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Defining A European Engineer Profile Within A European University Alliance

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DEFINING A EUROPEAN ENGINEER PROFILE WITHIN A EUROPEAN UNIVERSITY ALLIANCE (RESEARCH-PRACTICE)

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ABSTRACT

The world needs more engineers and Europe provides a rich and diverse environment to train them, including shared values of sustainability and interculturalism. In this paper we attempt to build a profile for a “European engineer” based on skills and competences acquired in a European University Alliance centred around engineering education (EELISA, European Engineering Learning Innovation Alliance). We carried out an on-line survey for students and staff of partner universities as well as nine in-depth interviews (50 min) with relevante stakeholders. The questions included in the survey are described as well as general results from 75 respondents. The overall results from the in-depth interviews are also presented and discussed within the framework of the training concepts also promoted by international associations, including SEFI. Finally, we use our findings to suggest four conceptual fields for a European engineer profile: 1) Scientific and theoretical knowledge including digital skills, 2) Addressing sustainability, 3) Interculturalism: an engineer embracing the European project, and 4) Business and communication skills: practical and applied knowledge.

1 INTRODUCTION

The world needs more engineers and Europe provides a rich and diverse environment to train them. That training can involve mastering technical disciplines and science-based processes and phenomena, as well as softer skills to help integrate technical, environmental, and social dimensions. Engineers face new challenges in a global society where multiple professional practices can be required to tackle global issues, while respecting local specificities. All this requires mastering a new skill set or gamut of competences that are not always clearly defined.

Most universities provide excellent scientific and technical knowledge to train different types of engineers, but there is more debate about how to educate students in more transversal skills, such as certain values like ethics, sustainability and interculturalism, so as to train them to be able to manage and innovate once in front of complex problems in their professional practice. Within the context of the European Universities Initiative (European University Alliances) and increasing collaboration with industry, it has become increasingly important to define and to be able to compare university studies in terms of an overall engineering profile, as commented by other authors. For example, Magarian and Seering (2021) indicate that engineers obtain a unifying work attribute called “design responsibility”, which includes product efficacy and safety through governance of new or existing designs. Zhu et al. (2021) formalize very precisely the skills involved for engineers in a Chinese industrial context such as sensemaking, relating, visioning, and inventing, which go far beyond technical skills in engineering. Diaz-Lantada and Nuñez (2021) recognize the importance of basic disciplines of science and technology and Diaz Lantada et al. (2016) underline that theoretical focus on basic science and technology is a required first step and must be detailed in depth, to then be able to focus on more applied activities. Indeed, a thorough knowledge of the basics will also allow students to be more flexible in their applications later on.

In terms of future joint degrees, where students will move from their home institution to study in one or more different EU countries, several universities must agree on basic requisites for more fundamental and more transversal skills to be able to create and compare study programs. A profile or definition of course requirements for different degrees may be fairly straight forward, but less work has been done to help define the requirements for more transversal skills.

In this study, we aimed to develop a profile for a European engineer along those lines. This can help to create joint degrees and the framework can be used to attract and host more international students, improving prestige and moving towards a European identity. The idea is for the profile to include the attributes, skills, lived experience and attitudes that make a graduate in engineering most adapted to the needs of the workplace, to help students be more prepared to conduct his/her professional activity within a sphere of certain values and to seek opportunities for innovation and responsivements to societal, economic and environmental challenges.

2 METHODOLOGY

Here we summarize efforts within Work Package 2 of the EELISA Erasmus+ project to define an engineer profile with the EELISA Alliance, based on the results from an on-line survey and in-depth interviews with relevant stakeholders.

2.1 On-line survey

This survey consisted of five general questions which could be answered online. It was sent to the nine partner universities of EELISA (Budapest University of Technology & Economics, Ecole des Ponts ParisTech, University of Erlangen Nuremberg, Istanbul Technical University, Scuola Normale Superiore di Pisa, Scuola Superiore Sant'Anna, Polytechnic University of Bucharest, Universite PSL, and Universidad Politecnica de Madrid). The first three questions were related to the job and field of work of the person being questioned, and whether they were from a university in the EELISA alliance. The following two questions (questions 4, 5) are summarized in Table 1.

Table 1. List of questions 4 and 5 in the survey sent to EELISA partners (students and staff).

4. Reflection on the profile of a European engineer.	
	a) Please rate the interest of a European engineering degree in addition to a national engineering degree* (rate low interest-1 to extremely interesting-10)
	b) Please rate the interest of a European engineering degree instead of a national engineering degree (rate low interest-1 to extremely interesting-10)
	c) What should be the minimum scientific and technical learning outcomes common to all engineering disciplines? (rate low interest-1 to extremely interesting-10)
	c.1. To analyze and synthesize complex problems by mastering scientific fields c.2. To design, implement and validate innovative methods, products and solutions c.3. To carry out research activities and to set up experimental devices c.4. To be adaptable to current and future real-life challenges c.5. Other (please specify):

	d) What are the required learning outcomes related to social and environmental issues of an engineering degree? (rate low interest-1 to extremely interesting-10)
	d.1. Developing human-centred view of solutions d.2. Knowledge of ethical responsibilities d.3. Knowledge of health, safety and diversity issues d.4. Consideration of the societal and environmental consequences of developed solutions (products/devices/processes, etc)
	e) What are the required learning outcomes related to management and leadership skills of an engineering degree? (rate low interest-1 to extremely interesting-10)
	e.1. Project management e.2. Innovation and creativity e.3. Ability to find compromises e.4. Recognizing the value of other (foreign) systems and approaches e.5. Curiosity and pragmatism (not self-centred) e.6. Team management, practice collaborative and remote work e.7. To be able to communicate with specialists and non-specialists
	f) What are important intercultural skills that can be taught to strengthen the European dimension of the of engineering education? (interest-1 to extremely interesting-10)
	f.1. Knowledge of histories and cultures of other countries f.2. Accept different abilities to work in relation to different nationalities, societies and ways of life f.3. Mastery of one or several foreign languages f.4. Knowledge of systems of thought of the societies f.5. Knowledge of social, political and economics frameworks of the societies
	g) What are the aspirations of students in terms of professional endeavors in your point of view? (max 5 keywords, separated by commas)
	h) Are there other areas or learning outcomes you would like to mention? (max 750 characters)
5. Here is a list of EUR-ACE © learning outcomes which are recommended to train an engineer. Could you provide a specific innovative teaching method you think of, or a best practice you have in mind to obtain these learning outcomes?	
	a) Knowledge and understanding b) Engineering analysis c) Engineering Design d) Investigations e) Engineering Practice f) Making Judgements g) Communication and Team-working h) Lifelong Learning

2.2 In depth interviews

A second survey consisted in hiring a consultancy firm to interview nine European leaders working at companies in Europe. Two main questions were asked, 1) What characteristics should the engineer of the future have? 2) What is the set of skills that he/she should develop to face a professional development for being a leader. The people questioned included 9 leaders/senior level management positions in leading companies and organizations (men and women) in 5 different countries which host the universities within the EELISA alliance (France, Germany, Romania, Hungary and Spain) and respondents based outside Europe with international functions. Each interview lasted 50 minutes and was open to spontaneous discourse.

3 RESULTS

3.1 On-line questionnaire

A total of 75 people participated in the web survey, 16% of which were not staff or students from the EELISA universities. Approximately 37% were professors or research staff from universities and more than half were students (55%). Most of the respondents felt an interest in obtaining a European degree, although students were less keen on obtaining a European engineering degree instead of a national one, underlining that the view is more of an additional degree than a substitution of local degrees. Regarding the learning outcomes of scientific and technical knowledge, most respondents (above 70%) mentioned being adaptable to current and future real-life changes and being able to analyse and synthesize complex problems, and design, implement and validate innovative methods, products and solutions.

Related to learning outcomes on social and environmental issues (question 4d), respondents were more interested in outcomes related to “ethical responsibilities” and “societal and environmental consequences of developed solutions”. Regarding business and management skills (question 4e), respondents mostly underlined the ability to communicate (with specialists and non-specialists), team working skills, as well as curiosity and pragmatism. Responses about intercultural skills (question 4f) were more varied but mostly centred around the ability to work with different nationalities and master several languages.

When asked about what types of innovative teaching methods could be used for different learning outcomes based on the EURACE accreditation system (Question 5), the responses were also quite varied but the word cloud analysis suggests the following pairing: knowledge and understanding (practise), engineer design (solutions), research (studies), engineering practise (real projects), making judgements (learning by projects), communication and team-working (team work).

3.2 In depth interviews

The results from the in-depth interviews of nine senior managers in leading European companies suggest that the specialized knowledge of current engineer graduates in Europe is excellent and should be maintained at a high level, including basic science skills. Most respondents found it difficult to predict the qualities required of engineers in the future, mostly due to uncertainties related to technological change. On the other hand, for the future they suggested improvements in the following fields:

Sustainability

According to the respondents, engineers should have the knowledge and the mentality needed to overcome different sustainability challenges. Younger generations seem well prepared. These were not seen as primary skills but as awareness necessary to motivate engineers to excel at their work. This could be further promoted by increased cooperation between companies and students during their studies, on state-of-the-art technological solutions to sustainability issues.

Interculturalism and inclusiveness

In general, respondents thought that European students have had some exposure to other countries and cultures, having studied abroad through different mobility schemes, but in some countries (e.g., France and Spain), the level of English could be improved. Regarding inclusiveness, for some companies, it is difficult to reach a gender balance but the incorporation of women is promoted and several interviewees mentioned that including more women in their workforce can create better working conditions.

Business and social skills

Respondents concluded that current and future engineers require stronger training in management skills, including human interaction/communication, entrepreneurship, finance and leadership. Although these skills can be acquired on the job, the overall feeling is that more of these subjects could be included in the degree programs. Engineers should be better trained to understand decision making in a company, under uncertain situations and to be prepared to react quickly about adopting new technologies. A better knowledge in economic viability (handling finance) of project would be welcome. When managing a project, engineers should also consider how the end client will use the proposed solution.

Social and communication skills could be improved by considering the knowledge of other people (inside a company) and by improving empathy. Engineers, especially those in leadership positions, need to know how to adapt their communication with stakeholders (higher authorities, other companies, social communities). This goes hand in hand with a good general culture in various fields (economic, political, cultural, etc.).

4 DISCUSSION

Within the overall framework of a degree program, which includes both a Bachelor and Master's degree in Engineering, knowledge of basic engineering and scientific skills is essential. These technical and knowledge-based skills involve understanding the importance of measurement (including data acquisition, literacy, analysis and management), in real or simulated contexts, and an analysis of how different equipment has evolved over the years, thanks to applied research. As confirmed in the general outline of the Learning Outcomes by ENAEE [5], engineers must have, first and foremost, "a thorough knowledge and understanding of mathematics and other basic sciences inherent to their engineering specialty". Acquiring these core skills is essential to support flexibility, adaptability to changing technologies and life-long learning. However, given the current ecological context, the applications and developments of new techniques need be compatible with planet boundaries and ecological limits [6]. They should also be compatible with democratically established societal goals.

Because these challenges (to which we can add the digital revolution) involve complex situations, uncertainties and multiple stakeholders, future engineers also need to acquire a series of skills revolving around the concepts of cooperation, innovation and entrepreneurship in an inclusive environment. Again, referring to the Learning Outcomes by the ENAEE, engineers must be able to “make judgements, communicate and work in teams”. They should be able to use different methods to communicate their conclusions, clearly and unambiguously, and the logical foundations supporting them, to specialized and non-specialized audiences, in national and international contexts. According to the Conference of Deans of French Schools of Engineering [7], future engineers should be active team-members and contributors to innovation, with competences in management skills, economics and finance, working in multiple disciplines and with a spirit of interculturality to propose innovative solutions.

4.1 A European engineer profile

Taking into consideration the results from the survey and in-depth interviews, we propose an outline for a European Engineer Profile (EEP) that includes a set of skills encompassing scientific, technical and more relational outcomes, within the European context of diversity and mobility. The EELISA-EEP can help to provide a scaffolding for the Learning Outcomes for a future joint degree, as well as ideas for the EELISA Supplement and Credentials. The EELISA-EEP is based on pre-existing frameworks such as the EUR-ACE® Framework Standards and Guidelines (November 2021) and the Washington Accord Graduate Attribute Profile (Nov 2021), but with additions emphasizing the importance of mobility and the European dimension. In that light, most international standards for engineer profiles underline the importance of key concepts such as understanding, practice, design, research, knowledge, methods and complexity. Most frameworks can also be divided into hard skills and transversal ones, with some emphasis on practical knowledge, but few point out the utility of mobility/diversity during the degree to help promote learning. We propose that the EELISA-EEP includes four conceptual fields within its framework.

Scientific, theoretical knowledge and digital skills

This part of the profile involves core skills or theory-based understanding of the basic sciences in each field of engineering, for example mathematics, computing, and their use to develop products, processes and systems. Students are exposed to theoretical problems and the formulation of possible solutions based on engineering fundamentals, in a design framework. Here access to research methodologies and relevant literature is key to help evaluate the data or processes using state of the art methods. Excellent scientific knowledge should be the backbone of the European engineer profile.

Addressing sustainability

European engineers will need to understand how the techniques they develop are compatible with the depletion of natural resources and avoid irreversible situations. Especially, they will need to consider the entire life cycle of products and services they design and produce. This implies a critical and thorough analysis of the socio-environmental risks pertaining to the development of new technologies.

Interculturalism: an engineer embracing the European project

Just as practical learning may help to understand engineering fundamentals, adding mobility in a degree program can help facilitate understanding and incorporating soft skills on a personal level. By being exposed to different professors, university environments and cultures, students will become more aware of different societal issues, ethical problems and cultural dispositions. Mobility also provides a means to being exposed to a working environment in a different country via internships. The ambition with mobility in EELISA is to go beyond an exposure to different cultures and different ways of thinking. The core of this project is to nurture an atmosphere of cooperation and common values around cohorts of students that will embrace the European engineer vision of EELISA and develop across geographies and over time a shared vision of Europe and its values.

Business and communication skills: Practical and applied knowledge

Engineers should be able to work with theories, concepts, materials, equipment and tools outside the classroom to apply problem solving techniques. This will also expose them to economic, organisational and managerial issues, and enhance a critical sense and judgment about the application of different solutions. They need to adopt a user-centric approach to gather societal expectations with technological ambitions. There are many ways to ensure students engage in work to acquire the expected expertise of engineering analysis, design and practice, including problem-based learning.

Given the uncertainty and complexity of real world situations, while applying the theoretical and practical knowledge they obtained, engineers will need to consider social objectives, and ethical responsibilities in addition to sustainability issues. Because they are at the interface between science, techniques and society, they will also require training related to communication skills, decision-making and independent learning to better integrate the views of multiple stakeholders into their decision and creative processes. These skills are best learnt in real contexts, in which students, having acquired basic principles, put them into practice in actual multi-lingual, multi-cultural and inter-disciplinary contexts. The complexity of decisions they will need to tackle involves a reflexive thinking posture on their own practice. This analytical thinking can feed back into their professional actions and further improve common knowledge. Given the fast evolving technological and societal environment, the European engineer needs to adopt a position of continuous learning that will maintain its ability to address societal challenges over time and to manage younger collaborators within its firms.

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