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"STEMANITIES" as a Future Fit Scholarship:

Trends and Challenges in Engineering Education for Industry 4.0

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ABSTRACT:

New labor market demands, shaped by advances in the era of Industry 4.0, require a shift in Engineering education. The paper argues that the core competences stemming from the Humanities-based education, also labeled "transferable skills," enable STEM graduates to develop cross-cutting capacities in a time of rapid globalization, thus making them more employable and flexible in their working environments. Due to the fact that tertiary education as a public value establishes a great level of trust with both graduates and businesses, introducing a more holistic approach to Engineering education with a "liberal education" concept might restructure the current curricula to better prepare engineers for future challenges.

1. INTRODUCTION

The demand for STEM graduates, especially those studying engineering, far exceeds its supply. UNESCO recently reported on shortage of engineers and decreased interest in engineering career around the world [15]. In order to systematically deal with the issue, UNESCO produced the world's first comprehensive study on Engineering titled *Engineering: Issues, Challenges and Opportunities for Development*, after analyzing socio-economic development in 5 global regions of the world. The study reports on current situations and future trends, demonstrating how Engineering is a necessary tool to achieve the Millennium Development Goals (MDGs), poverty reduction and sustainable development. The strong emphasis is placed to the importance of Engineering education, so that the tertiary education is one of the main foci of the UNESCO Engineering Initiative (UEI). The idea behind the Initiative is to promote Engineering as a viable and socially-impactful career option, so a number of Engineering-related events and programs are constantly being designed to promote Engineering at universities, colleges and vocational technical schools [15].

UNESCO's concern for educating engineers corresponds with the demands of the modern workforce in the labor market. It is reported that STEM occupations have significantly grown over the past 30 years, going from 9.7 million employees to 17.3 millions, thus outpacing overall US job growth [7]. The statistics say that whereas the overall employment grew only 34% in USA, STEM employment has grown 79% since 1990. These numbers imply that businesses around the world have been faced with

the new hiring choices and that they might have been deliberately hiring both STEM-educated and non-STEM educated workers, which has influenced the labour market to become more diverse and dynamic than ever.

The Engineering industry has one of the most competitive job markets, partly due to attractive salaries. There is evidence of the significant earnings advantage of STEM workers over non-STEM workers, with a typical STEM worker earning two-thirds more than non-STEM ones. In addition, computer workers, math workers and engineers have higher median earnings than other STEM subgroups [7]. As for the division of positions, engineers and architects are the third most popular occupations (2.7 million employed) after medical sciences, with the tendency of growth, based on the fact that computer industry jobs have more than quadrupled since 1990 (a 338% increase)[7].

Besides being well-paid and deficit in the job market, STEM workers tend to have relatively high levels of education compared with other workers. For example, among many STEM degree programs offered in USA, the largest STEM-educated group is those who majored in Engineering at 4.7 million workers [7]. The findings of the research conducted by Pew Research Center into STEM workforce in USA, conducted over the adults aged 25 or older in 74 STEM occupations, revealed that

2. STATE OF THE ART AND WHY "STEMANITIES"

The term Industry 4.0 or the Smart Industry stands for the cutting-edge trend in industry towards automation and data exchange in manufacturing technologies and processes which refer to Artificial Intelligence (AI), the industrial Internet of Things (IoT), Virtual Reality (VR), cyber-physical systems (CPS), cognitive and cloud computing etc. Industry 4.0, unlike its preceeding industries, is geared towards individual experience i.e. seeks to fulfill individual customer needs[4]. However, the scientific and technical advances in 21st century, apart from affecting economy and politics, have also added to the vulnerability of humankind [17]. In the context of Industry 4.0, social challenges related to privacy, ethical and security issues and distrust cannot be excluded. In order to tackle those problems, stakeholders and policy makers rely on STEM education. In the context of education, the strong impact of Industry 4.0 is best demonstrated in the term "Library 4.0" which denotes an endeavor to keep up with the industrial shifts brought about by the disruptive technological innovations worldwide [9].

STEM stands for the disciplines of science: Science, Technology, Engineering, Mathematics. The acronym was first introduced in 2001 by US National Science Foundation administrators [8]. As an interdisciplinary approach to learning in which the academic concepts are coupled with real-world lessons, STEM links educational goals with workforce needs. As students apply science, technology, engineering, and math in contexts that make connections between school, [community](#), work, and the

global enterprise they improve their ability to compete in the new economy[8]. STEM education is what many Americans view as a path to a "good job" [11].

On the other hand, STEM's counterpart in education and employment, the field of Humanities, Arts and Social Sciences (HASS), has showed negative enrollment trends all around the globe, but since 2008 the HASS crises has been alarmingly deepened. In November 2018, as many as 18 US universities and colleges announced cuts to Arts and Humanities majors and departments, aiming at eliminating low-enrollment programs, thereby laying off faculty, suspending programs and even closing campuses and multidisciplinary centers. Minors and majors to be cut out are history, French, geography, physics, sociology, Spanish, book studies, theater, religious studies, classical languages and literature etc. Two universities out of 18 decided to abandon the initial plans and instead consider a different kind of reorganization such as combining several departments. As for faculties, the plans include voluntary retirements, moving to part-time positions and reduction of faculty members by fall 2021 [15].

However, while the Humanities have obviously become less popular choices at universities and colleges, the humanities-educated workforce has been demonstrating excellent flexibility at workplaces and employees report of their overall satisfaction with those workers. Graduates in the Humanities gain a variety of skills over the course of their degrees, resulting in the development of human capital [3]. This is because the humanities graduates possess a variety of diverse skills, usually not found in STEM engineers. Engineers are often perceived as lacking communication and interpersonal skills [12] due to – lack of importance given to these disciplines during their engineering education [12]. They are generally bad at writing, public speaking, delivering presentations, and they are less experienced in aiming at creativity which arguably spurs innovation [12]. In today's geopolitical circumstance "governance requires high quality, broadly educated public servants and enlightened citizenry" [17].

Nowadays, employers are looking for more than just an engineer with a STEM background - they are looking for critical thinking, communication skills, problem-solving abilities [6]. A survey conducted by The Association of American Universities revealed that 73% of employers in USA rejected the trend towards narrow technical training asking colleges and universities to emphasize critical thinking and analytical reasoning more [17]. The same study informs us that 78% of employers look for intercultural competence in job applicant, whereas 80% thought written and oral communication are key skills [17]. New qualification requirements for Industry 4.0 include cultural and intercultural competence, life-long learning, interdisciplinary thinking, decision making [2]. More specifically, the World Economic Forum recently placed complex problem solving, critical thinking and creativity as top key skills for Industry 4.0 [19]. Many employers identified the greatest skills gap in the labor market as skills in communication, problem solving and critical thinking [3],[11]. Some of those are labeled "soft skills" or

"essential skills" - observation, empathy, logical thinking, social perceptiveness are the skills of leadership, the most wanted ones in corporations and at workplaces worldwide [13].

Transferable skills, broadly defined as non-technical skills such as Teamwork, Communication, Problem-solving, Innovation and Emotional Judgment [3], have become widely acknowledged as essential in successful leadership and business. These skills are becoming more important than ever – it is anticipated that the share of the workforce with "transferable skills" is going to increase from 53% in 2000 to 63% in 2030 [3]. Similarly, the Canadian job market is expected to employ 2.4 million people in the next 3 years all of which will have to prove they possess the set of skills to thrive in the age of disruption [13]. The projected skills demand for all occupations, based on the Royal Bank of Canada Report tops active listening, critical thinking and reading comprehension, with persuasion and negotiation skills being of medium importance, whereas equipment maintenance, repairing and installation are at the bottom of the list [13].

These skills are easily found in the Humanities graduates who are well rounded and exhibit persuasive written and oral skills, being thinkers with superior critical thinking skills along with a sense of empathy [3]. A 2013 research at the University of Oxford confirmed that "transferable skills," easily found in the humanities graduates, are the key factors in determining outcomes in hiring and advancement [18]. As many as 11,000 Humanities graduates are reported to have contributed an increase share of the national economic growth, and accordingly they emphasized the value of their Humanities-based education as a key to their success [18].

3. GOOD PRACTICES IN EDUCATION AND BUSINESS

There is a broad consensus that STEM students benefit from exposure to the Humanities. Massachusetts Institute of Technology (MIT), claiming to be a "bastion of STEM education," believes that the Humanities, Arts and Social Sciences are essential elements of MIT education due to their mission of educating graduates who are prepared to solve the world's most challenging problems, since MIT argues, "poverty, climate change and disease are always embedded in broader human realities" [14]. Therefore, MIT students are offered a broad range of HASS subjects such as literature, economy and music on which they spend 25% of their total class time. Thus, they enhance their listening and speaking skills, help gain wider cultural and historical perspective, improve their creativity, innovation capacity and willingness to adapt and experiment. With such curricula, MIT graduates gain in-depth understanding of human complexities which enables them to develop cross-cutting capacities in a time of rapid globalization. Since MIT has been ranked as the number 1 university in the world (for 2019) in 11 STEM subject areas for 7 straight years, their educational practice which gives equal weight to humanities (based on the premise that an integrated approach to learning improves results learning outcomes) could serve as a starting point.

Similarly, employers have experienced manifold benefits of the humanities-based educated workforce. For example, Google hired close to 6,000 people in 2011, intentionally selecting many of them with degrees in the Humanities. Google decided to look for intelligent employees capable of interacting with others, arguing that the Humanities graduates are "a desired commodity for industry" [6]. Another example is of the IBM's shift in labor force: they have reoriented their hiring policy by introducing "design researchers who are specialists with science and humanities background," which has brought the most profound change to the company's operations [3]. Finally, a founder of Apple Steve Jobs once said: "It is in Apple's DNA that technology alone is not enough – it's technology marries with liberal arts, married with the humanities, that yields us the results that make our heart sing." [13]

4. SUGGESTED SOLUTIONS AND CONCLUSION

In order to secure drivers for change in the context of Industry 4.0. re-designing the core concepts of Engineering education by applying a more holistic approach in which STEM and the Humanities are integrated into "STEMANITIES" must be assured. This implies that it is essential to focus more on finding connections between the fields than aspects of their delineation, since "the common tendency to position STEM hierarchically above creative competences and industries [...] is not only outdated but misleading" [19]. A more of a liberal education approach, which provides students with broad knowledge of the wider world (science, culture and society), as well as in-depth study in a specific area of interest, can prepare engineers to fulfill their cultural and civic responsibilities [12].

Having analyzed the Higher Education in USA and the Demands of the Twenty-First Century [11] a group of experts provided an exhaustive compendium of all the research universities, community and liberal arts colleges, institutes and centers in USA which offer integrative Arts, Humanities and STEMM Programs within curriculum or as a co-curricular program more than 200 programs with the Emory University. The study revealed that there has been a rise in the number of transdisciplinary centers and collaborations for creativity, innovation and discovery. In the context of the Balkans higher education, there has been a long tradition of HASS (poor but still present) integration into Mechanical Engineering curricula dating back from the 1980s, although not contextualized [1]. They were introduced with the idea of providing support to future engineers.

Since it is evident that, worldwide, tertiary education as a public value establishes a great level of trust with both graduates and businesses, and universities and colleges are recognized as drivers for change related to Industry 4.0, it looks like that engineering education is where institutionalisation of new teaching/learning approaches must begin. In order to keep the core concepts for Engineering literacy and technical skills, but at the same time change a narrow technical mindset that characterizes many Engineering graduates, several solutions can be suggested:

Firstly, more hybrid degree programs which are interdisciplinary in the nature can be designed. For example, Digital Humanities (originally called "humanities computing") were introduced in US in 2008 to help link contemporary technical advancements and humanities by focusing not only on texts but also on video, audio, games, maps, simulations and 3D modeling. In 2015 there were 37 such programs in Anglophone countries [5], with steady addition of several programs each year. In Europe, the Digital Research Infrastructure for the Arts and Humanities (DARIAH EU), established in 2014 as a strong network of people, expertise and tools, deals with digitally-enabled research and teaching across the arts and humanities. DARIAH's database lists 102 DH degree programs, with the highest concentration in Germany, 33% [5]. With 19 EU member countries and 8 and cooperating partners, it is currently one of the most influential and diverse consortium in the field of DH in the world.

Secondly, returning to a more integrated approach to education, with a more holistic perspective, moving to a more liberal education might be a solution. In order to prevent chaotic time waste on new syllabus designs and unexpected financial costs they bring along, it might be wise to update the existing curricula first by introducing a bigger number of Humanities courses focused in minors or elective courses. Leach [17] argues that a kind of "energizing" the academy with more cross-disciplinary majors would be helpful, of which he provides two models; the first one is the Oxford's case of introducing *Philosophy, Politics and Economy* Program (PPE), and the second of the Harvard's *Social Studies* major comprising of similar courses as in the Oxford's case. Departments should be more emerged in multi-disciplinary approaches and research trends, allowing graduates to "pick and choose" the courses they find interesting. Finally, it is what democratized education is all about – being able to act according to your personal preferences and individualize a process of learning. Securing interdisciplinarity in the process is a "must".

Thirdly, turning to experiences of businesses and the labor market can additionally help fine-tuning the role of universities and colleges in preparing engineers for Industry 4.0 labor market.

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