Structuring of work related competences in chemical engineering

STRENGTH

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Purpose and need for the LdV Project STRENGTH

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Introduction

The STRENGTH project aims at introducing a synergic transfer of an existing model training system (Vocational Qualification Transfer System in Public Health) for workplace basic skills development within the Chemical Engineering field keeping green abilities awareness in four EU countries - Spain, Bulgaria, Slovenia, and England, regarding the shift of the European labour market towards knowledge-based economy and sustainability of jobs. The STRENGTH project provides strategic advice on formulation of a green economy strategy, engaging global best practices and making connections to global network of green economy lessons learned. It analyzes the global trends in green economy with focus on clean technology investments and fiscal instruments to generate efficient use of energy, water, mining, building, transport, and wastes.

The project objectives are focused on introduction of the 'green abilities' concept to create new opportunities of vocational education and training (VET) teachers and systems to build up green employability skills and further ecological awareness development in job seekers. In this way participants in VET will acquire knowledge for new generic employability and green skills for performance of personal development, employability and introduction in the European labour market.

Chemical Engineering as an academic discipline

Chemical engineering, as an academic discipline, involves the design and management of biological, chemical and physical processes that enable raw materials to be converted into valuable products. It is a discipline that is based on scientific knowledge from chemistry, physics, biology and mathematics combined with engineering principles. Chemical engineers design both products and the processes and manage their operation and optimization in order to ensure that they are economically viable and environmentally acceptable. On the other hand, the processes that are managed, as a part of the designed plant, include biological and/or chemical reactions in a sequence that provides minimal loss of materials and consumption of energy. The same unit operations are equally applicable across industries such as petroleum/petrochemical industry, food processing, mining and related industries, production of plastics and chemicals, pharmaceuticals production, environmental management, and biotechnology where, in some cases, additional skills of the chemical engineer are needed. It is important to note that Chemical Engineers must be capable of reacting to any change in production conditions and partly because the Chemical Engineering is closely related to discoveries in the enabling sciences of the profession such as biology, chemistry, biochemistry, microbiology and physics. Hence, the chemical engineer must be familiar with the language and principles of these sciences (at least to acquire additional specific skills) and/or to be able to work closely with specialists from these fields and other fields of engineering, management and industrial relations.

Green Chemistry and Jobs: Definition, current state and future trends

In general, Green Chemistry (including Chemical Engineering) can be defined as the "design of chemical products and processes to reduce or eliminate the use and generation of hazardous substances" and illustrates the 12 principles of Green Chemistry, a set of "design rules" which illustrate that field, announced in 1998 by Paul Anastas and J.C. Warner (1). Bearing in mind the "engineering part" of Chemical Engineering, it would be of great importance to additionally include the 12 Principles of Green Engineering elaborated by Anastas and Zimmerman (2). It is clear that Green Engineering is the development and commercialization of industrial processes that are economically feasible and reduce the risk to human health and the environment. All the above principles should be taken into account when determining the details of the STRENGTH Project Matrix of Green Competences. To analyse historically the development of the concept of Green Chemistry it would be interesting to use database of scientific publications generated along the last 20-30 years. The evolution of Green Chemistry scientific publications increased from less than 100 in 1990 to more than 600 in 2012. On the other hand, if we examine the distribution of these articles by field it appears that the majority belong to Chemistry Multidisciplinary while only 3.75% of the total number belongs to Chemical Engineering (3).

One of the first and widely accepted definitions for "green jobs" particularly by research and policy-makers is the one from the report by the United Nations Environmental Programme (UNEP), International Labour Organization (ILO, International Trade Union Confederation (ITUC) and the International Organization of Employers (IOE). The report defines Green jobs as jobs created, under decent work conditions, in activities that reduce environmental impacts of sectors, companies and economies. The definition further considers green jobs as "green" positions in agriculture, manufacturing, construction, installation, and maintenance, as well as scientific and technical, administrative, and service-related activities that contribute substantially to preserving or restoring environmental quality (4).

It should be noted that "green jobs" are widely recognised as an evolving concept and therefore it is difficult to give a strict definition valid in a long-term. The definition of "green jobs" in wider context might comprise any new job in a defined sector of economic activity, which has a lower than average environmental sign and at least partly contributes to improving overall performance. Due to this broad interpretation of the subject the counting and monitoring of the numbers of green jobs is a tricky task. A new job maybe greener than a previous, yet not green enough. Here, the pure statistics of direct green jobs counts less than the support of the idea that sustainable development transforms employment patterns and the labour market. Namely, this process at EU level is continuous and positive.

Another issue is the quality of green jobs. At present, many green jobs are still informal (mainly those connected with recycling, construction, biofuels production). This highlights the complicated route of achieving sustainability. In other words it is not possible to address the environmental dimension without also focusing on the national and international social and economic policies regarding decent work conditions. International labour standards provide

practical guidance for green jobs, particularly instruments on safety and health, chemicals and on working conditions. Thus, one of the key challenges is to ensure that the green jobs are decent work and contribute to socially sustainable development.

The EU has devoted more public research resources to environmental-related sciences than any other research system in the world. According to the data available, there are about 7,360,000 jobs in the EU in green sectors but there is still a gap between the potential for eco-innovation and the current state of "green-based" activity. It should be noted, however, that there was, until recently, a lack of based on a reliable, comprehensive and comparable system of green jobs evaluation in the European Union. The lack of a standard data definition of green jobs resulted in highly differing figures for present green jobs and future potential in the EU (5).

Undoubtedly, Green Jobs are an important part of the employment linked to a more environmentally sustainable economy. On the other hand, they are critical for making the shift to Green Economy in general, and Green Chemistry in particular, and technically feasible and economically viable. One of the most critical points in this process is that without skilled and motivated workers in new green growth sectors and in key occupations across the economy, the investment made and the technology deployed will not generate the expected benefits for sustainable development. The manufacturing sector has a huge potential for greening. Managing materials in a green way implies not only recycling but looking at the composition of materials themselves. Materials science and in particular green chemistry is a growing area where new skills are emerging as technology advances. Production processes become green when green technology and improved materials are applied, outputs of waste and inputs of energy and resources are reduced, and account is taken of products and materials throughout their entire life. Occupations affected by these changes vary from one industry to another, but across the sector include those of executive manager, researcher/developer, engineer, industrial technician and machine operator. Other related occupations where skills are likely to change include those of chemical engineers, chemical equipment operators and tenders, chemical plant and system operators, chemical technicians and chemists.

The need of Green Skills introduction into Chemical Engineering education

"When will ecologists learn engineering and ecologists learn ecology?"

William Mitsch, Editor-in-Chief, Journal of "Ecological Engineering"

Experts in the field of education in general, and in Chemistry and Chemical Engineering are split over which is more desirable: specific green chemical skills training or a more general background including more specific subjects different from the traditional ones. Production industrial sectors are divided by the same manner. Some years ago the journal Nature published a special report on Green Chemistry (7) citing hiring managers of some important companies. For example the hiring managers at the multinational General Electric, green

qualifications are less important than raw talent while others say green chemists have some advantages, including greater awareness of environmental issues. It is now widely accepted that students following the Green Principles in their education in green chemistry are uniquely positioned to address industry concerns because of their specific training in both industry regulations and particular process constraints.

Another important point concerning the need of green skills implementation is job creation in the field of Chemical Industry bearing in mind the steady decline of students in chemistry titles in Europe. It is not a secret that chemistry has not been a popular career choice in recent years worldwide. Particularly in Europe, with 1.7 million people employed in the chemical industry in the 27 countries of the European Union, the industry is fighting to remain a competitive employer. To avoid the radical decline in chemical industry employment, the European Technology Platform for Sustainable Chemistry (SusChem; http://www.suschem.org) clearly promotes novel skills such as expertise in biocatalysis, process design and nanotechnologies. To increase work in these areas, SusChem hoped to boost the European Union's funding of training and research in chemistry by 75%, to 5.5 billion euros till last 2013. SusChem fully supports the Innovation Union and the goals of the "EUROPE 2020 Strategy" addressing direct technical innovation areas and two supporting areas such as Resource and energy efficiency; Water; Raw materials; Smart Cities; Enabling Technologies; and Education.

In order to meet the Horizon 2020 goals, innovate successfully, and remain sustainably competitive the European chemical sector needs human resources equipped with the right mix of skills. Motivated by recommendations in the report of the European Commission's High Level Group on the Competitiveness of the European Chemical Industry published in July 2009, the Chemical Industry Council (CEFIC) published a study which aimed to investigate the critical - business, personal, scientific and technical – skills that scientists and engineers will need to boost innovation in the European chemical industry of the future (8): it is clear that the main need concerns Multidisciplinary/Interdisciplinary Broad Skills set introduction into the Chemistry Curricula.

One of the most important conclusions when analysing the available literature on Green Chemistry, Green Jobs, and Green Skills is that there is an urgent need to design appropriate educational schemes and resources that can be used at undergraduate and Master's level to develop the skills needed the chemical industrial sectors. In support of the above, let's take Ecological Engineering, which should obligatory include Green/Sustainable Concepts. Ecological engineering is defined as the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both (9, 10). The goals of ecological engineering are well defined as: (1) the restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution or land disturbance, and (2) the development of new sustainable ecosystems that have both human and ecological value (11). Particularly the development of new sustainable ecosystems makes ecological engineering broader. According to Prof. Mitsch, who is an expert in Ecological Engineering and the Editor-in-Chief of the journal of Ecological Engineering, "ecosystem

restoration, as currently practiced throughout the world, is done by practitioners who have little experience in design (scientists study systems, they do not design systems) and by engineers who do not appreciate the capabilities of ecosystems to self-design (engineering is a field devoted to removing uncertainty and controlling natural processes)" (12). The approaches of many restorations projects that are less successful than anticipated are over-designed by engineers with unsustainable technology. The main conclusion of progress evaluation of six long-term restoration projects in the USA, is that for this kind of ecological activities to become more accepted and predictable, they need to be better integrated and more trans-disciplinary-organized in Universities. It appears that ecological engineering academic programs controlled by engineers alone are unsuccessful because of the lack of both ecological and biological training in traditional engineering programs. Similarly, the field of restoration ecology should provide more allowance for emerging ecosystems, and "not always focus on putting things back to the way they were". Design and problem solving of mega-ecological problems are needed in the fields of ecological engineering and ecosystem ecology. Engineers and scientists should recognize the importance of the naturally occurring self-design and accept time as a component in ecosystem development when designing projects aimed at creation of functional ecosystems. These expert recommendations based on long-term observations of in fact green-oriented activities illustrate the urgent need of reconstruction of both Engineering and Ecological Curricula in order to create more sustainable and science-based Green Education in Universities. Similar conclusion can be made following the most recent evolution of the trajectory of "green articles" which shows that in the field of research Green Chemistry in general broadens its focus (in particular to the field of biocatalysis) and is trying to work at the intersection of different knowledge fields or principles.

Active skills policies will therefore be important, with the main lessons pointing to the need of anticipating future skills requirements and make adjustments in education and training systems. In the field of Chemistry, Chemical Engineering, and Biotechnology the value of encouraging the acquisition of generic skills in science, technology, engineering and mathematics (skills defined as STEM skills) is an important task as well as the urgent need to boost green skills development as an adaptive response to the rapid climate challenges. An excellent example in this direction is the initiative of the OECD that has created a Forum on Green Skills, bringing together stakeholders in skills development for a low-carbon economy (13).

THE STRENGTH PROJECT

Need analysis and conclusions of Project National Reports

As a part of the STRENGTH Leonardo da Vinci Project, a short analysis of the above information and of a set of National Reports elaborated to determine the need of green jobs, and particularly in the field of Chemical Engineering Education and Industry, has been carried out.

The European Union green good and services sector more than doubled in size in the last decade, according to latest figures released by European Commission Eurostat. As a result, the European Union's new strategy for sustainable growth and jobs, Europe 2020, puts again innovation and green growth at the heart of its blueprint for competitiveness. The green economy comprises a myriad of jobs and it could be concluded that the growth of green jobs employment is in parallel with its intensification. The information in the National Reports suggests that employment in green economy as well as in traditional industries, which are becoming green, increases with sustainable rate and particularly throughout the recent years of crisis. Shifting workers out of the crisis-hit construction and tourism sectors and into "green and ecological" jobs is a priority; and this transition needs to be accomplished by implementing well-designed policies. In the Project Members' National Strategies on Employment, initiatives for increasing employment in green industries and the promotion of green jobs are foreseen. The subsidising employment in green jobs was launched in all Partners countries simultaneously including them in the national classification of professions.

The mechanisms behind Green Chemistry, including Chemical Engineering, are based on a set of principles dedicated to creating more efficient industrial chemicals, drugs and products, and govern by a mixture of political, economic and cultural factors. The economic drive is to reduce waste. The political drive comes from regulations, existing in all Project Partner Countries, which are forcing companies to develop cleaner processes. The green economy development requires technological innovations in production as well as economic and social infrastructure based on national legislation – adopted in all countries in the last years. Finally, consumers and scientists who are becoming more aware of the need for cleaner processes provide the cultural drive. Demands for engineers, scientists and technicians are set to boom. For example, UK will need 100,000 new engineers by 2020. If industry is to adopt green chemistry technologies, today's students must be trained to design products and processes that do not use hazardous substances. Through green Chemical Engineering education, a new generation of chemical engineers will be better equipped to meet tomorrow's scientific challenges.

Although the benefits of implementing green abilities in the companies and use green technologies are still not convincing for business managers and investors, there is increasing pressure in industry for companies to become more sustainable by developing environmentally friendly products, minimizing waste, using renewable resources, and to maintain cleaner processes throughout. However, there are no explicit overarching national strategies targeting the green abilities needs. There is a lot of variety among Member States in skills programs for green jobs due to their differing social, economic and environmental conditions-some Member States are moving faster than others. The general abilities for several groups of professions, related to Chemistry/Engineering, are common. The "green" abilities are grouped for a set of professions, thus fitting the requirements of STRENGHT project for defining professions that share common special abilities. The institutions, involved in education of professionals working in the above-mentioned sectors, are Universities and other higher educational units and the adopted qualification by the specialists is in compliance with level 6 of EQF.

The National Reports agree that greening the economy and the corresponding education is a multi-dimensional challenge and therefore must be addressed through specific measures at the sectorial level that include targeted economic, employment and skills-development education policies. Particularly the Chemical Engineering should adapt its current curriculum programs to meet the new challenges and the needs of inclusion of the green chemistry and engineering principles. One of the most attractive approaches to acquired new (green) competencies is to apply a mixed teaching strategy and courses in non-engineering university disciplines. In STRENGTH project 5 competence areas are defined per occupational field: Environmental Health and Safety; Biotechnology; Food Science & Technology; Agricultural Engineering; Pharmaceutical Technology. All these areas are closely related to Chemical Engineering and offer immense possibilities for chemical engineers to increase their curriculum with specific green skills. For example, it is possible to move the present state of knowledge in Biotechnology University Education to a different state where Chemical Engineering and Biotechnology specific green skills could be are combined to form novel functional characteristics. The Food Science and Technology field of Science and University education could train Chemical Engineering specialists to be able to optimize and innovative processes and products, as well as to manage materials, products and wastes from the food industry. Similarly, Chemical Engineers can acquire additional knowledge and green skills in the fields of Agricultural Engineering, Pharmaceutical Technology, and Environmental Health and Safety.

The central point of the Project STRENGTH is to develop a Qualification Record based on competences related to green abilities that a chemical engineer could additionally acquire and, in addition, a Mobility Scheme that reflects the vision of the STRENGTH Consortium on the transnational VET mobility aimed at international recognition and validation of competences and qualifications. The description of the competences on the various steps of competence development takes place in a context-related manner. STRENGTH model core work tasks are comprehensive tasks within the green jobs context a person with the respective occupational profile has to deal with. Thus, the descriptions of the competences are designed to form a clear picture of how they can be applied in the green jobs context. The descriptions include green jobs-related categories to clarify the work activities in the Chemical Engineering field. It is important to note that while the common competences describe what a trainee, completed a full training programme in Chemical Engineering area should be able to do, the green competences specify the knowledge and skills trainees in a defined Chemical Engineering area should have in green-jobs related context. Both types of competences are covered through the accomplishment of specific study courses. Each competence is linked to the specific learning objectives of the relevant study courses. As the Chemical Engineering specific competencies are interdisciplinary by nature, for many of them one and the same specific course is required to be covered. The Project also includes a Competence Profiler unit. Being formed from defined parts of a Competence Matrix, the competence profiles generally cover certain part of all competences described in the Competence Matrix. The organizational profile is formed by identifying competences relevant for the corresponding qualification. It is foreseen to be in compliance with the requirements of the authorities responsible for the

respective qualification. The individual profiles reflect the competences that can be acquired by an individual in training.

The STRENGTH Project members do hope to provoke interest in the National and European authorities, students, professional organizations, and enterprises in order to make more attractive and greener the Chemical Engineering education and work.

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