongly agree; 4: agree; 3: neutral; 2: disagree; 1: strongly disagree.

– Is the content of the teaching unit (course) adequate?

– Is its position in the overall program appropriate?

– Is its duration/workload/ECTS appropriate?

– Are the training objectives clearly formulated for this teaching unit (course)?

– Does it allow access to pre-defined levels of knowledge taxonomy (knowledge, understanding, application and analysis)?

After the responses of the different stakeholders to the questionnaires, the value of the second indicator is calculated by the relationship:

$$I_2 = \left(\frac{1}{5}\right)S + \left(\frac{1}{5}\right)G + \left(\frac{2}{5}\right)A + \left(\frac{1}{5}\right)E$$

### A2.2.3. *Relevance of the proposed pedagogy*

This indicator deals with the form of the teaching unit. It is clearly based on the pedagogical engineering and the teaching method chosen. Does this allow for effective acquisition of the skills and knowledge taught? It is always evaluated by means of questionnaires that can be completed by students (weight 2), graduates (weight 1) and academics (weight 2).

The employer's opinion is difficult to take into account here. The Likert scale is always used, according to: 5: strongly agree; 4: agree; 3: neutral; 2: disagree; 1: strongly disagree.

– Is the proposed pedagogy adapted to the learning objectives?

– Does the proposed pedagogy improve the levels of taxonomy of knowledge (knowledge, understanding, application, analysis)?

– Is the proposed pedagogy adapted to the different learning styles of students?

– Does the proposed pedagogy improve professional skills?

– Does the proposed pedagogy improve teaching?

– Does the proposed pedagogy allow you to work in a professional situation?

– Does the proposed pedagogy make it possible to evaluate progress?

– Is the course intellectually stimulating?

– Can interest in the subject be increased as a result of the proposed pedagogy?

– Can we learn something interesting?

– Are group interactions encouraged?

– Is the balance between traditional and active learning appropriate?

– Can students understand the relevance of the subject to their future career?

– Do additional readings, bibliography, homework, laboratories (if applicable) contribute to the understanding of the subject?

– Are the methods of evaluating student work fair and appropriate?

The value of this indicator is calculated by:

$$I_3 = \left(\frac{1}{5}\right)S + \left(\frac{2}{5}\right)G + \left(\frac{2}{5}\right)A$$

### A2.2.4. *Perception of pedagogical relevance*

This indicator deals with students' perception of the specific pedagogical approach within the teaching unit, mainly from a qualitative and organizational point of view. It is assessed by a questionnaire that can only be completed by students, with a Likert scale always: 5: strongly agree; 4: agree; 3: neutral; 2: disagree; 1: strongly disagree.

– Has the proposed pedagogical approach improved my interest in the subject?

– Was the quality of equipment (videos, laboratories, problems, etc.) and resources appropriate?

– Were the teacher's explanations clear?

– Has the proposed pedagogical approach allowed me to better understand the subject?

– Does the score I received reflect my level of understanding/effort?

– What pedagogical approach(es) would you suggest to improve the teaching and learning process of this subject? (This question is not quantified! Students have the opportunity to suggest one or more of the following methods: registered lectures, problem-based learning, self-study, project-based or problem-based learning, lectures, practical instruction, reverse pedagogy, etc.).

Finally, the indicator is calculated by the relationship:

$$I_4 = \left(\frac{5}{5}\right) S$$

### A2.2.5. *Evaluation of acquisitions*

This indicator characterizes student acquisition during and just after the academic unit. It takes into account the regular monitoring and evaluation of students.

Exam scores reflect acquisition, but the difficulty here is to compare different student promotions, with (perhaps) different types of exams. The average scores are then compared with those of the previous three years, as well as with the cohort's results in the other subjects. Standard deviations are also taken into account, and even compared with those of previous years and the cohort for other subjects.

For example, an increase in average scores could mean a more effective teaching methodology, while a decrease in standard deviation indicates a more consistent understanding of the cohort. Couldn't this also indicate the absence of lost students in some parts of the course? Comparison with the overall scores and standard deviations of the cohort should also be included to avoid any bias resulting from a change in student profile.

The value of indicator 5 is calculated according to the relationship (average mark for mean score and STD for standard deviation):

$$I_5 = \left(\frac{AverageMark_{currentyear}}{AverageMarks_{formeryears}}\right)_{course} * \left(\frac{AverageMark_{formeryears}}{AverageMarks_{currentyear}}\right)_{cohort} /$$
$$\left(\left(\frac{STD_{currentyear}}{STD_{formeryears}}\right)_{course} * \left(\frac{STD_{formeryears}}{STD_{currentyear}}\right)_{cohort}\right) * 3$$

### A2.2.6. *Evaluation of the transfer*

The previous indicator quantifies what students have learned, this one quantifies what they have learned and are able to do in a professional situation. However, the transposition of knowledge and skills into industrial performance depends not only on scientific or technical mastery, but also on transversal and general skills and a personal factor. This indicator therefore not only assesses the pedagogical effectiveness of a single module, but also provides a measure of the overall training. It always comes back to the difficulty of evaluating a single module.

In any case, the evaluation of the transfer must be carried out, in a professional situation, during the traineeship if possible, or at the beginning of the career. The questionnaires can still be used and completed by graduates (weight 2), academics in the case of internships (weight 1), and employers (weight 2). The students' opinions are not taken into account here. The Likert scale is used, with responses according to: 5: very good; 4: good; 3: average; 2: bad; 1: very bad.

– Does the course achieve the expected competencies in the subject concerned?

– Does the course offer the possibility of combining theory and practice to analyze the problems encountered in professional life?

– Does the course make clear links between the subject matter and professional work?

– Does the course offer the opportunity to apply or extend the concepts to new problems?

– Does the course offer the opportunity to improve written and/or oral communication skills?

– Does the course offer the opportunity to develop teamwork skills?

– Does the course enhance students' management skills?

The value of this last indicator is calculated by the relationship:

$$I_6 = \left(\frac{2}{5}\right)G + \left(\frac{1}{5}\right)A + \left(\frac{2}{5}\right)E$$

### A2.2.7. *Conclusion*

This methodology was applied (in particular) to the comparison of different teaching methods for the chemical reaction engineering course in the different partner institutions of the project. The results of the evaluations for the different indicators are presented in Figures A2.4. Apart from the difficulty in obtaining the results of the various surveys or in identifying changes in student results over several years (only two partners were able to calculate the fifth indicator), they do not reveal any significant difference between the different pedagogies tested.

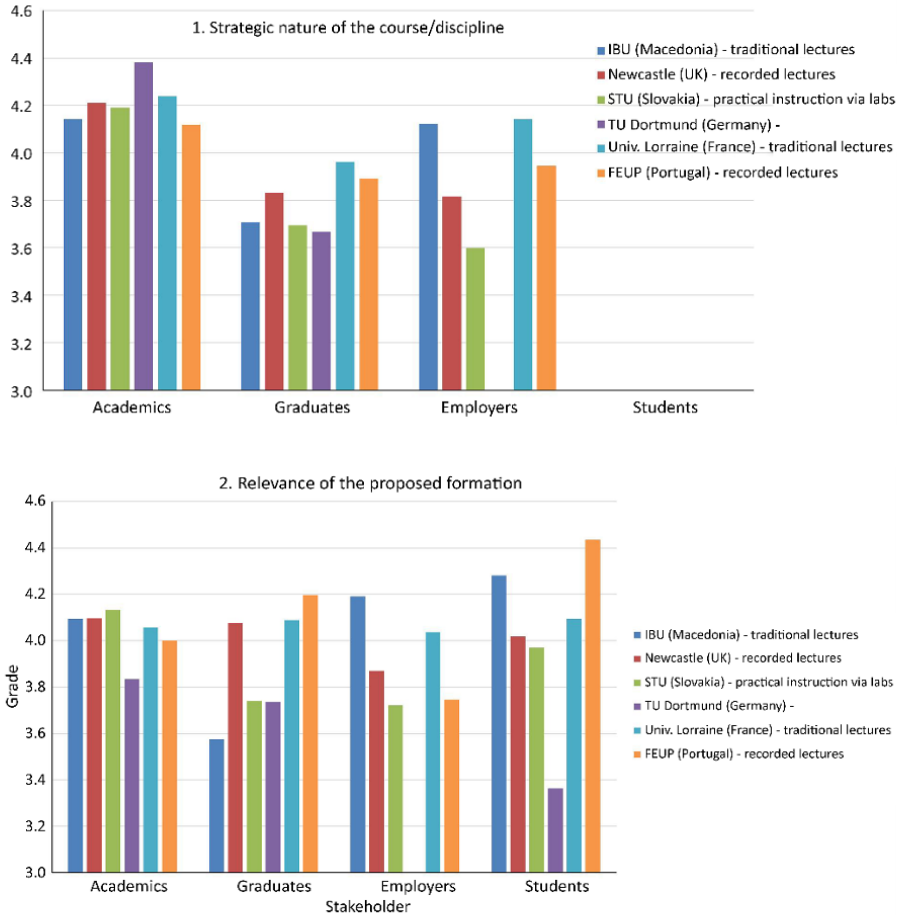
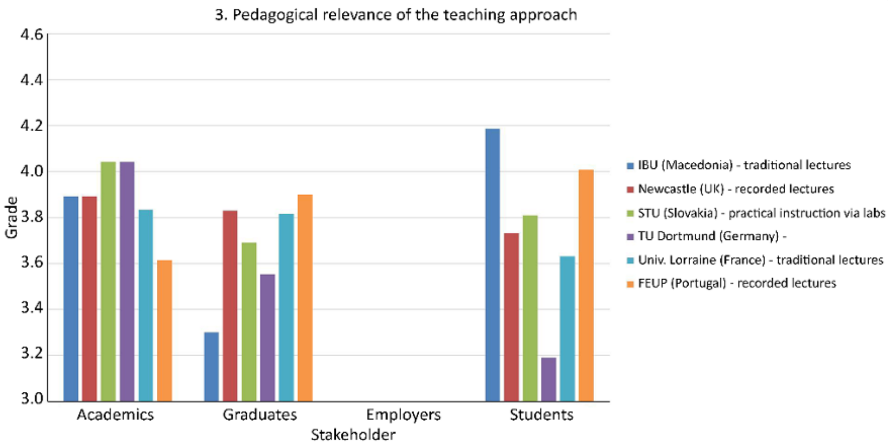



**Figure A2.4a.** *Comparison of different teaching methods. For a color version of this figure, see www.iste.co.uk/schaer/process1.zip*



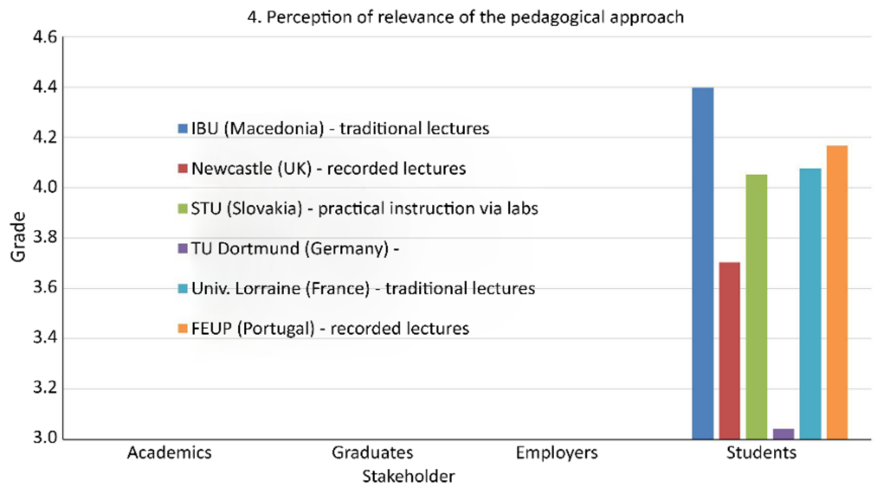
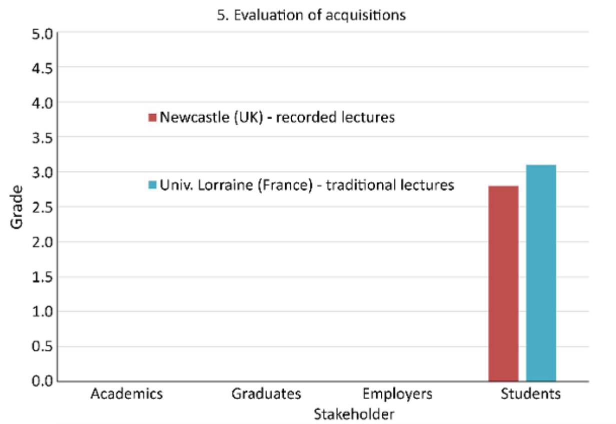




**Figure A2.4b.** *Comparison of different teaching methods (continued). For a color version of this figure, see www.iste.co.uk/schaer/process1.zip*



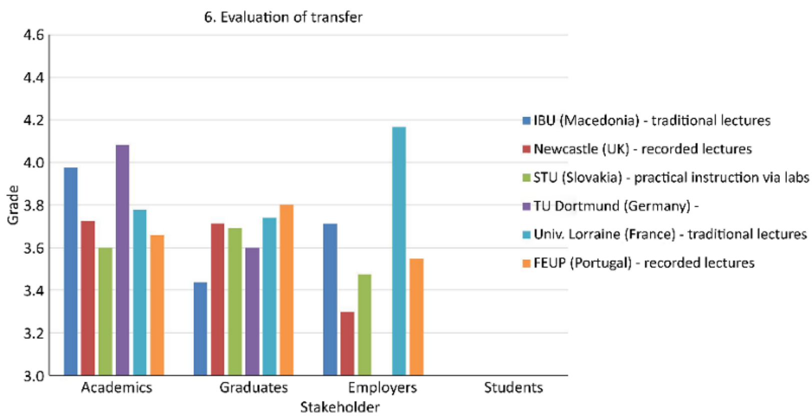




**Figure A2.4c.** *Comparison of different teaching methods (continued). For a color version of this figure, see www.iste.co.uk/schaer/process1.zip*

## A2.3. Conclusion

Two frameworks, based on several parameters reflecting the effectiveness of a complete training and the effectiveness of teaching a single module, were developed and quantified. Their uses and applications, within chemical engineering training structures, were carried out as part of the iTeach project. They make it possible to identify areas for continuous improvement, to compare training institutions or teaching methods, but the results are still linked to the measurement and quantification of many parameters, which are not always easily available.

> The more the technique develops, the more specialized it becomes. Any new solution generally offers an advantage in a narrower field of

application than the technology that has been replaced. Any innovation, however effective it may be from a technical point of view, involves an increasingly narrow economic sector, resulting in a gradual decline in the overall economic performance of these innovations. (Ellul 1988)

The consumer society thus reintroduces mankind... Man is proposed as a principle and as the end of economic activity. It is in his name that we are now innovating.... Material and finite need gives way to desire and an infinite number of objects strive to satisfy an infinite number of desires. (Scardigli 1983)

Our constant discontent is for the most part rooted in the impulse of self-preservation. This passes into a kind of selfishness and makes a duty out of the maxim that we should always fix our minds upon what we lack, so that we may endeavour to procure it. Thus it is that we are always intent on finding out what we want, and on thinking of it; but […] as soon as we have obtained anything, we give it much less attention than before. We seldom think of what we have, but always of what we lack […] like the bear in the fable that throws a stone at the hermit to kill the fly on his nose. We ought to wait until need and privation announce themselves, instead of looking for them. (Schopenhauer 2009)

Everything than can be invented has been invented. (Duel 1899)

Arthur Koestler was not far off when he described the behavior of certain creators in science by comparing them to that of sleepwalkers, encountering major discoveries. But the time must also be right and the minds prepared, and luck must eventually come to support you. (De Gaulejac 2012)

Heaven save us above all from the snobbery which not only admits the possibility of this thin and perfunctory work, but which cries out in a spirit of shrinking arrogance against the competition of vigor and ideas, wherever these may be found. (Wiener 1950)

Any progressive reform is regularly criticized by the Conservatives. The latter are constructed according to three variations: the perverse effect thesis (where the proposed intervention only aggravates the problem in question), inanity (where the intervention does not achieve any result) and jeopardization (where the intervention threatens to weaken achievements obtained at the cost of great effort in the past). (Hirschman 1991)

Nothing would be more fatal for the Government of States to get in the hands of experts. Expert knowledge is limited knowledge, and the unlimited ignorance of the plain man who knows where it hurts is a safer guide than any rigorous detection of a specialized character. (Letter written in 1902 by Winston Churchill to H.G. Wells, cited by Morozov 2014)

Research [...] is a victim of motorway toll syndrome. This paradigm describes situations in which an ancillary device to improve the function of the system is so costly that it absorbs the majority of resources. (Ségalat 2009)

I would like to say that the really difficult problems of morality are not to choose between Good and Evil. The much more difficult cases are those where you have to choose between gray and gray. (Ricoeur 1994)

Because scientific knowledge was increasing exponentially, most researchers stopped thinking about unification. As long as their theories worked, there was no need to look any further... The vast majority of scientists have never been anything more than gold diggers paid by the day. This is even more true today. They receive the necessary training to reach the border of the explored lands and make their discoveries as quickly as possible, because life in these regions is expensive and risky. Scientists[...] do not have time to imagine any overall vision and they do not see the benefit they could get from it. (Wilson 1999)

The best way to have good ideas is to have lots of ideas. (Pauling 2014)

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