Lifelong Learning Programme

Improving Teaching Effectiveness in Chemical Engineering Education

ITEACH

Pilot versions of the assessment frameworks

Deliverable 3.2.

September 2016

Contents

Executive summary

The two frameworks developed in the former deliverable D.3.1. are here clearly defined and quantified.

The first one, related to the effectiveness of a whole formation is based on 7 global indicators :

- Pedagogy,
- Learning outcomes,
- Attractiveness,
- Relations with research,
- Relations with industry,
- Employment and
- Quality),

gathering more than 150 parameters. All the parameters are quantified, according to Gaussian laws or threshold values, and their mean values, standard deviations and weights are also defined. This work was based on the literature analysis, on the recommendations of the European Federation of Chemical Engineering, and on several internal discussions within the consortium.

The second framework, related to the evaluation of the teaching effectiveness of a single module is assessed through questionnaires, by different stakeholders involved in the teaching process : students, graduates, academics and employers. The questionnaires are organised into 6 metrics, related to the :

- Strategic nature of the teaching unit,
- Relevance of the proposed formation,
- Pedagogical relevance of the teaching approach,
- Perception of relevance of the pedagogical approach,
- Evaluation of the acquisitions,
- Evaluation of the transfer

The questions inside each metrics have been discussed within the consortium, and are quantified by Likert scale. The global values of the metrics are finally quantified according to the responses of the stakeholders, and to different weights that were also discussed between the project partners.

After a first survey in academic year 2015-16, a revised version of that second framework has been developed, for utilisation during the 6 last months of the project.

1. Introduction

This report details the developed frameworks for the assessment of the effectiveness of core knowledge and competency for their pilot evaluation in WP4. It follows the first report D.3.1. detailing their derivation, and also contents two parts : one devoted to the evaluation of the effectiveness of a whole formation, and a second one for the evaluation of a single teaching unit.

2. Evaluation of a training center in Chemical Engineering

2.1. Introduction

A formation can be seen as an industry, with its incomings, its transformation processes, and its out coming. As an industry, efforts are to be performed on the quality of incomings (which can be quantified as attractiveness), the quality of the production processes (which can be quantified as both pedagogy and quality management) and the consistency of its outcomes in relations with industrial, social and scientific evolutions, which can be quantified as learning outcomes, relation with industry and research, and of course, of the employment of graduates.

The global indicators for the effectiveness of a whole formation defined in D.3.1. are listed below:

- Pedagogy,
- Learning outcomes (or LO)
- Attractiveness,
- Relations with research,
- Relations with industry,
- Employment,
- Quality.

Those indicators include several parameters (almost 160), which have been defined within the consortium, but that may now be clearly quantified.

2.2. Toward a quantification of parameter

The challenge in this case is to convert an observed parameter into a quantified value that may reflect the effectiveness of the proposed indicators.

Starting with the pedagogy indicator, for instance, a given number of European Credit Transfers System for different teaching methods (classical lectures, tutorials, labs, projects or problem based learning, or any other non-traditional teaching methodologies) is proposed. Some average values may be defined, although a number of accreditation bodies are very careful about prescribing a number of credits for specific teaching methodologies, and although no specific teaching methodology proved until now to be clearly better than any other. Moreover, our goal is not to emphasize on a particular

teaching methodology, all may have their own interest, depending on the taught subject, the number of students, the way it is implemented and so on. Hence it seems obvious that some degrees of freedom have to be proposed: a formation is unlikely to change from a very good efficiency value to an unacceptable one if the number of ECTS for a given methodology (for this example) changes only slightly. In that case, a Gaussian type approach is profitably used to define the effectiveness in this respect:

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

where e is the effectiveness, v the value (here the number of ECTS for a given teaching method), μ the average value (in this case defined by the project consortium, although this may be modified by the relevant regulatory body/institution seeking to use the framework) and σ the standard deviation?

The exponential is not divided here by the standard deviation (unlike a conventional Gaussian law, where the integral equals one) so that the maximum value remains equal to one. In the given example, the efficiency variations are presented in Figure 1 below, with a mean value of 150 and a standard deviation of 50.

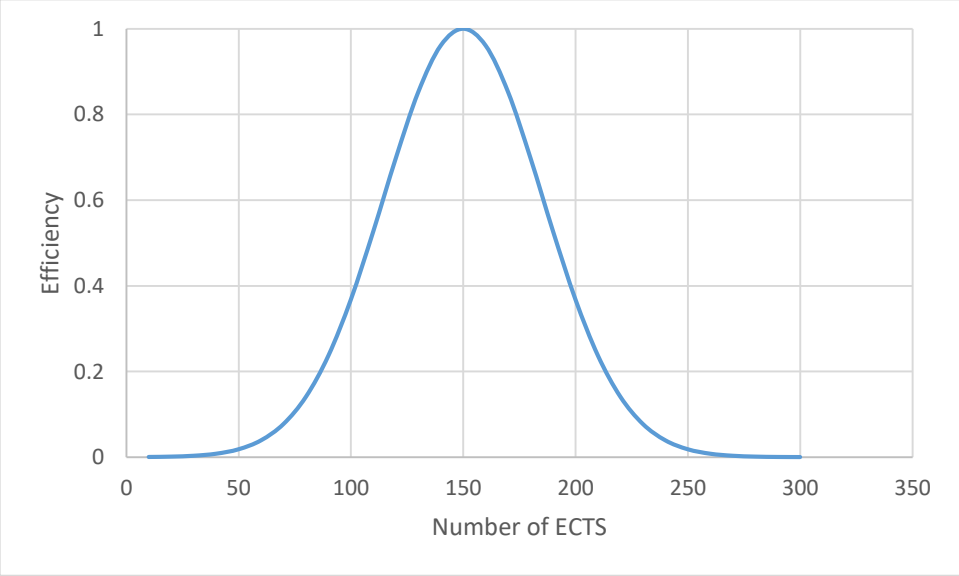


Figure 1 : Proposed efficiency factor

Finally, the proposed parameter can be multiplied by a factor taking into account the relative importance of this parameter in the stated global definition of an indicator. These factors have also been discussed and agreed by the consortium.

Some other parameters, such as the use of feedback questionnaires in Pedagogy (see Table 1 in the Supplementary materials), may just be defined in a binary fashion where the responses are either yes

or no. In that case, a value (predefined by the consortium on the basis of the importance of the assessed parameter) is simply added or not according to the presence of such a parameter.

The details of the global indicators, including the quantification of each parameter are then presented in the following paragraphs.

2.2.1. Pedagogy

In the case of pedagogy, the proposed indicators are then defined in Table 1. The staff to student ratio is of course taken into account, as in numerous ranking surveys, but many other parameters, such as the numbers of traditional and interactive hours of teaching (expressed in ECTS), the use of student feedback questionnaires, the number of teaching hours for one ECTS (whilst this is mean to be uniform on the basis of the definition of the ECTS, the initial survey revealed marked variations in this parameter and hence it was included in the framework), the number of hours of teaching per year or the teachers' training. Mean values and standard deviations of each parameter have been proposed based on consortium discussions, and on the actual standard values for these parameters.

The proposed maximum score for Pedagogy is thus of 300.

Table 1: Details of the parameters for Pedagogy indicator

Teaching	Parameter	Mean value (μ)	Standard Deviation (σ)	Score
	ECTS of classical lectures	100	30	10*e
	ECTS of tutorials	50	30	10*e
	ECTS of labs	50	30	10*e
	ECTS of Problem & Project Based Learning	50	30	10*e
	ECTS of non traditional teaching methodologies	50	30	10*e
				Maximum score for teaching : 50

Use of feedback questionnaires (evaluating the following aspects)				*If yes : 5, if no : 0*
	Learning	y	n	5/0
	Enthusiasm	y	n	5/0
	Organization (including course materials)	y	n	5/0
	Group interaction	y	n	5/0
	Individual report	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 response to feedback questionnaires ?	y	n	15/0
				Maximum score for feedback questionnaire: 60
Number of face to face teaching hours equivalent to one ECTS (an ECTS also includes independent work)		10	5	30*e
Total hours of face to face formation per year (as given by accreditation bodies)		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 postponing: 60
Availability for teaching				
	Office on site	y	n	10/0
	Email address	y	n	10/0
	Percentage of time for teaching	50	10	10*e

	Number of students/teachers	5	5	10*e
	Percentage of permanent academics	100	10	10*e
	Continuous professional development for academics	y	n	10/0
	Academiv tutors	y	n	10/0
				Maximum score for teaching availability: 70
				Total 300

2.2.2. Learning outcomes

Some ECTS for learning outcomes have been defined by the European Federation of Chemical Engineering. These figures are suggested as minimum values to achieve the required chemical engineering learning outcomes. In a same manner, some degrees of freedom have to be added, to reflect the unique features of individual formations. The consortium does not propose any maximum values, since as the maximum ECTS value for a formation is limited to 300, if some ECTS were exceeding significantly in one area, they would not fulfil the requirements in other areas, to keep the formation in the Chemical Engineering field.

It has been proposed that the efficiency remains at its maximum at around the recommended ECTS values, and decreases outside of this range as reflected by a Gaussian distribution.

The skills and competencies are for the moment evaluated in a binary fashion as present or absent. This part may be developed further in the future, taking for instance the number of ECTS devoted to the development of each of these competencies.

The first and second cycles internships are taken into account, as well as the accreditation of the institution by any relevant (inter)national body. Details of the parameters evaluated within this indicator are listed in Table 2.

Again, the proposed maximum score for Learning Outcomes is 300 (see Table 2).

Table 2: Details of the parameters for Learning Outcomes indicator

Learning outcomes		**Min ECTS value**	**Standard deviation**	**Score**
Fundamentals of sciences and natural sciences		45	15	20*e
	Mathematics			
	Physics			
	Chemistry			
	Computer sciences			
	Numerical methods			
Chemical engineering fundamentals		35	15	20*e
	Mass and energy balances			
	Thermodynamics			
	Fluid dynamics			
	Heat & mass transfer			
	Chemical reaction engineering			
	Separations,			
	Biomolecular and biological engineering			
Chemical engineering applications		15	10	20*e
	Basic process & product engineering			
	Health, Safety & Environment			
	Analytical techniques			
Non-technical subjects / competencies		10	5	20*e
	Social Sciences and management			

	Languages			
First cycle Internship		15	5	20*e
Extension of scientific subjects		15	5	20*e
Advanced courses, chemical engineering depth		40	15	20*e
	Advanced Chemical engineering			
	Product design			
	Biotechnological processes			
	Process management			
Second cycle Internship		30	5	20*e
	Total	205		*Maximum score for consistency: 160*
Accreditation (CTI, IChemE…)		y		20/0
ECTS of Active formations				Number of ECTS/10
Learning outcomes of the formation clearly articulated		y		10/0
ECTS of internships or formation outside the home institution		30	5	20*e
				Maximum score for habilitation: 60
Skills & Competences				
	Ability to gather information	y		10/0
	Ability to analyse information	y		10/0
	Self-learning ability	y		10/0

	Ability to identify and formulate problems	y		10/0
	Ability to solve problems	y		10/0
	Ability to work effectively as a member of a team	y		10/0
	Ability to communicate effectively	y		10/0
	Appreciation of an interdisciplinary approach	y		10/0
	Maximum score for skills: 80			
				Total : 300

2.2.3. Attractiveness

The attractiveness of a whole formation can significantly affect the student cohort size and quality of the students applying and thus indirectly affect the quality of the whole formation. As this indicator is relatively difficult to evaluate quantitatively, the framework relies on more qualitative values for this indicator.

Details of the parameters included in this indicator are shown in Table 3. The quantitative measures include the number of students applying for the formation and the registration fees. The general attractivity of the city, the national and international rankings, the marketing cell, its realizations and the potential implication of students are also taken into account, albeit these are more difficult to quantify. The average salary after graduation could also be included into the attractiveness indicator, but it has been decided to account for it within the employment indicator.

Table 3: Details of the parameters for Attractiveness indicator

Attractiveness		**Mean value**	**Standard Deviation**	**Score**
Number v of applicants/places per year				The number v if less than 30; 30 if it exceeds
Registration fee/mean salary				10-v (0 if negative)

Housing facilities		y	n	10/0
Size (number of inhabitants v) of the city				$v*1.10^{-5}$ (10 if it exceeds 10)
Average monthly accommodation costs /mean salary				5*(2-v) (0 if negative)
Existence of a marketing department (at least at the university level)		y	n	10
Number of employees in the marketing department				v (if less than 10)
Implementation				
	Informations provided (website, elevtronical letters, hard copies...	y	n	30/0
	Forums/Visit days	y	n	10/0
Participation of the students				
	In activities of the marketing department	y	n	10/0
	In attractivity	y	n	10/0
	In associations/Students societies	y	n	10/0
	In communication	y	n	10/0
Percentage v of foreign students (averaged over all study years, including exchange students)				v/10 (10 maximum)
International exchange agreements				v/10 (10 maximum)
Courses in English		y	n	10/0
National ranking (in the subject area, averaged over the last 3 years)				(100-v)/10 unless negative
International ranking (averaged over the last 3 years)				(500-v)/50 unless negative
Existence and influence of alumni association		y	n	10/0
Average mark v of incoming students		μ	σ	$50*(v-\mu)/\sigma$

Percentatge of students from disadvantaged social background (averaged over all years)		20	20	10*e
Male/female ratio (%)		50	20	10*e
				Total : 300

2.2.4. Relations with research

The significance of the research-led and research-informed teaching at tertiary level has been extensively argued in the literature (see for example Jenkins and Healey, 2005). The number of research internships, of hours taught by researchers and of innovation projects all contribute to this indicator (see Table 4, Supplementary material for detailed description of contributing parameters). The high weighting for students obtaining dual diplomas/degrees takes also into account the international dimension.

The number of students undertaking a PhD after graduation should represent a balance between further study and industrial relevance dimension of the formation.

Table 4: Details of the parameters for Relations with Research indicator

		Mean value (μ)	**Standard deviation (s)**	**Score**
ECTS of Research internship		30		v (if below 30)
Advanced courses (in ECTS) delivered by researchers conferences				v (if below 10)
Visits to research laboratories				v (if below 10)
Number of hours (ECTS) taught by staff exclusively on research contract				v (if below 30)
ECTS of innovation projects				v (if below 30)
Percentage of research active staff/number of academics in the department		100		v/10
Number of patents /year				v (if below 10)
Joint research with industry				v (if below 10)

Creation of startups/spin-outs in the last 10 years				v (if below 10)
Volume of research contracts/mean salary				v/100 (if below 10)
Number of dual diplomas/degrees agreements				
	National			v (if below 10)
	International			v (if below 10)
Percentage of students with dual diplomas/degrees (with foreign universities)		100		v
Percentage of graduates undertaking a PhD		10	10	20*e
				Total : 300

2.2.5. Relations with industry

The industrial relevance of the degrees, particularly in professional disciplines such as chemical engineering, is essential, as indicated by many accreditation bodies (IChemE, ABET). This indicator takes into account the industrial internships, the number of teaching hours delivered by industrials, the variety of hiring sectors or the different (first) job positions, as highlighted in Table 5.

Table 5: Details of the parameters for Relations with Industry indicator

		Mean value	**Standard deviation**	**Score**
ECTS of Industrial internships		30	0	v (if below 30)
Industrial tutorsadvisors		y	n	20/0
Number of visiting lectures deliverd by Industrialists conferences (averaged on the duration of learning)		10	0	v (if below 10)
Students visits to companies		10	0	v (if below 10)
Number of hours (ECTS) taught by industrials		10	0	v (if below 10)

ECTS of projects realized in collaboration with industry		20		v (if below 20)
Apprenticeship Formations		y	n	10/0
Percentage of students in apprenticeship formations		10	0	v (if below 10)
Percentage of students that form their company (5 years after graduation)		10	0	v (if below 10)
Number of industrialists on the steering committee		10	0	v (if below 10)
Number of industrial chairs		10	0	v (if below 10)
Existence of industrial open days		y	n	10/0
	Number of industrial sectors represented	10	0	v (if below 10)
Junior enterprise		y	n	10/0
Hiring sectors				
	Bulk chemicals	y	n	10
	Specialty chemicals	y	n	10
	Energy	y	n	10
	Engineering	y	n	10
	Pharmaceuticals	y	n	10
	Agro & Bio industries	y	n	10
	Environment	y	n	10
Job position				
	Production	y	n	10
	Research	y	n	10
	Design engineering	y	n	10
	Technical assistant	y	n	10
	HSE & Quality	y	n	10
				Total : 300

2.2.6. Employment

Once again, in professional disciplines such as chemical engineering, it is essential that the graduates gain the necessary knowledge and competencies sought after by the industry. The length of time for graduates to secure their first job, the level of the starting salary and the unemployment rate 6 months from graduation are traditionally used as indicative parameters of industrial relevance of the formation. The number of additional trainings after graduation, if excessive, indicates areas lacking in the formation or discrepancies between the formation and industrial requirements. Some parameters, such as the levels of responsibility 10 years from graduation are also important, although more difficult to evaluate and alumni associations may be required to help quantify this parameter. Details of all the parameters included in the Employment indicator are provided in Table 6.

Table 6: Details of the parameters for Employment indicator

		Mean value	Standard Deviation	Score
Average starting salary of graduates/mean salary		3	0.5	10*v (if below 30)
Time to find the first job (months post-graduation)		0	2	30*e
Unemployment rate 6 months after graduation		0	100	60*e
Influence of alumni association on employment		y	n	10/0
Percentage of additional training after graduation		10	10	10*e
Percentage of additional research formation after graduation		10	10	10*e
Average salary 10 years after graduation/mean salary		10	1	v (if below 10)
Percentage of full time employment 10 years after graduation		100	0	v/10
Level of responsibility after 10 years				The sum of the figures below should not exceed 100
	Project manager	10		v
	Head of service	10		v
	Expert	10		v

	Sales manager	10		v
	Plant manager	10		v
	Executive officer	10		v
	Research director	10		v
	Director of company	10		v
	Director of Human resources	10		v
	Full Professor	10		v
Geographic hiring areas				The sum of the figures below should not exceed 30
	Outside the country of formation	10		v
	in Europe	10		v
	in the rest of the world	10		v
				Total : 300

2.2.7. Quality

Finally, quality assurance indicator is an important indicator of ensuring continuing and improving quality and effectiveness of the whole programme/formation. Parameters considered within this indicator typically relate to quality assurance procedures higher education institutions are regularly subject to through national and accreditation procedures. These include various programme/formation review processes, the composition of the steering committee, and the regular use of teaching evaluation procedures, as highlighted in Table 7.

Table 7: Details of the parameters for Quality indicator

		Mean value	**Standard Deviation**	**Score**
Existence of a steering committee		y	n	20/0
Composition of the committee/board				
	Industrialists	y	n	10/0
	Number of sectors represented	10		v (if less than 10)

	External (to the institution) academics	y	n	10/0
	Internal academics	y	n	10/0
	Students	y	n	10/0
	Researchers	y	n	10/0
	Alumni	y	n	10/0
Frequency of meetings (per year)		4		2.5*v
Evidence of forward planning		y	n	10/0
Frequency of programme/formation review (per year)		1		10*v (if less than 10)
Staffing decision making local to the department/course unit		y	n	20/0
Evaluation of teaching				
	Frequency of evaluations/year	2		10*v (if less than 20)
	Evaluation of pedagogical competences	y	n	10/0
	Evaluation of teaching materials	y	n	10/0
	Evaluation of scientific & technical contents	y	n	10/0
	Evaluation of skills & competences contents	y	n	10/0
	Feedback of evaluation to the students	y	n	10/0
Academic staff development regularly monitored		y	n	20/0
Existence of an educational committee		y	n	20/0
Existence of a direction board		y	n	10/0
	Industrialists	y	n	10/0
	Academics	y	n	10/0
	Students	y	n	10/0
	Local governments	y	n	10/0
				Total : 300

2.3. Conclusion

In order to determine the cost effectiveness of a given provision, the final score is divided by the cost of the formation taking into account staff salaries, infrastructure, maintenance, and all overheads per year and per student. To account for differences between countries, the cost is related to the average national salary.

Seven indicators, taking into account more than 150 parameters have thus been defined and quantified. Some threshold values, mean values and standard deviations have been proposed, discussed, modified and finally consensually validated by the consortium.

The premise of this research is that the teaching efficiency could thus be measured (and improved) through the above defined indicators. The indicators can be visualized in a radar plot presented as in Figure 3. The maximum value of these criteria should be related to the cost of the formation and the national average salary, as indicated above, to ensure international comparisons.

Teaching efficiency could thus be measured (and improved !) through those indicators, that can be presented as in Figure 2. The maximum value of these criteria should be related to the cost of the formation and the national average salary to ensure international comparisons.

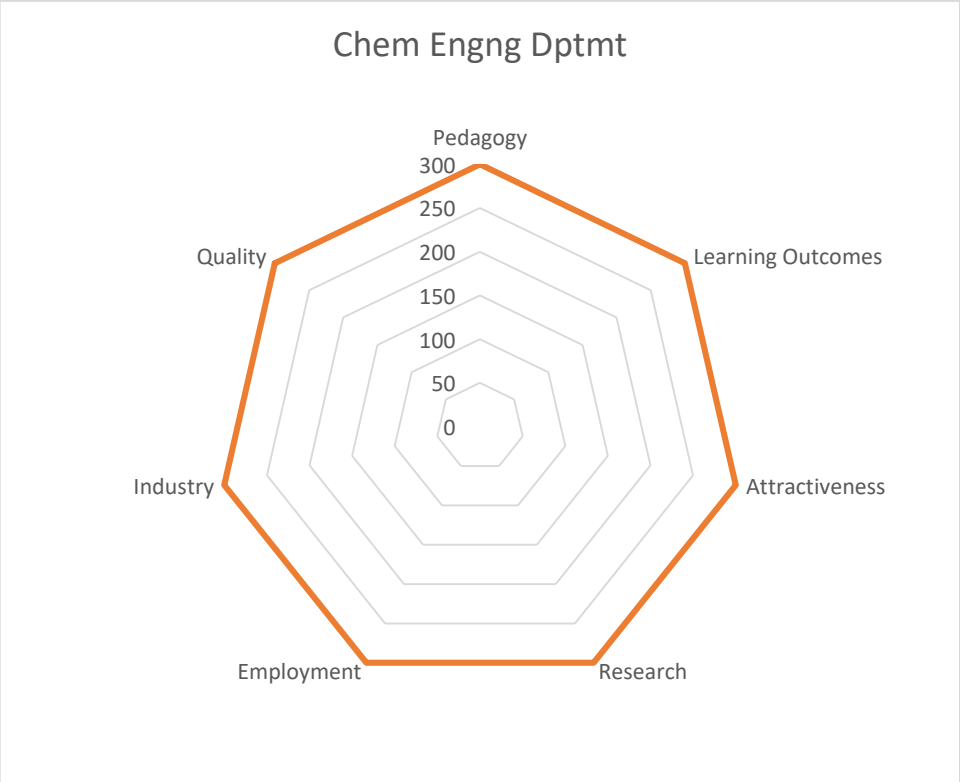


Figure 2 : Teaching effectiveness

3. Evaluation of a single teaching unit

Six indicators (or metrics) are proposed for the evaluation of single teaching unit. The general assessment is applied to the population concerned by the teaching unit : students; graduate chemical engineering students; teachers (including the one delivering the course) and pedagogical team; hiring sectors of graduate students, or employers. These groups are related to the specificity of the chemical engineering formation.

Some metrics are assessed by questionnaires, by the teaching unit description, and by evaluations.

A first version was developed at the end of WP3, and was subsequently used for assessing a common course of Chemical Reaction Engineering among different countries, using different pedagogical approaches. After the first results of WP4, and the agreement of extension for 6 additional months, a second version of the questionnaires was developed in collaboration with the persons in charge of WP4, and will also be detailed.

3.1. First version of the pilot for the evaluation of a single teaching unit

This first version was used in 2016 for the evaluations of a common course of Chemical Reaction Engineering, and corresponds thus to the first results detailed in the pilot implementation.

3.1.1. Strategic Nature of the Teaching Unit

This metric deals with the importance of a teaching unit for the global leaning outcomes of a chemical engineer. Does this teaching unit bring necessary knowledge and skills for a (future) chemical engineer? Is it adapted to what the graduates are supposed to apply in professional situation?

This metric may be assessed by the graduates (weight 1), the academics/teachers (weight 2) and employers (weight 2 also). 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.

Issues to take into account:

- Analysis of the needs: Is this teaching unit necessary for a chemical engineer?
- Does it cover all the needs it should ?
- Is it too detailed for a chemical engineer? (*here, the values of the Likert scale have to be changed : 5 : strongly disagree… 1 : strongly agree, it's just to be sure that people read correctly the questionnaires…)*
- Is it adapted to the real activities of a chemical engineer ?
- Does it include a prospective approach ? Bringing new concepts and taking into account the future needs of the market ?
- Is the study program in concordance with other competing universities ?

- Does this teaching unit contribute to the attractiveness of the formation towards future students ?

After the responses to the questionnaires by the different stakeholders, and quantification of the results according to the Likert scale, the metric 1 value can be calculated according to the relation :

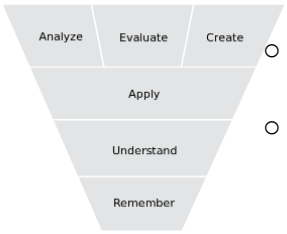
$$M_1 = \left(\frac{1}{5}\right)G + \left(\frac{2}{5}\right)A + \left(\frac{2}{5}\right)E$$

3.1.2. Relevance of the proposed formation

This metric deals with the content of the teaching unit. Does-it allow to reach a sufficient level for an engineer, does-it cover all it should ?

It is also assessed by questionnaires that could be fulfilled 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 responses such as : 5 : strongly agree ; 4 : agree ; 3 : neutral ; 2 : disagree ; 1 : strongly disagree.

- The content of the teaching unit is adequate,
- Its position in the overall program is appropriate,
- Its duration (workload/ECTS) is adapted,
- Appropriate learning outcomes are clearly formulated for this teaching unit (course)
- Its relations (or prerequisites) with other teaching units are appropriate,
- It allows accessing the four levels of taxonomy :
    - Knowledge (Exhibit memory of previously-learned materials by recalling facts, terms, basic concepts and answers)
    - Comprehension (Demonstrative understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas)



    - Application (Using new knowledge. Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way)
    - Analysis (Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations), Synthesis (Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions) and Evaluation (Present and defend opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria)

After responses of the stakeholders to the questionnaires, the metric 2 value can be calculated according to the relation :

$$M_2 = \left(\frac{1}{5}\right)S + \left(\frac{1}{5}\right)G + \left(\frac{2}{5}\right)A + \left(\frac{1}{5}\right)E$$

3.1.3. Pedagogical relevance of the teaching approach

This metric deals with the form of the teaching unit. It clearly relies on the pedagogical engineering, and on the chosen teaching method. Does-it allow an efficient acquisition of the taught skills and knowledge ?

It is still assessed by questionnaires that can be completed by students (weight 2), graduates (weight 1), and academics (weight 2). The employer's opinion is here difficult to consider… The Likert scale is still used, with responses such as : 5 : strongly agree ; 4 : agree ; 3 : neutral ; 2 : disagree ; 1 : strongly disagree.

Depending on the audience, different questionnaires may be proposed. Some parts (those related to pedagogy) of the questionnaire for the students are taken from the SEEK. Some parts of the academic questionnaire are taken from the TEVAL project.

3.1.3.1. Questionnaires for Students

- Teacher's explanations were clear
- The course is intellectually challenging and stimulating
- The teaching unit (course) is dynamic and enthusiastic
- My interest in the subject has increased as a consequence of this course
- I learned something which I consider valuable
- Group interactions were encouraged
- The breadth of the teaching unit (course) was appropriate
- Proposed objectives agreed with those actually taught, so you knew where the course was going
- The balance between classical and active learning was adequate
- I understand the relevance of the topic for my future profession
- Further reading, homework, laboratories (if applicable) contributed to the appreciation and understanding of the subject
- Methods of evaluating student work were fair and appropriate
- Feedback on examinations/graded materials was valuable
- The mark you obtained (if already available) reflects my level and effort
- Course pace was appropriate
- I was able to appraise my progression
- If I need some explanations :
    - I can search on internet *(corresponds to 1, it's not very innovative nor interacting)*
    - I can ask to an other student *(corresponds to 2, it's a bit better)*
    - I can read the course handout *(corresponds to 3, means a reference document exists),*
    - I can ask the teaching team *(corresponds to 4)*
    - I have at my disposal several complementary documents *(corresponds to 5)*
- To revise the examination :
    - I read my hand notes *(corresponds to 1, it's a minimum)*
    - I can redo the exercises that were proposed in tutorial sessions *(corresponds to 2)*
    - I have former examination subjects to test myself *(corresponds to 3)*
    - I have several multimedia documents to improve my knowledge *(corresponds to 4)*
    - I can access the teaching team *(corresponds to 5)*

3.1.3.2. Questionnaires for Academics and Graduates

- The proposed formation and pedagogy is appropriate to the learning outcomes
- The proposed pedagogy allows accessing and improving different levels of knowledge taxonomy (Knowledge, Comprehension, Application, Analysis)
- The proposed pedagogy is appropriate to different students' learning styles (Active and Reflective learners, Sensing and Intuitive learners, Visual and Verbal learners, Sequential and Global learners)
- The proposed pedagogy promotes active learning
- The pedagogy improves skills and competencies
- The proposed pedagogy (e.g. labs, tutorials, projects, works, multimedia documents (if present)) improve the teaching
- The proposed pedagogy enables working in professional situation
- The proposed pedagogy enables appraising the progression

The metric 3 value can be calculated according to the relation :

$$M_3 = \left(\frac{1}{5}\right)S + \left(\frac{2}{5}\right)G + \left(\frac{2}{5}\right)A$$

3.1.4. Perception of relevance of the pedagogical approach

This metric deals with the perception of the specific pedagogical approach within the teaching unit by the students, from a qualitative and organization point of view essentially. It is assessed by a questionnaires that can be completed by the students only, with Likert scale such as : 5 : strongly agree ; 4 : agree ; 3 : neutral ; 2 : disagree ; 1 : strongly disagree.

- The proposed pedagogical approach improved my interest in the subject
- Course materials were well prepared and carefully explained
- The quality of the materials (e.g. videos, …) and documents was appropriate
- Teacher's explanations were clear

The metric 4 value can be calculated according to the relation :

$$M_4 = \left(\frac{5}{5}\right)S$$

3.1.5. Evaluation of the acquisitions

This metric deals with the acquisitions of the students during and just after the teaching unit. It includes regular evaluations of the students.

We propose to regularly assess the level of understanding of the students during the teaching unit by multiple choice questionnaires, which could be proposed to the students at the end of a compulsory session, on the different taxonomy levels :

- Knowledge,

- Understanding,
- Application,
- Evaluation, creation, analysis

These questionnaires could take a few minutes, should be corrected very rapidly by the teaching team, and their marks could be rated between 0 and 5. These questionnaires could, eventually, be proposed to the students at the beginning and at the end of a project.

The marks at the examination also reflect the acquisition, but the difficulty here is to compare different promotions of students, with (maybe) different kind of examination (there exists an "archive" system in France, where students give the examination subject to others, to better revise, and to know how the teachers assesses…) The marks reflect the acquisition, provided the exam is proposed from a competencies point of view. The average marks of former 5 years, and corresponding average deviations could also be involved. For example, an increase in the average marks could significate a better efficiency of the teaching methodology, whereas a decrease in the standard deviation indicates a more uniform understanding of the cohort ? This could also indicate the absence of students who were lost in some parts of the course ? The comparison with the global marks and standard deviations of the cohort should also be included, to avoid any bias involved by a change of the students' profile.

Finally, the evaluation criteria could be an average mean of all these evaluations ? This may reduce the weight of the final examinations, which however depends of the assessment method (written examination or project, for example…). The metric 5 value could be calculated according to relation :

$$M_5 = QCM + \left(\frac{AverageMark_{currentyear}}{AverageMarks_{formeryears}}\right)_{course} * \left(\frac{AverageMark_{formeryears}}{AverageMarks_{currentyear}}\right)_{cohort} / \left(\left(\frac{STD_{currentyear}}{STD_{formeryears}}\right)_{course} * \left(\frac{STD_{formeryears}}{STD_{currentyear}}\right)_{cohort}\right) * 3$$

3.1.6. Evaluation of transfer

The metric 5 quantifies what the students have learnt, the metric 6 what they are able to do in professional situation. However, transposition of knowledge and competencies into business performance depends not only on scientific or technical mastering (T), but also on transversal and general (G) competences (project management, for example) and on a personal factor (P) (behavioral skills), so that the performance would be something like: (T + G) x P. This metric thus assesses not only the teaching efficiency of a single module, but gives also a measure of the whole formation... It always comes back to the difficulty of assessing a single module.

Anyway, the evaluation of transfer has to be performed, in professional situation, during internship if possible, or during the early career years. Questionnaires may still be used, and completed by graduates (weight 2), academics in the case of internships (weight 1) and employers (weight 2). The opinion of students is not considered here. The Likert scale is used, with responses such as : 5 : very good ; 4 : good ; 3 : average ; 2 : bad ; 1 : very bad.

The questionnaire is be adapted from the EUR-ACE Standards and from internship evaluations in different institutions of the consortium :

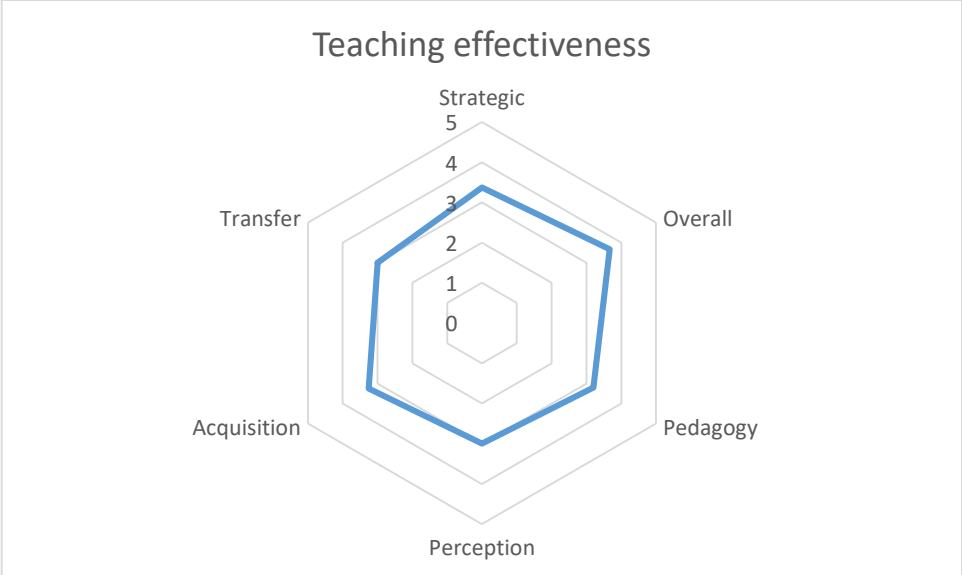
- Work skills & competencies
  - Control of concepts in chemical reaction engineering,
  - Practical skills,
  - Ability to combine theory and practice to analyse the engineering problems
  - Ability to comply with practice standard and know how to deal with hazards
  - Ability to apply the concepts to new problems
  - Ability to extend the concepts to new problems
- Personal qualities and skills
  - Ability to work in professional situation
  - Ability to evaluate own performances and outcomes
  - Motivation,
  - Adaptability
  - Written & oral communication
  - Team work

The metric 6 value can be calculated according to the relation :

$$M_6 = \left(\frac{2}{5}\right)G + \left(\frac{1}{5}\right)A + \left(\frac{2}{5}\right)E$$

3.1.7. Conclusion

This version aims at detailing the assessment framework application for e.g. chemical reaction engineering teaching evaluation. The questionnaires are used, some situational judgment tests have been introduced, and marks of the students are also taken into account.



This first version was improved in September 2016 by the members of the consortium after evaluation of a common course dealing with Chemical Reaction Engineering, for further use in academic year 2016-17, after agreement of extension.

3.2. Second version of the pilot for the evaluation of a single teaching unit

This second version will be used in academic year 2016-17 for the evaluations of different courses within the consortium. It has been improved according to the first feedbacks, to the comments of the responsible of WP4, and to some comments from colleagues of educational team. The goals were to simplify the survey, to ensure good response rates from the stakeholders, and to clearly assess the different metrics.

3.2.1. Strategic Nature of the Teaching Unit

This metric deals with the importance of a teaching unit for the global leaning outcomes of a chemical engineer. Does this teaching unit bring necessary knowledge and skills for a (future) chemical engineer? Is it adapted to what the graduates are supposed to apply in professional situation?

This metric is assessed by the graduates (weight 1), the academics/teachers (weight 2) and employers (weight 2 also). 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 future graduates' profession?
- Does it cover all the needs expected from a course of this nature at this level?
- Is it aligned with the real activities of a graduate professional in this discipline?
- Does it include a prospective approach, introducing new concepts and taking into account the future needs of the market?
- Is the study program in concordance with other competing universities?
- Does this teaching unit (course) contributes to the attractiveness of the program of the formation of future graduates?

After the responses to the questionnaires by the different stakeholders, and quantification of the results according to the Lickert scale, the metric 1 value can be calculated according to the relation :

$$M_1 = \left(\frac{1}{5}\right)G + \left(\frac{2}{5}\right)A + \left(\frac{2}{5}\right)E$$

3.2.2. Relevance of the proposed formation

This metric deals with the content of the teaching unit. Does-it allow to reach a sufficient level for an engineer, does-it cover all it should ?

It is also assessed by questionnaires that could be fulfilled 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 responses such as : 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 appropriate learning outcomes clearly formulated for this teaching unit (course)?
- Does it allow the access of the predefined levels of knowledge taxonomy (Knowledge, Comprehension, Application and Analysis)?

After responses of the stakeholders to the questionnaires, the metric 2 value can be calculated according to the relation :

$$M_2 = \left(\frac{1}{5}\right)S + \left(\frac{1}{5}\right)G + \left(\frac{2}{5}\right)A + \left(\frac{1}{5}\right)E$$

3.2.3. Relevance of the proposed pedagogy

This metric deals with the form of the teaching unit. It clearly relies on the pedagogical engineering, and on the chosen teaching method. Does-it allow an efficient acquisition of the taught skills and knowledge ?

It is still assessed by questionnaires that can be completed by students (weight 2), graduates (weight 1), and academics (weight 2). The employer's opinion is here difficult to consider… The Likert scale is still used, with responses such as : 5 : strongly agree ; 4 : agree ; 3 : neutral ; 2 : disagree ; 1 : strongly disagree.

The sale questionnaire is now proposed for each stakeholder.

- Is the proposed pedagogy appropriate to the learning outcomes?
- Does the proposed pedagogy allow the improvement of the predefined levels of knowledge taxonomy (Knowledge, Comprehension, Application, Analysis)?
- Is the proposed pedagogy appropriate for different student learning styles?
- Does the proposed pedagogy improve professional competencies?
- Does the proposed pedagogy improve the teaching?
- Does the proposed pedagogy enable working in a professional situation?
- Does the proposed pedagogy enable the evaluation of the progression?
- Is the course is intellectually stimulating?
- Can the interest in the subject be increased as a consequence of the proposed pedagogy?
- Can one learn something valuable?
- Are group interactions encouraged?
- Is the balance between classical and active learning adequate?
- Can students understand the relevance of the topic for their future profession?
- Does further reading, bibliography, homework, laboratories (if applicable) contribute to the understanding of the subject?
- Are methods of evaluating student work fair and appropriate?

The metric 3 value can be calculated according to the relation :

$$M_3 = \left(\frac{1}{5}\right)S + \left(\frac{2}{5}\right)G + \left(\frac{2}{5}\right)A$$

3.2.4. Perception of relevance of the pedagogical approach

This metric deals with the perception of the specific pedagogical approach within the teaching unit by the students, from a qualitative and organization point of view essentially. It is assessed by a questionnaires that can be completed by the students only, with Likert scale such as : 5 : strongly agree ; 4 : agree ; 3 : neutral ; 2 : disagree ; 1 : strongly disagree.

- Did the proposed pedagogical approach improve my interest in the subject?
- Was the quality of the materials (e.g. videos, labs, problems, …) and resources appropriate?
- Were the teacher's explanations clear?
- Did the proposed pedagogical approach allow me to understand the subject better?
- Did the mark I obtained reflect my level of understanding / effort?
- What pedagogical approach(es) would you suggest to improve the teaching & learning process of that subject? (*This last question is not quantified ! Students should here have the possibility to select none or more than one of the following approaches : recorded lectures, problem-based learning, self-instruction delivery, work-based learning, traditional lectures, practical instruction via labs, flipped classrooms, other…)*

The metric 4 value can be calculated according to the relation :

$$M_4 = \left(\frac{5}{5}\right)S$$

3.2.5. Evaluation of the acquisitions

This metric deals with the acquisitions of the students during and just after the teaching unit. It includes regular evaluations of the students.

The questionnaires introduced in the first version of the framework are no more proposed here, since their comparison could be difficult from an university to another

The marks at the examination reflect thus the acquisition, and the difficulty remains to compare different promotions of students, with (maybe) different kind of examination. The marks reflect the acquisition, provided the exam is proposed from a competencies point of view. The average marks of former 3 years, and corresponding average deviations are still involved. The comparison with the global marks and standard deviations of the cohort should are also still included, to avoid any bias involved by a change of the students profile.

Finally, the metric 5 value is calculated according to relation :

$$M_5 = \left(\frac{AverageMark_{currentyear}}{AverageMarks_{formeryears}}\right)_{course} * \left(\frac{AverageMark_{formeryears}}{AverageMarks_{currentyear}}\right)_{cohort} / \left(\left(\frac{STD_{currentyear}}{STD_{formeryears}}\right)_{course} * \left(\frac{STD_{formeryears}}{STD_{currentyear}}\right)_{cohort}\right) * 3$$

3.2.6. Evaluation of transfer

- Does the course provide the expected competences in the particular subject?
- Does the course provide the opportunity to combine theory and practice to analyse the problems encountered in professional life?
- Does the course provide clear links between material covered and professional work complying with the required professional practice standards?
- Does the course provide the opportunity to apply or extend the concepts to new problems?
- Does the course provide the opportunity to improve written and/or oral communication skills?
- Does the course provide the opportunity to develop team work competencies?
- Does the course promote students' management capabilities?

The metric 6 value can be calculated according to the relation :

$$M_6 = \left(\frac{2}{5}\right)G + \left(\frac{1}{5}\right)A + \left(\frac{2}{5}\right)E$$

3.2.7. Conclusion

This second version of the framework was developed in coordination with the colleagues in charge of the pilot implementation WP4 to simplify the surveys, to obtain better responses rates and to clearly define and assess the different metrics. It will be used at the beginning of academic year 2016-17, for the last 6 months of the project.

4. Conclusion

Two frameworks, based on several parameters reflecting the effectiveness of a whole formation and the effectiveness of teaching of a single module have then been developed and quantified. The reference guide D.3.3. will give some details about their application, and their implementation for different Chemical Engineering Departments, and different teaching approaches in different European universities will be performed in the Work Package 4 of the iTeach Project.