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Developing Global Engineers- A Comparison Between Scotland, Usa And Chile

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DEVELOPING GLOBAL ENGINEERS: A COMPARISON BETWEEN CHILE, SCOTLAND, AND THE UNITED STATES

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ABSTRACT
Engineering-accredited programmes are reviewed every 4-5 years by professional bodies with the aim of assuring standards that guarantee that graduate engineers can fulfil the highest technical demands of the industry workforce in order to achieve

a sustainable economy and society. The approaches to develop these require global engineering competences (GECs), such as international and intercultural teamwork, language skills, critical thinking, and ethical and human-centered problem solving, are proving insufficient to meet the emerging challenges that this century's society is facing. To develop these GECs, engineering programmes have been working on including physical and virtual mobility such as Collaborative Online International Learning (COIL) together with other experiential learning interventions in order to provide the necessary requirements to become a global engineer. The aim of this practice paper is to compare and to discuss how three different universities, located in Chile, Scotland, and the United States have designed their engineering programmes to develop global engineers. This research provides preliminary results, based on an auto-ethnographic approach to analyse the curriculum design approaches and structures, that highlight opportunities for collaborative interdisciplinary experiences as well as more country- and institution-specific approaches (Engineers Without Borders) that support the development of these GECs. Analysis showed that the majority of the GECs are achieved by the three universities, however Virginia Tech is the only university that explicitly encourages and motivates other students through an assignment and cultural simulation activity. This research is part of a larger investigation that will analyse how engineering graduates perceive their development of GECs.

1. INTRODUCTION

Global engineering competences (GECs) have become increasingly crucial in today's interconnected world, where engineering projects and teams often span multiple countries and cultures. While technical expertise remains important, engineers must possess a range of competences beyond technical skills to be successful in the global engineering profession. These competences include cultural awareness, communication skills, ethical decision-making, and leadership abilities, among others (Bremer, 2008; Davis, 2018; Downey et al., 2006; Parkinson, 2007).

According to the Engineers Europe website and the EngineeringX website, GECs are critical for success in the 21st century engineering profession. The growing emphasis on addressing global challenges, such as sustainability, healthcare, and energy, underscores the need for engineers to possess the skills and knowledge to tackle these issues on a global scale. Additionally, engineering employers have found that technical skills alone are not sufficient for success in the engineering profession, and that professional skills such as communication and teamwork are equally important (SL Controls website n.d.). As a result, engineering education programmes are incorporating GECs into their curricula to develop engineers with the skills required for the contemporary workforce; and to ensure the sustainability of these engineering programmes, these GECs must be reviewed periodically in conjunction with the industry in order to respond to the changes/challenges caused by the constant evolution of our society and our economy.

Universities' system differ from UK and America with regards the length of their undergraduate degree. In Scotland a bachelor's degree in engineering can last between 3 to 4 years. Accredited 4 years degree allows to become chartered after few years of experience. In the United States of America, an engineering program at the bachelor's level generally lasts 4 years, whereas in Chile, the equivalent degree program typically has a duration of 5.5 years. Universities in the UK follow the UK Standard for Professional "Engineering Competence". The universities in the United

States follow the Accreditation Board for Engineering and Technology (ABET) standards, while the universities in Chile are accredited by the National Accreditation Commission of Chile (CNA). However, these standards offer institutions flexibility in how they design their programs to meet these requirements (Engineering Council, 2023; ABET website, 2021, CAN website, 2023).

To prepare students for success in a global workforce, universities have developed different strategies and interventions that provide opportunities for students to be exposed to the complexities of developing GECs (Sharma and Alvi, 2021). While international experiences are important, it is also crucial to establish a collaborative dialogue among experts, including academics, industry professionals, and higher education decision makers, to create effective learning outcomes that help students develop GECs (Moore, 2022; Ortiz-Marco, 2020).

This practice paper focuses on an ongoing project among University Austral in Chile, Glasgow Caledonian University in Scotland, and Virginia Tech in the United States. The project aims to reflect on and compare the approaches taken by each institution to develop and achieve GECs.

2. THE GLOBAL ENGINEERING COMPETENCES: A FRAMEWORK

Global engineering competences (GECs) have become a topic of interest for researchers in recent years, as they play an essential role in the success of engineering professionals in a globalized world. The Engineers Europe website and the World Economy Forum website (2021) have identified several key GECs, including technical, cultural, communication, ethical, leadership, entrepreneurial, and global competences. Other studies have emphasized the importance of professional skills such as communication, teamwork, and leadership, in addition to technical skills, for success in the engineering profession. Research suggests that industry recognizes the importance of these skills, with communication skills being particularly valued. Additionally, cultural awareness and the ability to work in diverse teams are also considered important for success in the global engineering profession.

For the purpose of this practice paper, the comprehensive list of global competences identified by Ortiz-Marcos (2020) will be used as the framework. These competences were collected through an extensive interviewing process with engineering companies located in five European countries, providing valuable insights into the most valued skills and knowledge in the global engineering profession.

Downey et al. (2006) argue that GECs must include developing the knowledge, ability, and disposition to work effectively with people who define problems differently than oneself. Hence, to understand and assess GECs better, it is essential to understand how different universities in different countries perceive the development of GECs. Johri and Jesiek (2014) have suggested a broader approach to defining global engineering competency as the capabilities and job requirements that are uniquely or especially relevant for effective engineering practice in a global context. They argue that the attributes of a globally competent engineer belong to three dimensions: technical coordination, engineering cultures, and ethics and standards and regulations. Table 1 provides a fusion between three dimensions proposed by Johri and Jesiek (2014) and the global competences suggested by Ortiz-Marcos (2020). It is noteworthy that while some competences may belong to one of the three dimensions, there are others that can be transversal and, therefore, not associated with a unique dimension. Communication is an example of a transversal competence.

Table 1. Dimension/Definition and suggested Global Competences (Adapted from Johri and Jesiek 2014 and Ortiz-Marcos 2020)

Dimensions	Definition	Global competences
Technical coordination	It involves managing social relationships and communication in multinational/cultural settings, with a focus on technical experts and problems. It differs from cross-cultural business or management situations, which do not necessarily involve technical expertise or issues.	GC1:Communication GC2:Communication in a foreign language GC3:Holistic system thinking GC4:Negotiation GC5:Conflict management GC6:Cooperation GC7:Problem solving GC8:Encourage and motivate others GC9:Teamwork GC10:Understand the connectedness of the world GC11:Decision making
Engineering cultures	They refer to the diverse practices and processes of technical problem solving across different multinational and cultural contexts. They are characterized by a strong focus on technical expertise and technical problems.	
Ethics, standards, and regulations	This category arises when technical coordination or problem solving occurs amidst conflicting normative and policy contexts.	

3. METHODOLOGY

Although this is a practice paper, we consider it important to report on how our analysis and the preliminary results were identified and presented. Our work is informed by an auto-ethnography approach; which is a qualitative research method that promotes self-inquiry in a critical way that involves reflection and narrative inquiry (Hughes and Pennington 2017); this means that there is a high content of self-reflection which allows the researchers to be the objects of study while having the flexibility to position themselves in relation to the phenomenon of study (Hughes 2020). We considered this an appropriate method to share our combined experiences and our critical reflective process of how our institutions in each country develop GECs. To conduct the comparative analysis, we defined a qualitative scale to assess the degree of alignment or congruence between competences from specific engineering programs and the GECs (Ortiz-Marcos 2020.The scale presented for evaluating the indicators of performance was derived from a combination of the authors' experiential knowledge, professional judgment, and the application of the auto-ethnography approach. Based on experiences and expertise in the field, the authors reached at a consensus on the development of the following indicators of performance:

1. Not Aligned (NA): no significant overlap or agreement between the GECs and the outcomes competences of the specific engineering programme. In other words, the skills and knowledge that are emphasised in the programme do not match with the competences that are required for engineering practice on a global level.

2. Partially Aligned (PA): some overlap or agreement between the GECs and the outcomes competences of the specific engineering programme. Some of the skills and knowledge emphasised in the programme match with the competences that are

required for engineering practice on a global level, but there are also significant gaps or areas where there is no alignment.

3. Fully Aligned (FA): high degree of overlap or agreement between the GCECs and the outcomes competences of the specific engineering program. The skills and knowledge emphasised in the program closely match with the competences that are required for engineering practice on a global level, indicating that the program is well-designed and relevant to the needs of the industry.

In the following section, we describe the different institutions, programmes, and at the end we provide the table that summarises how we self-assess our GECs development.

4. DEVELOPING THE GLOBAL ENGINEERING COMPETENCES: THREE CASE STUDIES

4.1. THE CASE OF CHILE

University Austral was established in 1954, where The Faculty of Engineering Sciences, founded in 1989, offers eight undergraduate programmes, five master's programmes, and two diplomas.

In this study GECs for mechanical engineering and industrial engineering will be analysed. These two programmes are a five-year degree where students are required to take a course in communication in a foreign language (English) during their first semester and a general communication course during their second semester. Although engineering students are required to read and review various English resources throughout their programme, courses related to technical competences do not typically require verbal or written communication in English.

The mechanical engineering programme stands out for its incorporation of the problem-based learning (PBL) methodology, where six modules use this approach offering practical experience in solving real-world problems. The PBL courses are offered from year 3. The projects involve interaction with real stakeholders, especially those dealing with issues like water supply, energy supply, and domestic and industrial waste management. Additionally, the programme includes a one-semester professional practice and a final project. Notable outcome competences linked to this programme include problem-solving, teamwork, cooperation, and decision-making.

In the case of industrial engineering, students are required to take an English communication course for four semesters and a general communication course for two semesters. Also, communication and teamwork competences are developed during the professional cycle of the programme through collaborative projects across various subjects. These projects are usually presented to classmates, but only in Spanish (students first language). Problem-solving is a skill that is enhanced throughout the degree through professional practice and a final project that requires students to analyse and solve engineering problems in real-world contexts. The final project also contributes to competences such as cooperation, holistic systems thinking, and decision-making. Although students have a sponsoring teacher, they enjoy considerable autonomy in selecting the organisation where they will develop their project, the topic, and the approach.

The University also offers optional student exchange opportunities with foreign and national universities. These exchange opportunities contribute to the strengthening of global competencies.

4.2. THE CASE OF SCOTLAND

Glasgow Caledonian University was established post 1992. Among all their programmes it offers a total of 5 engineering programmes at undergraduate level which includes mechanical engineering. Glasgow Caledonian University's Strategy 2030 is underpinned by UN SDGs and has been developed to respond to these demands where a transformative education is key to develop globally competent graduates. Technical, communication, ethical, leadership and entrepreneurial competences are achieved through the degree by different types of activities/assessments included in different modules. In the first year students are introduced to ethics and practices, engineering responsibilities and challenges of the engineering profession such as in the Engineering for Society module. Team building/skills are key in engineering and these are introduced from 1st year.

Recognising the importance of GECs, 2nd year students take part in compulsory four weeks virtual mobility activity, such as Collaborative International Learning (COIL), where students not only gain knowledge in the area of engineering, but also develop cultural awareness, international perspectives, and ethical sensitivities. This activity is deliverable included as not all students take part in international collaboration due to different personal commitments. From 2nd year onwards students are involved in Problem-Based learning (PBL) and in modules such as Integrated Engineering Studies (3rd year) where a business case study is included; in these modules, the best projects get to enter the Engineers without Borders: Engineering for People Design Challenges competition. The final year project gives students the opportunity to showcase all competences developed along with their degree and the opportunity to analyse and solve an engineering real life problem. The university also provides opportunities for students to participate in physical mobility through international exchange for level 3 students (few examples: Touring Scheme (former Erasmus scheme), European Project Semester, International Project Week, Engineering vision, etc.) and the possibility to apply for a Year in Industry programme just after 3rd year to gain industrial experience before returning to the final year of their degree.

4.3 THE CASE OF USA

Virginia Tech, College of Engineering, among all their programmes offers 14 undergraduate degree-granting engineering majors.

For this study, the Rising Sophomore Abroad Program (RSAP) was selected. This program provides first-year engineering students with an opportunity to expand their global competences through an international experience. RSAP integrates an on-campus, Spring course on Global Engineering with a short-term international module immediately following semester exams. The class during the Spring semester meets for three hours each week including 2 hours of lecture and 1 hour of travel development according to students' individual tracks. Each year the program has multiple international tracks where students travel to different parts of the world. This pre-trip attention has helped the students make the most of their short-term study abroad experiences. Similarly, the course has 3 modules associated with 3 mini project that students complete: 1) Global Challenges, 2) International Preparation, and 3) Global Communication. At the end of the Spring semester, students travel abroad on one of the multiple international tracks for a period of two weeks. The program tracks have included the following countries: 1) China, 2) the United Kingdom and Ireland, 3) Italy, Switzerland, and Germany, 4) Chile and Argentina, 5) Spain and Morocco, and 6) Australia and New Zealand. To meet the program's goal of global engineering competences, students visit companies, universities, and are immersed in cultural and social attraction sites in the respective host countries.

Table 2 summarises the GCs achieved by the three universities involved in this study.

Table 2. Summary of the Global Competences achieved by each of the three universities involved in this study

Global Competences	University		
	Austral	Glasgow Caledonian	Virginia Tech
GC1: Communication	FA	FA	FA
GC2: Communication in a Foreign Language	PA	NA	NA
GC3: Holistic system thinking	FA	FA	FA
GC4: Negotiation	PA	PA	PA
GC5: Conflict management	PA	PA	FA
GC6: Cooperation	FA	FA	FA
GC7: Problem solving	FA	FA	FA
GC8: Encourage and motivate others	NA	NA	PA
GC9:Teamwork	FA	FA	FA
GC10:Understand the connectedness of the world	FA	FA	FA
GC11:Decision making	FA	FA	FA

NA: Not Aligned- PA: Partially Aligned- FA: Fully Aligned

5. DISCUSSION

As observed from the results the three universities provide opportunities for students to develop GECs. When analysing Table 3, the majority of the GCs are achieved by the three universities involved in this study, however GCs 4, 5 and 8 are either NA or PA. The reason for this decision is that these competences are implicit when working in teams, but not explicitly defined as a learning/skill outcome.

Additionally, as mentioned in Section 2, language and cultural skills are one of the skills required to be a global engineering and as observed in Table 2, GC2: Communication in a Foreign Language is NA for Glasgow Caledonian University and Virginia Tech and PA for University Austral where English language must be taught in the first years of the degree. English is considered an international language, 510 million people use English Language to communicate daily and there are 53 English speaker countries around the world (Hammond 2014). This is an obvious advantage that students from Scotland and USA have compared to students from Chile.

Regarding GC8: Encourage and Motivate others, Virginia Tech, is the only university that explicitly addresses this competence through an assignment and cultural simulation activity. The assignment is focused on understanding what is required for a student to work on an international team with an explicit focus on how to lead others to engage in productive conversations and work. Similarly, the cultural simulation activity has the goal to understand cultural differences but also to motivate others to do so.

The Global Engineering Competence 'International opportunities' was highlighted as highly important by industries (despite not included in Table 1), however it is an important aspect considered by the industry when recruiting engineers, as graduates that have taken part of an international experience show adaptability, resilience, cultural and self-awareness (Ortiz-Marcos 2020). Following this, Glasgow Caledonian University provides the opportunity to study abroad, however taking into account personal challenges students might face that impact their opportunities to experience physical mobility, Glasgow Caledonian University included a compulsory activity in level 2 which is a Collaborative Online International Learning (COIL) experience (virtual mobility). This helps to become responsible global citizens through the development of intercultural competences, ethical sensitivities and international perspectives at the same time that provides teamwork and dynamic skills while it is used as an opportunity to compare international variations in engineering education and practice and an understanding of business and engineering cultures of countries involved. It also provides equal opportunities to all learners to experience an international experience.

6. CONCLUSIONS AND FUTURE WORK

In this practice paper, we have presented our initial findings from an ongoing research project that aims to identify the opportunities and challenges in bridging the gap between global competences (GCs) and outcome competences in engineering programs at three universities. Our analysis suggests that while GCs such as "holistic system thinking," "communication," "cooperation," "problem solving," "teamwork," "understanding the connectedness of the world," and "decision making" are fully developed in the programs at these universities, there are other GCs that require further attention.

For instance, our study indicates that all three universities could benefit from emphasizing communication in a foreign language and providing tools to develop competencies in negotiation and encouraging and motivating others. Additionally, the results suggest that universities can learn from each other to reduce the gap with respect to certain GCs. For example, University Austral and Glasgow Caledonian University could learn from Virginia Tech’s approach to acknowledging and addressing the competence of "conflict management," and University Austral could adopt the learning strategies used by universities of Glasgow Caledonian University and Virginia Tech to promote international interaction among engineering students.

Furthermore, we suggest that virtual mobility can serve as an effective option for addressing different GCs, particularly when "real" mobility is limited. This approach can help students gain skills such as adaptability, resilience, cultural awareness, and self-awareness. Overall, our study highlights the need for continued efforts to address the gaps between GCs and outcome competences in engineering programs and suggests several ways in which universities can work together to achieve this goal.

Moving forward with our ongoing project, our next steps will involve conducting a quantitative analysis of the engineering programs at the three universities to determine how they are addressing GCs. Specifically, we plan to distribute surveys to students to gather data on how they perceive themselves as global engineers. This data will help us gain a deeper understanding of the students' perspectives on their own competences and identify any areas where further improvement is necessary. The results of this survey will provide valuable insights into the effectiveness of current teaching practices and the potential for future improvements to address the gaps between GCs and outcome competences in engineering programmes.

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