Project Title:

Innovating Education of Talents in Chemistry for Business Success in SMEs' Innovations

InnoChem

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Roadmap for enhancing education

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Chapter 1 “Summary of the key findings of SQA”

Background

To reach the objective of addressing the societal challenges of tomorrow, the European chemical industry needs the right workforce.

One of the major milestones of INNOCHEM project was a study that would mainly aim at investigating the critical skills that scientists and engineers will need to improve innovation in the European chemical industry of the future.

In this sense, each INNOCHEM partner circulated a questionnaire to several SME’s in order to identify industry’s views about future innovation skills (2015-2025) needs of scientists and engineers employed in the European chemical industry.

In particular, this questionnaire aimed in identifying the skills needed to successfully exploit new and emerging technologies including industrial (or white) biotechnology, materials technology as well as reaction and process design.

Purpose

The intention was to gather the views of senior management in European chemical companies about skills needs that will be critical for improving innovation in the chemical sector in Europe. This study seeked to identify the potential lack of fit between the skills training for engineers and scientists that European educational establishments currently provide and the skills that may be required by the chemical industry to support innovation in the future. The first critical step was therefore to identify with the industry the skills required for future engineers and scientists and the final objective was to validate and improve current courses at higher educational institutions and, if necessary, to stimulate the development of new courses that meet the future skills needs of the chemical industry.

The purpose of this study was to get SMEs’ view about the future of their sub-sectors of the chemical industry - rather than issues which may be specific to each company.

The SQA’s main target was in obtaining a picture of the demand for specific skill sets needed to ensure that the chemical sector is well placed to meet tomorrow’s societal challenges

Implementation

The Status Quo Analysis describes the specific characteristics of the chemical sector in Greece and its structure, the R&D expenditures (public and private funds) by sector and summarizes the results of a survey conducted by HACI and NTUA among 21 small and medium-sized enterprises (SMEs) from Greece in 2015, focused on personal and business skills, as well as technical and scientific knowledge which are important for future chemical engineers and scientists. Companies which participated to the questionnaire, operating in the following sectors:

- paints, coatings and inks manufacturers;
- environmental management and manufacturers of water treatment chemicals;
- process design consulting companies;
- producers of detergents, surfactants, biocides and cosmetics;
- producers of fertilizers and inorganic chemicals;
- industrial gases producers;

- construction materials;
- polymers;
- certification bodies;

Each SME has been asked to respond to the several questions related to scientific, technical, business and personal skills of future engineers and scientists in order to identify and bridge the existing gaps between universities and industries as well as to underline the skills that industries require for the successful implementation of tasks from engineers and scientists.

a) Scientific and technical skills of future engineers and scientists

At first, the participants were asked to indicate which skills are likely to be of critical importance (among several skills) for engineers and scientists in their sub-sectors. The results are reported in detail in the following figures:

Figure 1. Skills of critical importance for engineers

Figure 2. Skills of critical importance for scientists

Comparing the results from scientific and technical skills of future engineers and scientists, it is clear that the skill requirements for engineers are mostly focused on process mechanics (process design, process control and optimization and process instrumentation), whereas for scientists the most necessary skills are considered these associated with chemistry (polymer, inorganic and materials chemistry).

On the other hand, in both cases the less important skills seem to be those which are based on biology (biocatalysis, biomechanical engineering).

The participants were also asked to indicate the five most important scientific, technical, business and personal skills in 2015 and beyond. The results are presented in the following Figures:

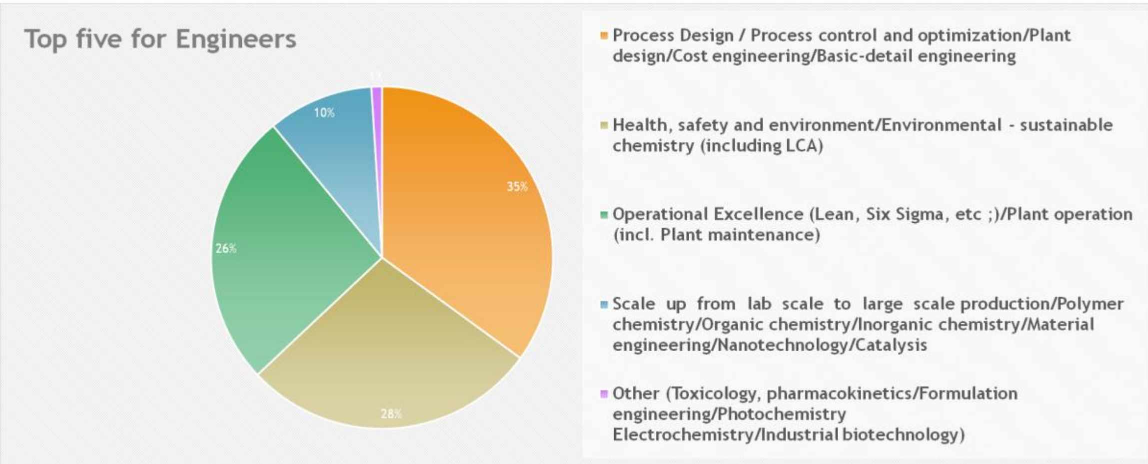


Figure 3. Five most important scientific and technical skills for engineers

It seems that Process control and optimization is considered to be the most important skill for engineers. This finding is in total agreement with the previous cumulative results for engineers.

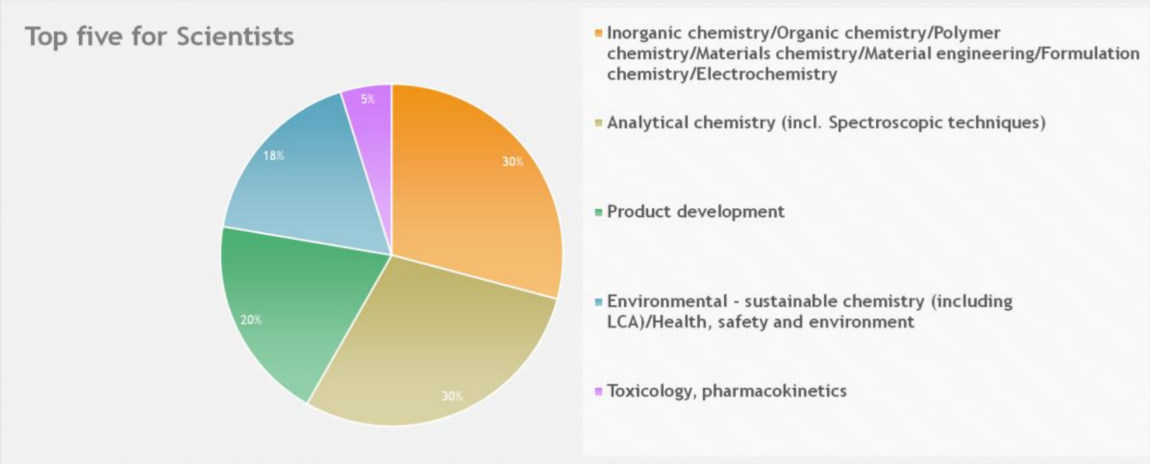


Figure 4. Five most important scientific and technical skills for scientists

As scientists it is clearly evidenced that Polymer chemistry and in general chemistry is the most crucial skill that industries require from candidate scientists to successfully implement their tasks.

b) Business skills of future engineers and scientists

There are several business skills that are of critical importance for future engineers and scientists. For example, intellectual property law skills are the most important skills for future scientists since innovative ideas must be protected by patents. On the other hand, well structured project management abilities are essential for engineers who have to turn innovative ideas into profitable and cost-effective business.

In that sense, the second question of the survey was to indicate which of these business skills are likely to be of critical importance for engineers and scientists to support innovation in their sub-sector(s) of the chemical industry, as well as the five most important business skills for engineers and scientists. Their answers are shown in the following figures:

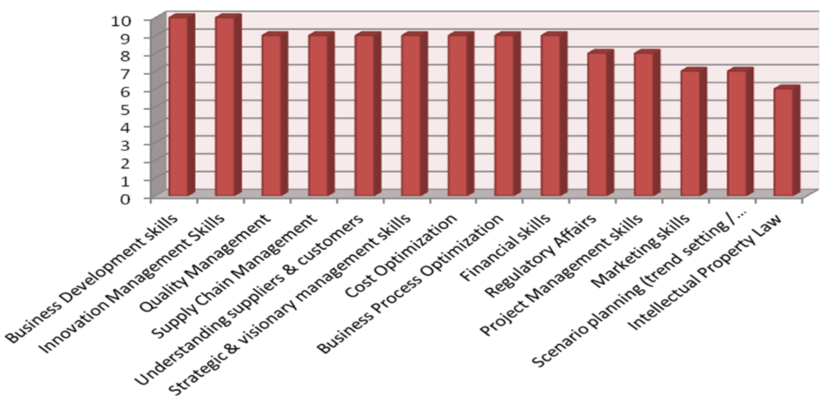


Figure 5. Business Skills for Future Engineers

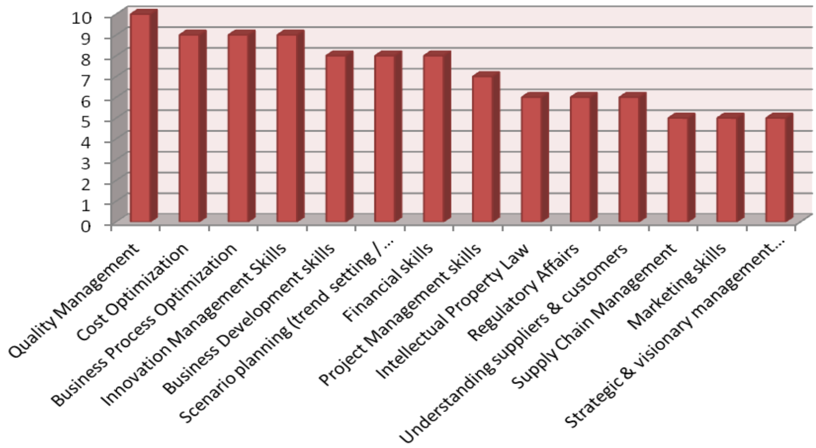


Figure 6. Business Skills for Future Scientists

Regarding business skills, it is clearly evidenced that engineers should have a vast knowledge of multidisciplinary skills ranging from business development up to regulatory affairs and marketing skills. On the contrary, the most important skill for scientists is quality management and the other required features focus on cost and process optimization as well as other managerial skills.

Generally, engineers are responsible in a greater degree for turning ideas into sustainable markets.

c) Personal skills of future engineers and scientists

Creative thinking is and will remain the most important skill for scientists while communication skills will be crucial for engineers who will have to promote ideas both internally and externally towards customers and business partners.

The results from the five participating SMEs in NTUAs Status Quo Analysis are shown below:

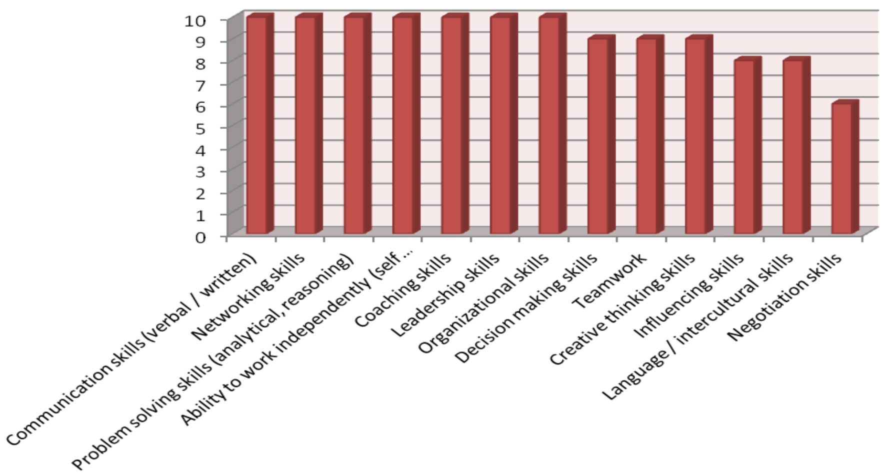


Figure 7. Personal Skills for Future Engineers

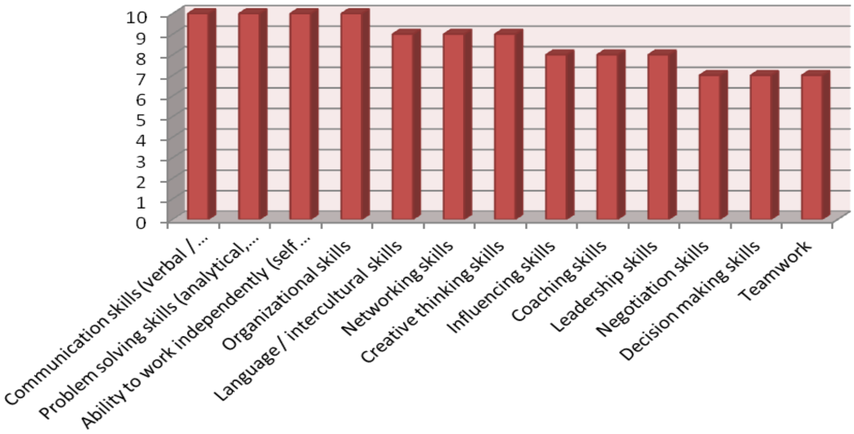


Figure 8. Personal Skills for Future Scientists

From the interpretation of personal skills results, it is clearly reported that communication skills, problem solving skills and ability to work independently are most important in both cases. This finding is quite normal, as the successful collaboration is crucial to support high quality scientific and technological breakthroughs and promotes innovation in the European industry. In general, both engineers and scientists should focus on different personal skills to support effective interdisciplinary work.

<u>Conclusions</u>

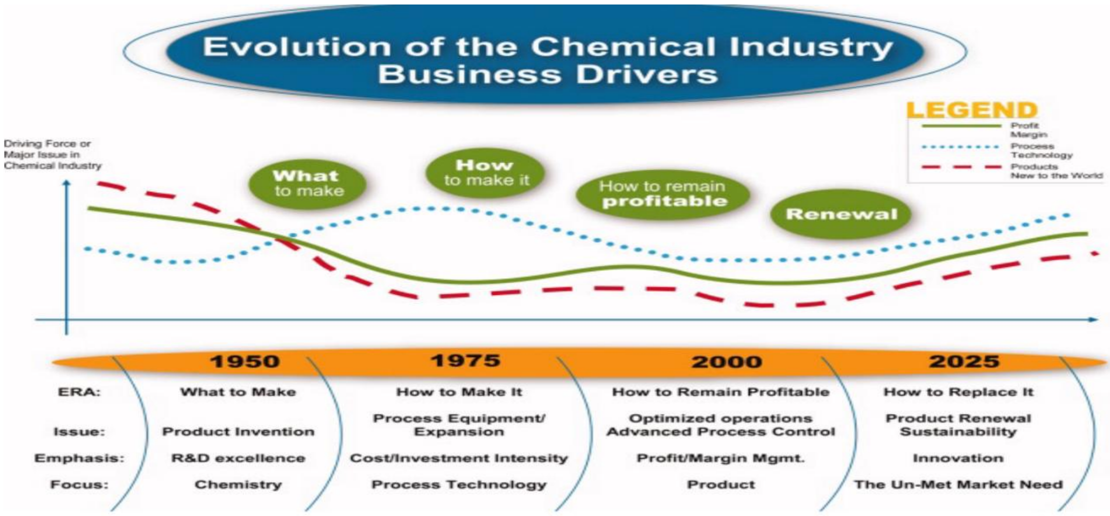
To conclude, industries demand the development of a wide range of skills from both engineers and scientists in order to effectively respond to a demanding market and new occurred challenges.

Chapter 2 “Tertiary education of chemistry in Europe and worldwide: Current situation”

The role that graduate education in the chemical sciences must play in this century is to assure the continuing success of the chemical industry sector and the vitality of the world's prosperity which is gained through chemistry.

Since the 1800s, chemistry has been an extraordinarily successful science. Just since World War II, it has made tremendous advances in such far-flung areas as catalysis, pharmaceuticals, spectroscopy, and the synthesis of complex natural products.

During ’50 the basic question for the chemical sector was “what to make” in order to cover the increasing demand of the societies for new products. So the basic issue was the product invention with emphasis on R&D excellence in chemistry. After 70’s the driving force was “how to make it efficiently in order to cover the increased global demand for a number of chemical products” and so the basic issue was the process equipment and the expansion of the production units with emphasis on cost – investment intensity and focusing on process technology and industrial techniques. During 00’ we have been focusing on the optimised operations and the advanced process control in order to remain profitable. The driving force for the recent years according to chemical engineering societies will be the question “how to replace it” meaning that the life cycle analysis of chemical products, the sustainability and the circular thinking of the economy will boost innovation and economic development.
The discovery and use of sources of energy pose many interesting chemical problems, from what is the nature of combustion to what is the ultimate future of solar energy, from the effects of nuclear radiation on chemical compounds to how to conserve energy and protect the environment. A cell is a collection of chemical reactions, none of which is alive by itself but all of which combine to constitute life. Understanding how living cells function is entirely a chemical problem. The chemical flows into, out of, and within megacities offer a wealth of fascinating chemical problems. Even major societal issues like environmental sustainability, the rising costs of health care, and enhancing national security have major chemical underpinnings.



As a result, the strategy for the tertiary education is not over to support but to lead this new vision for the sector and the economy in general by providing all the technical, business and personal skills to young students that will become the future staff for the chemical sector.

The current science and engineering system, saying that we have a system right now in which we tend to use the phrase “science and engineering”. However, there are actually three really important activities, science; engineering; and invention and discovery. Science understands things; engineering, solves problems; and chemistry, in a general point of view, can work in the area of invention and discovery. Scientists can work on things that they don't understand but that exist, and engineers do a fantastic job of making things really work. But there has to be more of the activity of going from something where there wasn't a scientific or technical activity to one where there was[6].

A number of difficult issues should be briefly listed in order to understand the current situation and to propose factional solutions:

- Research institutions and individual researchers would need to achieve a new balance between curiosity-driven research and problem-solving research, which would require careful consideration of many tradeoffs.

- Academic research is a “fundamentally elitist activity” and may need to become more so. Perhaps not many people are needed to do it, and they need to do it well to create new jobs and solve difficult problems.

- With graduate education, more can be less. As students take longer to earn their PhDs, five to six years spent learning the same technique may not do a student much good.

- Student outcomes need to be tracked to gain a better understanding of the kinds of jobs they are getting and how well they are doing.

- A question should be asked whether PhD theses are narrow technical presentations for jobs that no longer exist. Should graduate students from Greece and Europe be doing organic synthesis if most organic synthesis is being done in China? That's not to say that these aren't really important activities, but we need to somehow connect our investment in graduate school with what's actually needed to give jobs to students.

- Does everyone need a PhD for a technical job? A good master's program may be enough to teach technical skills.

- Traditional groupings such as organic, physical, inorganic, and so on will not work well for integrative ideas and problems. The proper way to combine these fields is not yet clear—it may differ for different institutions. Interdisciplinary groupings could bring in fields outside of the natural sciences such as economics, management, and finance where appropriate.

- Can a single academic group make more headway on a big problem than a consortium?

- In an interdisciplinary future, graduate school will need to be—and should be—more demanding. Organic chemists, for instance, will need to know biology and immunology. Students will need to work in a global culture, not just a national culture, which will require that they have experience with those cultures.

- Postdoctoral fellows are the future of the academic world, yet academia is still uncertain whether they should be treated as students, as junior colleagues, or as employees paid to do a job. Unless we get that straightened out, … we're going to waste some of the best people in science[6].

Changes in the curricula are recommended, not because the previous approaches were wrong, but because the technological and science leaders of this century must have skills crafted to meet the demands of the vision of the European Union for sustainable development, circular economy, environmental - health and safety protection, competitiveness and innovation.

Chapter 3 “Overall strategy of tertiary education of young talents in chemistry”

Background

In recent years, the progressive reduction of young peoples’ interest upon Science, Technology and Engineering studies has been observed. This tense originates from several social, economic and educational factors and has led academia and European policy bodies to establish new approaches, in order to make STEM (Science, technology, engineering, and mathematics) studies more attractive for young students. In this sense, the “learning outcomes” approach emerged during the last years, constituting the main policy approach on education across Europe and giving students and educators a common reference point, providing the ground for improved and active learning procedures for students, as well as better quality teaching methods for educators[1].

Learning outcomes is an approach that changed the way that higher education is structured, focusing mainly on “what a learner is expected to know, be able to do and

understand at the end of a programme or course” (European credit transfer and accumulation system, ECTS, 2009). It also emerged new significant challenges for higher education institutions and driven them to define new qualifications that provide a clear understanding of goals and objectives of a learning programme, as well as of the teaching methods which are able to support the development of the required competencies. In this sense, Higher Education Institutions will need to ensure that their learning outcomes - based programmes provide:

- A contiguous assembly of specific knowledge areas which offer sufficient integration of required skills for students.

- Sufficient opportunities for the development and demonstration of the required competencies, throughout the whole duration of the learning programme.

- An increment of the level of cognitive complexity through the whole duration of the programme, to ensure that students will be adequately prepared for lifelong learning and to enter the labor market[3].

Learning outcomes may not be new, but only in the last few years it became a high-level priority for Europe. Actually, learning outcomes are increasingly incorporated in educational policies all over Europe, and more specifically in the shape of new reformed curricula. This approach is being already assimilated in most of the European educational systems and policies, providing more comparable and transparent qualifications for students[2].

Outcome - based Design

According to the ECTS guide (2009), learning outcomes provide verifiable statements of what learners who have obtained a particular qualification, or completed a programme or its components, are expected to know, understand and/or be able to do[3].

In another definition from Cedefop (Cedefop, 2014a, pp. 164-165) learning outcomes "are defined as sets of knowledge, skills and/or competences an individual has acquired and/or is able to demonstrate after completion of a learning process, either formal, non-formal or informal"[2].

The relation between these two different definitions can be understood as the relation between intended and actually achieved learning outcomes[2]. According to the first definition, learning outcomes as used in curricula are mainly considered as statements of goals. They are not actually outcomes of learning, but more of desirable targets. Achieved learning outcomes can only be identified following the learning process, through assessments and demonstration of achieved learning in real life. The application of learning outcomes requires continuous interaction between theoretical and actual outcomes, in order to improve stated expectations based on the actually achieved outcomes[2].

"Learning outcome" statements are typically characterized using active verbs that express knowledge, comprehension, application, analysis, synthesis and evaluation. Learning outcomes can be written for an entire learning programme, a course, a unit or even for a single lesson[3].

Structuring the Curriculum

When learning outcomes apply, the curriculum not only delimits the content to be learned but also the skills and abilities to be developed to the students. In this sense, any curriculum following the learning outcomes approach should account for both aspects. The basis for such a curriculum should be a "Learning Outcomes-Based Education in Chemistry and Chemical Engineering" clear statement, followed by the structuring of a learning programme that will establish the teaching, learning and assessment strategies and facilitate the development and assessment of the required outcomes[3].

Curricula are aligned with level descriptors and standards set out at national levels. The way in which the curricula are designed have a significant impact on classroom teaching and assessment. For example, whether theory and practical tasks are taught together or separately, or how outcomes relate to other parts of the curricula[2].

Once the learning outcomes for a course have been formulated, curriculum designers can turn their attention to the issue of structuring the learning process. Creating a learning programme requires effort in each of three domains:

- Identifying and defining measurable learning outcomes for the various knowledge areas associated with the qualification. This will establish the indicative knowledge area content for the programme

- Identifying the teaching and learning methods that will be used to deliver the specified content, and facilitate the development of required outcomes to the desired levels, and

- Identifying the assessment methods that will be used to determine whether, and how well, these outcomes have been achieved[3].

In the curriculum development process, it is important to ensure that syllabi, learning objectives, and teaching and assessment methods, result in a coherent curriculum in which all components have well-defined and interconnected roles in achieving course objectives. In the case of a chemistry or chemical engineering programme, the recommended knowledge areas:

- Should have a coherent core of mathematics, natural sciences and fundamental discipline specific sciences (e.g. engineering sciences) to provide a viable platform for further studies and lifelong learning. The coherent core should enable development both within the traditional discipline and in related emerging fields.

- Should include some supplementary tasks that give emphasis to the practice of the discipline, including economics, the impact (positive or negative) of technology on the environment and society in general, as well as to the practice of communication skills, as dictated also by the results of the Status Quo Analysis.

- Could also include specialist study which may take on many forms including further deepening of a theme in the core, a new sub-discipline, or a specialist topic building onto the core[3].

<u>European University - Business Cooperation</u>

Most of the policies and initiatives being undertaken to encourage Science and Engineering take-up are carried out in the educational sphere. Unfortunately, there are few initiatives or research focusing on the labor market and industry settings. Increased school-industry partnership is stressed as imperative in advancing all the above policy approaches – but is particularly important in career guidance initiatives[1].

In fact, most of the educators in HEIs are not engaged at all in any kind of University - Business cooperation (UBC) or only to a low degree, while the institutions themselves engage in some degree of University - Business cooperation. More specifically, almost the 40% of academics are not engaged in UBC at all, while another 20% of the academics undertake only a low extent of UBC. The remaining 40% undertake a medium or high extent[4].

As for the institutions, according to stats most of the HEIs (around 90%) engage in some extent of UBC at an institutional level, with approximately 65% of HEIs having at least a medium degree of UBC[4].

In order to address this inconsistency, several ways in which universities and business cooperate have been proposed, including collaboration in research and development (R&D), commercialisation of R&D results, entrepreneurship **and curriculum development and delivery**[4].

Business contribution to curriculum development and delivery

In this kind of cooperation universities and business work closely in order to reform existing or design whole new degree and postgraduate programmes, which often try to mix research and teaching specialism of the university with specific need of a particular industry. Usually, there is a geographic basis to such collaboration, which is supported by local economic operators, though there are several examples of collaborations with an international extend[5].

b) Potential impacts

Such collaborations can support economic growth, not only in terms of staffing industrial sectors with skilled manpower (on specific industrial needs) but also in terms of limiting unemployment since the employers will be reassured that their requirements and needs will be met by young employees. This in turn will effect on the graduate retention in the local area[5].

Depending on the industrial sector, such collaborations can offer multiplicated and innovative partnerships. For instanse, in several specialised industries where it is hard to find potential graduates with specific skills, these collaborations can lead to close links with schools and universities in order to drive students to new courses[5]. Furthermore, such partnerships can result in further business-HEIs engagement in other areas, like research[5].

c) Challenges

Usually, complex challenges come along with great opportunities. This stands also for business-universities collaboration since each side measures success with different criteria and comes in discussion with different agenda. Industry is mainly interested on practical knowledge and skills, while academia seeks for wider learning programs balancing between practical and theoretical practices[5].

Timescales can be also challenging, especially in terms of establishing post graduate programmes, since HEIs tend to have strict processes for approving new courses which are often not appreciated by industrial partners or funding authorities[5].

At last, there can be also risks associated with the close link of the university teaching with specific demands of the regional economy, since the economic conditions can change from time to time, leaving universities vulnerable to economic crisis. This could also affect the ability of the universities to attract students from other areas[5].

Chapter 4: Key objectives & supporting objectives for implementing the proposed strategy

The current curriculum of the Chemical Engineering School of NTUA (which has been selected for innovation) should be briefly mentioned in order to propose and adopt any new strategy.

APPROACH – 5-YEAR DIPLOMA CHEMICAL ENGINEER DEGREE PROGRAM

Information pertaining to the 5-year curriculum leading to a Chemical Engineer Diploma that has been provided to the authors of this report included the current studies guide course offerings, and past presentations given by the Dean of the School. The 5-year curriculum leading to a Chemical Engineer Diploma aims to provide fundamental knowledge and practical skills to enable graduates to practice as chemical engineers, work together with other engineers and processionals in the context of the socio-economic environment, and instil life-long learning. The curriculum currently consists of 55 courses spread over 9 semesters, plus Practical Training (an aspect of experiential learning) in the 9th semester and a Thesis/Diplomarbeit typically involving research, carried out during the 10th semester. The curriculum is organized in the context of "routes" (basic sciences foundation), "stem/core" (process engineering), "branches" (which include TEE requirements and processional development), and "leaves" (electives and specializations,). In total, about 125 courses are offered every academic year, that cover a plethora of topics. All courses with enrolment over 80 students are spilt and offered in multiple Sectors. The content, level of rigor, and organization of studies could enable diligent students to achieve the goals and objectives of the 5-year curriculum leading to a Chemical Engineer Diploma (assuming there would be no disruptions due to internal/external factors). The current curriculum has been in place since 2002/3. The curriculum incorporates the internationally accepted elements and course-offerings of chemical engineering. It also reflects the organization of the School in Sectors/Laboratories. The structure of the curriculum appears to follow the School's traditions and is worth revisiting and updating. Other than the faculty, the Hellenic Association of Chemical Engineers and the Technical Chamber of Greece (TEE), it is not clear whether other stakeholders (e.g., students, employers, alumni and an Advisory Board) have been consulted.

The curriculum is consistent with the objectives of the Curriculum and attempts to meet the needs of the evolving scientific, professional, and socio-economic environment. However, some elements of the curriculum are outdated and others have significant overlap to necessitate a comprehensive review and update.

) and approved by the school general assembly. The curriculum meets TEE requirements. It is not clear whether other constituencies (e.g., alumni or employers) are being consulted. It is not clear whether and how student input (e.g., from course evaluations) is being utilized. It seems that students have a concern about the lack of response from the School to their course evaluations.

Curriculum revisions took place in 1983, 1993, and 2002/3. According to the self-evaluation report and the faculty presentations, a process for update/revision of the current curriculum is currently underway at the level of the Committee on Studies. The Committee recommends that the School forms and seeks input from an Advisory Board.

The curriculum appears to implement the goals of the School of Chemical Engineering and it can be stated that it is a hybrid that incorporates universally-accepted standards in the field of chemical engineering and the central European tradition of technical chemistry and Thesis/Diplomarbeit, and is supplemented by courses that reflect the specific professional/research interests of current faculty (as also stated by the external monitoring evaluation team).

The curriculum is functional, albeit possibly a bit rigid with respect to the specializations, as it appears to allow no course selection across specializations. The organization of course offerings along the four Sectors appears to limit flexibility in terms of coordinating course content and continuity, and eliminating duplication of content. The majority of courses include a laboratory component that expends a lot of time and energy from both the side of faculty/staff and that of students. Several of the electives/specialization courses are tied to the specific expertise of current faculty, and it is not clear how such courses are being staffed in the case of faculty sabbaticals or retirement.

Suggestions from the previous evaluation procedures (internal and external) which have been taking into consideration to adopt a new curriculum are the following:

- Prerequisites should be properly identified, implemented and enforced.
- Several faculty member spointed out that student attendance in lecturest ends to be low, while in the lab sessions is very high (according to the 2012-2013 studies guide, attendance in lectures is not considered obligatory, while in the labs attendance is obligatory). To the extent that the lectures contribute to student learning, the faculty should consider implementing various pedagogical methods (and share best practices) to enhance the student participation.
- The lab exercises are integral parts of the majority of courses, and their presence in the curriculum constitutes an element of pride among faculty and staff. However, their contents and effectiveness should be evaluated in the context of current constrains and opportunities.
- It appears that the “core” chemical engineering courses are offered relatively latein the curriculum, culminating with Process Design being offered in the 9th semester. The earlier in the curriculum such courses were to be offered, the sooner the students would feel part of the chemical engineering profession, and the sooner they could

contribute as chemical engineers during summer jobs or practical training of each of the "core" chemical engineering courses would appear adequate, the fraction of the sum of hours spent in the "core" chemical engineering courses within the 5-year curriculum is not adequate.

- There appears to be notable overlap between courses(e.g., in the case of Chemical Thermodynamics, Material and Energy Balances, Engineering Thermodynamics, Chemical Engineering Thermodynamics), fragmentation (e.g., elements of Product Design are delivered across different courses, some offered by Sector II and others by Sector IV), and overspecialization (individual courses in narrow topics). The above could result in missed opportunities to streamline the curriculum, and render it more efficient and effective.
- The 5-year Diploma engineer curriculum is considered by many to be of higher level than a Bachelor of Science degree, but courses with graduate-level content and rigor do not appear to be part of the current curriculum in the NTUA School of Chemical Engineering. This is not doing service to those students who may want to pursue such courses within their 5-year degree, and potentially takes away a competitive advantage that NTUA-educated Diploma chemical engineers might have in the European and world job markets.
- Thesis is currently delegated to the 10th semester. Having thesis offered in both fall and spring semesters of the 5th academic year could allow for more rational distribution of faculty/staff workload, allow those students who would like to start Thesis earlier (or possibly carry it out abroad) to do so, and could potentially bring the time-to-graduation closer to the intended 5 years.
- Thesis is currently written in Greek. In the context of developing the skills of NTUA students and promoting their research results outside Greece, it is worth considering allowing English as a language of the Thesis.
- The credit hours (ECTS) should be defined in away to facilitate student mobility (e.g., in European institutions) and to allow international employers to understand better the effort the students expended.
- Soft skills should be delivered to the students in a more organized/coordinated manner.
- Selected computational platforms (Matlab, Aspen) should be utilized throughout curriculum.
- Student advisement/mentoring should be offered in an organized manner(e.g., advisement sessions) so as to engage as many students as possible.
- Evaluation of teaching by students should be taken into account when assigning instructors and/or considering updates/revisions of course content and curriculum.

APPROACH – GRADUATE PROGRAMS

The authors considered the two inter-departmental programs of postgraduate study that the School of Chemical Engineering is coordinating: Materials Science and Engineering and Computational Engineering. The programs of study, names of faculty involved, number of students, and other related information were provided for these two programs.

The goals and objectives of each of the two inter-departmental programs of postgraduate study considered here are spelled out in the documents provided, and there is a well-defined path to achieve them. The postgraduate programs were established in the late 1990's when the legal framework allowed it. The curriculum was designed to address valid scientific, professional and societal needs.

A process for reviewing and revising the graduate curriculum is in place and should be implemented by the School.

The post-graduate programs in Materials and in Computational Engineering are in areas of interest to research activities of the School of Chemical Engineering, but also to other schools within NTUA. The structure of the two curricula is rational and clearly articulated.

The contribution of the post-graduate programs to the implementation of the goals of the School of Chemical Engineering has not been addressed. An opportunity for students in the 5-year Diploma curriculum and for doctoral students to attend (and potentially receive credit for) select courses offered in the post-graduate programs should be explored.

The language of instruction is currently Greek. It is worth considering instituting English as the language of instruction in post-graduate programs to enable a seamless collaboration with European partners and the recruiting of post-graduate students from outside Greece.

APPROACH – DOCTORAL PROGRAM

The goals and objectives of the doctoral program are provided, and a well-defined path to achieve them is spelled out in the document "General Guidance for Doctoral Theses", dated January 2004.

The School of Chemical Engineering has a large number of doctoral students (about 400) enrolled, however a fraction of them are not actively pursuing their research. Possible revision of the curriculum leading to the doctoral degree has not been discussed yet.

The current curriculum appears to be rational, clearly articulated, and coherent. However, the current time-to-degree and the number of inactive doctoral students suggest that there are issues with respect to student supervision.

The progress of the doctoral students is assessed annually by their advisor and dissertation committee.

The current doctoral curriculum could be augmented by elements that facilitate the research and professional development of the doctoral candidates, e.g., external and internal research seminars, career guidance, ethics, and how to seek research funding.

The main conclusions and recommendations resulting from the latest Annual Internal Report of the School can be described by the following SWOT analysis:

STRONG POINTS	WEAKNESSES
<u>Curriculum</u>: -increased use of laboratory applications / exercises - widely used computational tools (40	<u>Curriculum</u>: aged curriculum (latest revision 2003-2004) large total number of courses required

courses -visits to industries -thesis Attracting potential students a very high standard. The mobility of the students (16) in the Erasmus program. The School coordinates 2 Postgraduate programs and participates in other 8. Doctoral studies: Award significant number of PhDs (27). Infrastructure: auditoriums, halls, labs, Computer Center, Horizontal Lab, Laboratories Personal Computer. Very good staff at the School faculty members. Very good value "Students per faculty member." Good research performance of faculty members (mean 12.7 works the last five years per faculty member, h-index = 16.3). Very good participation and funding of our School of research programs. The international recognition of the high level of graduates (ER: Employment Reputation = 67.3-74.0 / 100.0, QS-Top Universities, 2012-15). International and National Collaborations Scientific Institutions, Industries, Universities, etc.. Connecting with society through participation in various activities. International recognition of NTUA (67th in 2015 - first in Greek universities - among Universities with subject «Engineering and Technology» (QS-Top Universities, 2015).	to obtain the Diploma existence of courses in material coatings high and growing accumulation students in some courses low success rates on participants in the exam large and increasing duration of study (2014-2015: 6.9 years) Non involving all faculty members in the supervision of Diploma work. Very limited participation of foreign students in the ERASMUS program because the language of instruction. Doctoral studies: high average length for acquisition doctoral studies and large total number of doctoral students. The non-renewal of faculty members. Maintenance of plant and equipment. Small and declining public funding.
OPPORTUNITIES Identifying the need of revision to the existing curricula. A new curriculum is under development and it's first draft introduced in 2016 after an extensive consultation and the implementation of which need to start from the Academic. Year 2017-18. Necessity for a new doctoral thesis guidance. International academic cooperation through NTUA - European ERASMUS + Programme, T.I.M.E. Network "Top Industrial Managers for Europe". Institution of the evaluating procedure for educational structures from the students	THREATS Frequent deviations from strict adherence to the academic calendar. Increasing number of students admitted. Problems in the maintenance of plant and equipment and the renewal of laboratory equipment. Limited financial support of Graduate Curriculum. Non-institutionalized framework to attract sponsorship. Unstable economic environment at National Level.

themselves, head of NTUA (MODIP). Existence of national and European "opportunities" to fund research projects. Actual network of scientific institutions, universities and companies for further cooperation. Innovative teaching methods and tools (e-learning)	

Proposed action plan

Short-term actions

- New curriculum: In the current period the School discussed a total reform of the curriculum in order to implement it from next the acad. Year.
- New guide for postgraduate thesis: Implementation of the acad. year 2016-2017 of the new guidance introduced in 2015.
- New regulation for doctoral studies: discussed the current period by the Faculty bodies to develop a proposal for new guidance for the elaboration of doctoral theses. Strengthening of the content of the course websites with educational and tutorial materials. Create active websites in all courses (undergraduate and graduate).
- Submit the updated CVs of all faculty members and auxiliary staff in the School website. Increasing the percentage of faculty members participate in academic-research networks (Google Scholar etc.).
- Continue and expand outward actions (participation in meetings, conferences, presence in research "events", etc.) for the presentation of the overall project of the School.

Medium-term actions

- Overall elaboration of a Strategic Action Plan for educational, research, and other operational issues.
- Improving research awareness of the School through growth of publications in high impact journals and stronger assertion of European programs and international partnerships.
- Responding to the continuous increase of the average patent acquisition time.
- Improving School connection with the graduates by enabling them at all levels.
- Implementation of a "culture of evaluation" in all activities of the School (education, research, administration).

Proposed new Curriculum

Beside each lesson is given in brackets, the number of hours of instruction weekly.
For the 8th, 9th and 10th semester teaching lasts eight weeks.

1st semester

Inorganic Chemistry (8)
Mathematics I (Functions of one variable) (4) Programming and Computer Use - Basic Software Tools (5) Physics I (5)

Introduction to Chemical Engineering (4)
English or French
Total teaching hours: 26

2nd semester

Organic Chemistry (8)
Thermodynamics I (5)
Mathematics II (Linear Algebra) (4)
Mathematics III (Functions of several variables) (4)
Physics II (5)
English or French
Total teaching hours: 26

3rd semester

Physical Chemistry I: Structure and states of matter (8)
Thermodynamics II (5)
Mathematics IV (Differential Equations) (4)
Statistics and experimental design (5)
Technical Engineering (3)
English or French
Total teaching hours: 25

4th semester

Physical Chemistry II: Chemical Kinetics and Electrochemistry (8)
Analytical Chemistry (7)
Transport Phenomena I: Fluid Mechanics (4)
Computational Methods (4)
English or French & Technical Terminology (2)
Total teaching hours * 25

5th semester

Engineering Physical Processes I (5)
Principles of Cellular Biology and Biochemistry (4)
Transport Phenomena II - Heat and Mass Transfer (4)
Electromechanical process equipment (4)
Economic Analysis and Business Administration (for engineers) (4)
Total teaching hours * 21

6th semester

Science and Technical Materials (7)
Engineering Physical Processes II (5)
Chemical Process Engineering I (5)

Polymer Engineering (3)
Science and Technique Food (3)
Total teaching hours * 23

7th semester

Chemical Process Engineering II (5)
Biochemical Engineering (5)
Setting Process (5)
Energy technology (5)
Design I (6)
Total teaching hours * 26

8th semester

Environmental Engineering (9)
Design II (9)
Deepening 1 (5)
Workshop
Total teaching hours: 23 hours (for 8 weeks)

9th semester

Industrial Installations Security (3)
Deepening 2 (5)
Deepening 3 (5)
Thesis I
Total teaching hours: 13 (for 8 weeks)

10th semester

Deepening of 4 (5)
Deepening five (5)
Diploma II
Total teaching hours: 10 (for 8 weeks)
+ Course hours (or optional subjects) as described below OPTIONS

During their studies, students have to take another 3 options, two technical and one in humanitarian or social science during semesters 4-7. These courses are taught half in the fall semester and half in spring and students will be able to choose when nd what they want after the 4th semester, more than one in a half. Courses options do not generate sufficient number of students will not be taught. Also, it is taught and seminar course on "Technical Drawing - Using the / Y (Flow Diagrams, CAD / CAM)», which will be indicated on the transcript but will not be counted to the extent of the patent.

Options on social sciences

- Sociology of Science and Technology
- History and Philosophy of Science and Technology (2)
- Applied Science Education and Technology
- Introduction to Economics
- elements of Law

Technical options

- Quality control
- Optimization
- Environment and Development (3)
- Product design
- Computational Analysis of Transport Phenomena
- Nuclear Chemistry and Technology
- Decay and Material Protection
- inorganic Technology
- Building materials
- Lesson from another school of NTUA from the Study Commission approval

Deeping courses

1. Each course will deepen has a total of 40 teaching hours. Thus it can be 8 weeks to 5 hours / week.
2. The spring courses will be "elevator" that could be the one to get either the 8th or the 10th semester.
3. In any deeper will have 3 or 4 courses. Two will be offered in the spring semester (E) and 1 (or 2) winter (X).
4. Each student takes three lessons a deepening and 2 from other (s).
5. Deepening Courses that do not generate sufficient number of students will not be taught.
6. Insights which do not generate a sufficient number of students for three consecutive years will be abolished as depressions. In this case subjects include those taught with a sufficient number of students will remain freely deepening courses. Only courses that are embedded in deepening former can remain freely deepening courses.
7. The number and the objects of deepening will be reviewed every five years.

Mechanical processes

- Advanced Fluid (X)
- Advanced Thermodynamics (E)
- Industrial Engineering Reactor (X)
- Advanced Process Setup (E)

Environment

- Pollutant dispersion (E)
- Environmental assessment and optimization of industrial processes (X)
- Industrial Waste Management (E)
- Water Management (X)

Food Science and technology

- Chemistry Microbiology and Food Preservation Principles (E)
- Food Engineering (X)
- Design food industries - Quality Assurance and Food Safety (E)

Biotechnology

- Industrial Biotechnology (E)
- Bioengineering (X)
- Environmental Biotechnology (E)

Polymers and Composite Materials

- Polymer Science (R)
- Polymeric Materials Production Engineering (X)
- Polymer Processing (E)
- Composite Materials (X)

- Operating and Multi-Scale Materials
    - Relationships and material properties (E)
  - Science and Technique of Metallic Materials (X)
  - Ceramic and Building Materials (X)
  - Nanomaterials and Nanotechnology (E)

- Energy
    - Liquid Fuels (E)
    - Gas and Solid Fuel (X)
    - Rational and Sustainable Energy Systems Management (E)

- Economics and Business Administration
    - Competition and Market Research Analysis (E)
    - Technology, Innovation and Entrepreneurship (X)
    - project management (E)

- Applied Chemistry and Technology
    - Pharmaceutical Chemistry and Technology (E)
    - Modern Techniques of Chemical Analysis (E)
    - Green Chemistry and Technology (X)

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