An international overview of diversity in engineering education

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INTRODUCTION

The term of "diversity" has become a fashionable word in the education realm worldwide. More and more institutions are making efforts to attract and retain a diverse population of students. More and more countries are creating policies and programs to complement, support or encourage these institutional efforts. Research studies suggest that there are both individual and societal benefits of diversity. For example, diverse work forces can work across national boundaries, contribute ideas that are "outside the box", promote viewpoints or approaches that enrich projects, or simply contribute to the reduction of prejudice in an organization. However, what constitutes diversity in different contexts is not necessarily fixed. What may be diverse in one society may not be diverse in another. This question of “Does the term diversity have the same meaning in countries across the world?” is critical to understand this dialogue worldwide, and to understanding how and why different countries, companies, and governments pursue the policies they pursue.

The goal of this paper is to identify the many types of diversity relevant to engineering education, as well as the reasons for investing in creating diversity in this field. In order to get a broad spectrum of contexts, five major players in engineering education have been selected as case studies: United States, European Union, Australia, Japan and India. The method used was to gather information available on

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the web pages of the educational government organizations responsible with engineering education, National Academies of Engineering and national and transnational Associations for Engineering Education. The first section of the paper presents a theoretical framework that links the different types of diversity to engineering education and their rationale. The second section presents five case studies that illustrate the particular diversity focuses and the stated rationale for engineering education. The conclusion focuses on the differences between how diversity could be defined and how it is defined.

1 THEORETICAL BACKGROUND

1.1 General discussion of diversity

"Diversity" is defined in the Oxford dictionary as "the state of being diverse, showing a great deal of variety, very different". The term is very broad and can be applied to any characteristic that shows variety. Therefore, the term "diversity in education" is usually used as an umbrella term that encompasses racial diversity, gender diversity, religious diversity, personality diversity, training diversity and many more other types of diversity. Because it is a popular umbrella term, its definition can be easily assumed to be known, without clearly defining the boundaries of the term in that specific context. This runs the risk to be misused or cause misinterpretations. This is problematic because the term "diversity" in education is now an intensely debated concept across the entire political spectrum [1].

The situation becomes even more complex when analyzing "diversity" through international comparisons. The "diversity in education" is tightly related to the diversity existent in the general population of a country or region, therefore there is huge variety in what is the focus of the definition in various countries.

When looking specifically at engineering education, there could be types of diversity specific to the discipline, such a diversity of fields of engineering, diversity of problem-solving styles, etc.

1.2 Types of diversity

A review of the literature shows that diversity in education can refer to a variety of student characteristics. These characteristics can be divided in easily quantifiable traits, such as sex, age, race, etc. (see Table 1) and traits that are rather hard to quantify such as personality, aspirations, lifestyle, etc. (see Table 2). These two tables include a list of quantifiable and non-quantifiable traits and their definition. This list has been compiled based on the definitions of diversity in use at governmental and non-governmental agencies, universities, companies, and in research studies. The literature shows that there is a relationship between some types of diversity. For example, gender diversity could include or incorporate aspects of marital status and pregnancy diversity. The authors do not claim that this list is exhaustive.

Table 1. Quantifiable student attributes

Type of quantifiable diversity	Definition
Gender	Refers to the sex (female/male) composition of a group

Table 2. Non-quantifiable student attributes

Type of non-quantifiable diversity	Definition
Personality traits	The combination of characteristics or qualities that form an individual's distinctive character

Race	Refers to the racial and interracial composition of a group
Age	Refers to the different age demographics in a group
Disability	Refers to the appropriate inclusion of people with physical, sensory, intellectual, emotional and developmental disabilities
Sexual orientation	Refers to the appropriate inclusion of people with non-heterosexual orientations (bisexual, homosexual)
Living conditions	Refers to the circumstances in which a person lives (habitability of the house, living with the family, distance from university)
Geographic origin	Refers to the country, region, city or neighbourhood a person is coming from
Location	Refers to the type of settlement (urban/suburban/rural/tribal) a person lives in
Nationality	Refers to the inclusion of people with different citizenships
Economic status	Refers to the income level of a person and of their household
Class and/or caste	Refers to different forms of social stratification (based on socio-economic principles or hereditary transmission of a lifestyle)
Lineage	Refers to the blood lineage based on ancestry.
Marital status	Refers to discrimination based on assumed characteristics of people who are married, single, or divorced
Dependents/ pregnancy	Regards the adequate inclusion of people who have dependents (children, spouses, siblings, parents) and pregnant women
Ethnicity/ Multiethnicity	Belonging to a social group that has a common cultural tradition

Personal experiences	The variety of internal and external events in a life of a person
Lifestyle	Refers to the way in which a person lives that reflects their values and attitudes
Personal aspirations	Refers to the personal goals and desires that a person is motivated to accomplish (can be related to family, life choices, etc)
Religious beliefs	Refers to the belief in different religions views(Christian, Muslims, Hindus, etc) or to atheism
Cultural beliefs	The ideas and thoughts common to several individuals that govern interaction and are not empirically discovered or analytically proved
Political ideology	Refers to the ideas on how the government and the economic system should be organized
Peer expectations	The social influence from a group of people of similar age, status or competency
Position within the household	Refers to the participation of an individual in the decision making of his/her household, relationship of power in the household, etc
Professional experiences	Refers to the experience working for companies based on qualifications
Thinking /learning style	The ways students perceive and process information (visual/auditory, reflective/ active, logically/ intuitively, memorizing, etc)
Technical and non-technical skills	Learned abilities in a specific field or broad abilities (communication, teamwork)
Aptitudes and talents	Domain-specific skills within the normal ability range (aptitude) and of exceptional quality (talent)
Professional aspirations	Refers to the professional goals and desires that a person is motivated to accomplish (can be related to education, career, etc)
Exposure to technology	Refers to access and familiarity with computers, mobile devices, software

First language	Refers to the language(s) a person has learned from birth or speaks the best
Type of highest degree	Refers to the variety of degrees at undergraduate level (theoretical vs. vocational) and at graduate level (masters, PhDs, etc)
Field	Engineering is a broad and dynamic disciple that encompasses many fields (aeronautical, biomedical, mechanical, chemical, etc)
Traditional / non-traditional	Cclassroom based versus online education, distance education, technology based instruction, etc

Academic strengths/ weaknesses	The field(s) of study or topic(s) that a person has a deep/poor understanding of

The majority of the definitions focus on observable traits, especially gender and ethnicity. Few include non-observable traits such as personality and aspirations, but these traits are always included towards the end of the definition.

1.3 Rationale for diversity

The argument of diversity in education has the potential to create long lasting political debates around what policies should be implemented, what groups should be targeted and how much support should be offered. Not always clearly defined is the rationale of these policies.

Several arguments have been advanced to support why diversity is important for engineering education. Certain arguments work better for certain types of diversity.

The first argument is the argument of diversity as an issue of equity and fairness, which comes from a critical multiculturalism perspective [1]. Equity as fairness of outcomes is emphasized more than individual equality of opportunity. The assumption is that historically marginalized groups have an inherently unequal achievement gap due to certain discriminatory barriers and governmental and institutional action is needed to correct for this imbalance. This argument can hold for almost all quantifiable traits (biological, environmental, social and cultural characteristics) depending on the country and on the historical context.

The second argument is the argument of diversity as a problem of demographics [2]. The group of students that dominates the engineering field is actually in minority in the entire population. This is the case for the White males in the United States who are earning 65% of the bachelor degrees in engineering, while their share in the 20-24 age US population is roughly 30.5% and expected to decline to 26% over the next 10 years [3]. This situation might lead to bottleneck in the supply of qualified engineers on the job market and can have economic repercussions. This argument can hold for certain quantifiable traits (such as gender, race, age, nationality, economic status, class, ethnicity, first language and educational characteristics) depending on the country and on the historical context.

The third argument is related to diversity as a necessity for creative solutions in engineering. The assumption is that a diverse population of engineers is able to bring in different life experiences, which allows for a creative environment. The lack of diversity is paid in the opportunity costs of not finding the most innovative solution possible and of not training the best engineers possible. The diversity positively

affects technological innovation and the economic competitiveness. This argument holds the best for educational characteristics and for certain non-quantifiable traits (such thinking, learning styles, professional and personal experiences, etc).

The fourth argument is diversity as a necessity for to harvest the potential of the untapped pool of talent in different areas. In order to promote excellence in engineering, the strategy is to attract the most capable and bright students possible. When certain groups do not have proper access to engineering education, some of the talented students in these groups are not able to reach their full potential and valuable human resources are lost.

The fifth argument is diversity as a necessity for true democracy. A fair participation of all the different groups in engineering programs could lead to more scientifically literate citizens and increase the number of government and business leaders from the "minority" groups. This argument is similar to the first argument and it can hold for almost all quantifiable traits (biological, environmental, social and cultural characteristics) depending on the country and on the historical context.

2 CASE STUDIES

The section presents the diversity in engineering education in four countries – United States, Australia, Japan, India – and in the European Union at large. In each case study, it is described in what ways the general population of each country is diverse, how that diversity reflects in the engineering student population and what the rationale for different diversity efforts is. The data was gathered indirectly from sources at three levels. The information was gathered from reports and web pages of the governmental bodies (National Department of Education, National agency responsible for science and engineering education, etc.), through the Associations for Engineering Education or through the National Academies of Engineering.

2.1 United States

At U.S. federal level, the National Science Foundation (NSF) is the government agency that directly supports fundamental research and education in science and engineering. NSF has strong commitment to encourage diversity and broaden participation in the science and engineering education and workforce. One of the targets of the NSF 2011-2016 Strategic Plan is to "prepare and engage a diverse STEM workforce motivated to participate at the frontiers" [4].

In NSF's vision, the main target underrepresented groups in science and engineering are women, underrepresented minorities (African Americans, American Indians including Native Alaskans, Hispanics and Native Pacific Islanders), and persons with disabilities. The support for diversity comes from four perspectives: 1) demographic concern ("departure of aging baby boomer scientists, engineers and educators from the workforce), 2) "drawing on the talents and interests of all sectors of the nation's diverse population", 3) desire to build a scientifically literate society and 4) necessity to keep the United States globally competitive [4].

In 2012, the Broadening Participation in STEM Education Act was introduced in the U.S. House of Representatives with the goal to increase the number of underrepresented students and faculty in science, technology, engineering and math (STEM) disciplines. Representative Johnson who introduced this bill mentioned several rationale behind this decision: 1) "a question of equity" 2) "the vast, untapped pool of talent in America and 3) "global leadership in innovation and job creation" [5].

The U.S. National Academy of Engineering is actively involved in promoting diversity in engineering workforce though a dedicated program. The focus is on gender and

racial and ethnical diversity, with the reasoning that "the paucity of women and underrepresented minorities in U.S. engineering classrooms, research laboratories, design studios, and corporate boardrooms diminishes the range of perspectives and the diversity of ideas/solutions available to the engineering profession" [6].

The American Society for Engineering Education defines diversity [7] as "the inclusion of individuals that represent variations in gender, race, ethnic background, disability, sexual orientation, age, socio-economic status, nationality and other non-visible differences resulting in an environment rich in intellectual variety and respect for the individual, and optimally suited to address the technological needs of the future." The rationale on ASEE's website is twofold: 1) technological competitiveness of U.S and 2) enriched educational experience and improved engineering practice.

2.2 Australia

The Australian Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education administers two programs that support diversity in higher education in general, engineering education being included as well [8]. One of the programs financially supports universities to improve access for students with disabilities, while the other is focused on students from low socio-economic backgrounds. These initiatives stem from the 2003 Higher Education Support Act that has a first objective "to support a higher education system that is characterized by quality, diversity and equity of access".

The Australian Academy of Technological Sciences and Engineering supports diversity initiatives in engineering education. As part of the Australian Council of Learned Academies (ACOLA), it has published an international comparison on STEM education policies [9]. A recommendation of the report was to develop programs that "take into account the diversity of students' contexts, including their gender, ethnicity/cultural background, SES status and indigeneity". The report has specific sections for girls and women and indigenous students. Specifically for women in STEM, five rationale for diversity are given: 1) more productive and relevant STEM research, 2) more creativity and reduced bias, 3) social justice and human rights, 4) equal access to public education and research funds, 5) competitiveness.

The Australasian Association for Engineering Education (AAAE) aims to "increase the participation rates of high school leavers in engineering education and training, especially of women and non-traditional students". No rationale is given [10].

2.3 Japan

The Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) promotes the progress of science and technology and internationalization as basic principles for education. Efforts are also made to strengthen graduate school education, diversify the fields of study for the students and support students from low economic background [11]. MEXT plans to reform the science and technology (S&T) system, by promoting female and foreign students and researchers [12].

The Engineering Academy of Japan (EAJ) supports "diversification and deregulation for education respecting individuality" in its statement regarding the educational reform. The main rationale is to train the next generation of scientists and engineers and to promote national security and economy [13]. There is no statement in English about diversity on the Japanese Society for Engineering Education [14].

2.4 India

The Department of Higher Education from Indian Ministry of Human Resource Development is responsible for overseeing technical education. The rationale to

support technical education is “to create skilled manpower, enhance industrial productivity and improve the quality of life for its people”.

The Twelfth Five Year Plan (2012-2017) [15] emphasizes curriculum and disciplinary diversity that match the great racial, ethnical, cultural, religious and linguistic diversity in student body. There is a national affirmative action policy based on belonging to disadvantaged casts [16] regarding admissions into all public higher education institutions, including the central and state government funded technical colleges.

There is no information related to diversity on the website of the Indian National Academy of Engineering [17] or the Indian Society for Technical Education [18].

2.5 European Union

The case of the European Union is unique because it encompasses many Western European countries where STEM has been a vital point in their national policies (such as Germany, Finland, Switzerland, etc). The focus of this case study will be only the initiatives related to diversity in engineering education at the European Union level, although there are numerous national policies in the member countries.

The Strategic Framework for European Cooperation in Education and Training (ET 2020) was signed by European Commission and the members states with the goal to support education and training and develop the knowledge society and economy [19]. Part of the strategic objectives are “the promotion of equity, social cohesion and active citizenship” and “the enhancement of creativity and innovation (…) at all levels of education and training”. The Directorate on Research and Innovation has reports specifically on women in science and engineering. As part of this directorate, the Science in Society (SIS) programme supports policy initiatives related to gender imbalance in many of the science and engineering fields [20].

The European Society for Engineering Education (SEFI) has a working group on gender and diversity [21] that focuses on “identifying best practices to attract and retain female students in higher engineering education”. The rationale presented on the website is the demographic shift and the lack of engineering experts.

3 CONCLUSIONS

The case studies show that there is variation regarding what types of diversity a country focuses on. Although some of this variation could be explained by historical reasons, the argument of equity is not the only one used as rationale for diversity. Certain countries use certain types of diversity to advance their economic and technological goals or to promote a more scientifically literate and democratic citizenship. Given the variation that we are seeing it remains a need to figure out a more structured way of looking at diversity across international contexts.

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