

Employability skills in engineering: towards a broader redefinition of professional identities

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Abstract— This paper undertakes a comprehensive examination of the multifaceted challenges and opportunities intrinsic to the integration of employability skills, particularly those of a non-technical nature, into the knowledge framework of engineering disciplines. Leveraging insights gleaned from Winberg et al.’s (2020) systematic literature review, the intricate process of transferring predominantly non-technical proficiencies into the specialized domain of engineering knowledge is not only acknowledged but also thoroughly discussed and critically assessed. Although numerous academic institutions across the globe have already adopted integrated and cohesive strategies to align technical and employability skills within their engineering degree programs, this paper posits that a more expansive and concerted effort is imperative. The argument presented herein contends that for employability skills to truly ascend to the status of a foundational element in a renewed and enriched professional identity for engineers, a broader societal commitment is requisite. While existing initiatives are commendable, this paper advocates for a scale-up of efforts, positing that such endeavours will accrue substantial benefits for learners, employers, and the broader societal fabric. Employing a Social Learning Theory approach and delving into the socio-technical intricacies of the engineering profession, the discourse underscores the necessity of expanding the current cadre of main stakeholders. In addition to higher education institutions, employers, professional bodies, learners, and practitioners in training, the paper contends that media, schools from early educational stages, and other relevant components of society should assume a more proactive and co-responsible role in reshaping societal perceptions of engineers’ professional identities. This expansion of stakeholder involvement is posited as a vital step towards fostering a comprehensive paradigm shift in how engineers are perceived within society.

Keywords— *Employability Skills, STEM Education, Integration, Engineering Disciplines, Socio-Technical Systems, Socio-Technical Ecosphere, Engineering, Engineering Education, Integration, Professional Development, Social Perception, Engineering Disciplines, Social Learning Theory, Professional Identity, Professional Identities*

I. INTRODUCTION

Recognizing the extensive body of literature on employability within engineering and STEM fields, the challenge of pursuing and developing relevant (mostly non-technical) skills into engineering education and training has not been fully resolved yet. A survey conducted in Pakistan reveals that a mere 10% of information technology (IT) graduates possess the necessary qualifications to be considered acceptable for employment. This situation has the potential to impede future progress within the industry [1].

According to [2], a study revealed that 67% of HR professionals choose not to provide a job offer to a highly proficient IT candidate owing to their deficiency in soft skills. The lack of interpersonal and communication skills not only hinders job prospects but also impacts the dynamics of the current workplace. According to the same study, 43% of full-time employees saw detrimental effects on their working relationships with the IT department due to concerns linked to soft skills. The research highlights the crucial significance of soft skills in the IT business, both for obtaining employment and for fostering efficient collaboration inside firms.

We have no reason to doubt that similar results could be obtained from many other work places, no matters where, employing STEM graduates: there is a gap between what employers expect and what graduates can offer, and that is well beyond technical competence. To minimize this gap, two main strategies have been adopted by numerous international Higher Education Institutions (HEIs), exemplified by Daffodil and Hertfordshire, and they involve 1. the addition of employability-focused dedicated modules built onto their STEM *curricula studiorum*, and 2. the introduction of employability skills embedded and integrated into or within individual technical modules. Whilst this paper explores and discusses the nuanced difference of employability between “building onto” and “integrating into” existing degree programmes and modules, it posits an essential question about the long-term and society-impacting efficacy of these common approaches and raises the need for a more ambitious and cohesive strategy to embed employability skills within the technical content, involving not just academia, employers, recruiters and professional bodies, but the overall society, governments, education and even cinema and media, so to aim at a renewed and broader redefinition of what it means and entails to be an “engineer” (whatever the technical domain of application they operate in).

II. LITERATURE SURVEY

Having adopted the systematic review from [3] as a starting point, our literature survey aimed at better exploring and understanding the imperative to address the relative transferability of non-technical skills into STEM study and specifically the engineering curriculum.

Several studies aimed at identifying which non-technical skills were functional to make graduates in STEM (and in particular engineers) employable (e.g., [4]; [5]; [6]; [7]; [8]). All of them seem in agreement that one of the non-technical skills, usually regarded as crucial for engineers, is related to their ability to manage (or to support the management of)

people, organisations and processes within technical working environments, often mixed with or plainly referred to as “entrepreneurship” and/or “leadership”.

Such expected managerial competences have been long investigated and have led to incredible changes in the panorama of education and training offers. In the past, this was mostly translated as how engineers were trained to be managers. Reference [9] provided a model (based on the so-called Social Exchange Theory) according to which all parties involved in the equation (the engineer-student, the employer-organisation and the university-college) should engage in such a “transition” (in the dual meaning of transitioning from engineer to manager and in the “exchange” occurring among relevant people, when engineers are deemed to become managers) by making all expectations and perspectives clearer together with the all expected costs and benefits. Since 1992, and even before, the need for engineers to be able of “management” (at the beginning mostly related to a matter of career progression: nowadays, fully integrated within the employability agenda) led to the development of new and highly competitive training and educational offers, from MBAs often specifically tailored for experienced engineers to plain degrees (both at undergraduate and postgraduate levels) in Management Engineering (with all the possible variations considered).

In both cases, the “built-onto” approach to employability (i.e., “onto” previous or concurrent technical studies, technical experience, technical training and apprenticeships) has been the first and main one to be adopted [10]. Along time, this approach has been incrementally complemented by an effort to have employability skills “integrated-into” the development of STEM-specific technical competencies.

III. EMPLOYABILITY SKILLS IN ENGINEERING (AND STEM IN GENERAL): STATE OF THE ART

Management-related skills (for example, leadership, planning, motivation, project management, team-work) are not the only set of skills that are usually associated to non-technical curricula. We could also mention communication, emotional intelligence, commercial awareness, critical thinking, professional ethics: all these are part of a spectrum of skills that usually struggles to be naturally associated and/or addressed whilst studying technical subjects, such as fluído-dynamics, programming, materials, etc.: if nothing else, this is because the above skills come with a different (and somehow weaker) epistemic relation between their own expected outcomes (and social impact) and the core learning outcomes of the technical subjects they should be embedded into [11].

Whatever the rational, several authors have been brutally honest and clear: the above skills have been traditionally neglected in Engineering programmes [12], [13].

There might be several explanations for such a neglect: the first one that comes to mind is that, traditionally, it was assumed there would always be job opportunities in STEM and for engineers, and therefore employability had never been perceived as a matter of urgency [14].

Even when the international labour market started changing significantly with the increasing globalisation provided by the advent of the internet and the associated new technologies [15], [16] READER employability was still somehow ensured by both global and national demand from

employers to be always greater than (or at least proportionate to) the offer and the availability of STEM graduates.

However, along time such assumption proved to be not always true and the demand unconditional: on one side, global trends and competition meant the labour market was (and still seems) going towards a high-skilled low-waged workforce [17]; on, the other side, a global labour market meant more and more students decided to engage with the training for a career in engineering (and in STEM, more in general). This provided a heads-up to the educational sector: employability for engineers and STEM graduates was no longer a given.

From mere larger availability of graduates in STEM disciplines and therefore more opportunities for employers to raise recruitment standards, to more graduates coming maybe with over-specialised competencies, but with less general technical proficiency and adaptability across the board [18], possibly also due to weak transferable skills agendas [19], to more “socially disadvantaged students” undertaking their education in STEM, whose background might have affected their academic performance and overall preparation towards employability [20], to a radical change of expectations and perspectives from employers [5]: all these proved to be factors affecting employability.

An interesting discussion on whether the UK had too many graduates and how this might affect their employability had been anticipated by [21] in their identification of four “key strands” in the British debate (the Elitist perspective, the Democratic perspective, the Vocational education advocates’ perspective and the Business investment perspective). The Authors conclude their white paper: “Widening participation and encouraging people to study at university can only be applauded, provided that it is based on genuine capability and not artificial targets”.

As argued so far, whilst technical knowledge, skills and overall competence have been (and will always be) an obvious crucial learning outcome in any engineering or STEM curriculum, these are no longer enough to ensure full employability of graduates in STEM and engineering. Because of an increased availability of workforce, resources and expertise made possible from the globalisation of the world economy, because of the internet and constantly evolving technologies (including AI) and work practices, some additional skills have now become critical to employers, such as the ability to search and find, critically assess and use smartly any relevant information on the internet [22], the ability to quickly learn new skills on demand [23], or even to master and exploit internationalisation in education (e.g., “study abroad” programmes, ERASMUS, etc.) for employability purposes [24], [25].

It is worth underlining that all of the above has now been somehow intercepted and actioned, to various degrees, by the vast majority of HEIs world-wide.

The existing approaches, illustrated by Daffodil University's "Employability 360" module and Hertfordshire's modules like "Preparation for Placement", “Professional and Academic Skills for Computer Science and Engineering” or “Professional Practice,” are all based on the assumption that modular additions “built onto” any STEM curriculum adequately address and support employability. Also, initiatives such as “assessment centres”, usually supported by

local employers, are becoming more and more popular worldwide. The generally accepted effectiveness of these “built-onto” approaches are to be acknowledged and celebrated, highlighting the support provided by career advisors, professionals, and practical resources, on top of any involved academic staff, especially those who have a double background, both in academia and industry. Also, complementary approaches that aim for a more robust integration of employability skills into STEM and engineering curricula have been identified and pursued consistently across the board by both Daffodil and Hertfordshire (as many other HEIs worldwide), ranging from the systematic adoption of work-based learning, authentic assessment, real-world case studies provided by employers, extensive use of team-work, projects, CDIO syllabus, study abroad and placements and, wherever available, “degree apprenticeships”. These “integrated-into” approaches have been incrementally pursued and developed in the past decade, and it is safe to say they have overall significantly contributed to further reduce the gap between education and employment [26], [27], [13].

In the following Figure 1, a simplified representation of the state of the art (and the overall life-cycle) in embedding employability skills in engineering is provided.

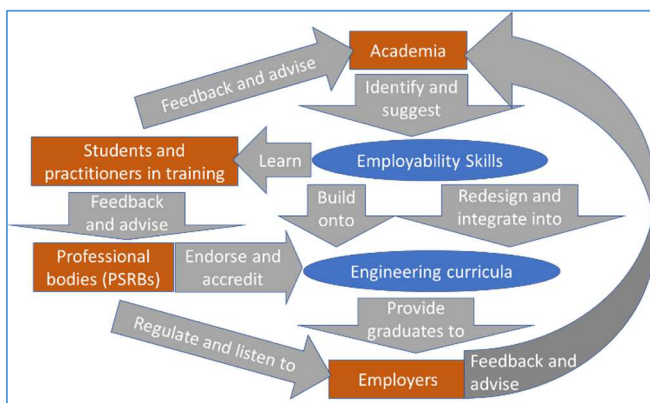


Fig.1. Simplified life-cycle for embedding employability skills into engineering curricula

Given the above, to what extent have employability skills proved to be an effective way to reduce the gap between what academia offers and what employers demand? And what can be done next to further improve such efficacy?

IV. PROPOSAL FOR A MORE INTEGRATED APPROACH: EMPLOYABILITY AS EMERGING FROM A COLLABORATIVE “SOCIAL LEARNING THEORY” LIFE-CYCLE

One evident aspect in the dual attempt to pursue employability for engineers and STEM by both the “built-onto” and “integrated-into” approaches is that most of the action has been taken so far by HEIs and a limited number of other stakeholders, namely employers, PSRBs (Professional, Statutory and Regulatory Bodies), and the expected recipients of the educational provision, students and practitioners in training: and out of these, we would argue that HEIs, notwithstanding any limited capability or political power, have been the main actors in promoting the employability agenda (within their own developed programmes, obviously, as well as by means of their marketing strategies, outreaching activities, research, some

lobbying towards national governments). Either way, it seems impressive how these few stakeholders have been able, worldwide, to explore and negotiate solutions about any relevant identified gap or problem, to pursue and implement these solutions and adjust accordingly their academic and training provisions and, eventually, to share results and good practices via research, educational marketing and any other institutional, commercial or even political activity, commitment or public engagement they have been able to elicit and drive.

The above stakeholders, also throughout their outreach activities, have invested serious efforts and resources, together with schools, associations and people of good-will, to ensure some broader and early exposure to professional experiences and extra-academic opportunities was granted to the youngest generations, for them to develop passion and curiosity about engineering and STEM-related jobs, and how employability skills would be an invaluable component of what it means to be an engineer.

Reference [28] has argued that “the professional path of an engineer is often closely related to the early professional experiences of his/her career”: from an academic perspective they advocate that some career perspectives are offered from the early stages of their curriculum, and that they are enabled to “participate actively in their own learning path, to build their future professional identity and to plan proactively their future career”.

A little longer than a decade after their paper and their reference to the French educational model (also adopted in Quebec), all of the above has been somehow absorbed worldwide by all HEIs and a vast majority of engineering students do consider employability skills core to their own professional profile,

For example, in a comparative study (pre-COVID vs post-COVID) on how students of system engineering in a public university in Peru felt confident about 10 criteria related to employability (for example their ability “to master practical professional skills”, “to have a positive attitude towards change and innovation” or “to act with autonomy and initiative”), results have been extremely encouraging, notwithstanding or even thanks to the changes due to reviewed organisational settings (for example, use of personal computers was encouraged, instead of sharing it in a lab) expected after the pandemic [29].

However, what is left ahead to do is still massive: employability should define the core of any professional profile in a much deeper cultural, sociological and even political sense than what has been achieved so far in the collective imagery. In a PhD dissertation, by critically reviewing and expanding the Lockwood model on how collective or social imagery of engineering is generated and consolidated, [30] asserted that “skilled engineers showed a strong concern with the production process itself; it is claimed that this orientation is a consequence of the craftsman's expertise in combination with his position in the division of labour”. In the same work, the foundation for a further argument has been provided, which we would kindly exploit: in the past, engineers seem to develop a social or collective imagery of their own work and professional role in society (and in business organisations) that is not necessarily similar or even just fully complementary to what is perceived or expected by the remaining components of society. This

also resonates with the old Shakespearian verses from the Julius Caesar: “for the eye sees not itself, but by reflection, by some other things”.

So, how could professional identity of engineers be redefined so to ensure that employability skills are perceived not as “additional” but “core” to the profession? How to ensure that engineers can re-conceive themselves not just from the mere technical perspective of whatever problem, product or process they are concerned with in whatever application domain, but also from the broader implications and impact their professional activities would have on people, organisations and society as a whole?

From Albert Bandura’s research onwards and the development of the so-called Social Learning Theory [31], later integrated within a broader Social Cognitive Theory [32], we are now fully aware that people learn mostly by simply observing and imitating others, in whatever “models” they recognise and identify themselves.

Cinema, the arts and the media (including the gaming industry) always played a great role in highlighting and celebrating engineers’ and professional achievements [33]. However, once sci-fi and romance are removed from the equation, surprisingly the great film productions quite seldom focused on how engineering had an impact on society. In most cases, especially by the end of the past century, it could be argued that writers and film directors have focused either on engineers’ and scientists’ technical ability and creativity (which, admittedly, is in itself an employability skill: for a review, see [34]) in their more superficial, marketing-appealing surface, or, more recently, on very concerning social issues, such as social disadvantage and gender disparity (e.g., see [35], [36], [37], [38]) or even political when not ethnic discrimination occurring against people working as engineers [39], [40], 41].

Very few movies and/or biopics have attempted to approach and assess in a critical and yet encouraging manner how engineers not only could exploit their scientific and technical competence to develop (or “engineer”) certain solutions, but also how engineers could and should read the socio-technical conditions for which their engineering products were (or are) to positively impact markets and society as a whole. It is true that, in the very last few years, successful productions about public figures like Steve Jobs or Enzo Ferrari (who had an incredible impact on society worldwide) have offered broader (and somehow even ethically challenging) perspectives to address what being (or becoming) an engineer entails, in particular by cultivating an entrepreneurial approach to whatever they developed as “engineers”, even if neither of the above mentioned “models” were in reality professional or qualified (respectively computer or automotive) engineers.

It is known that social and cultural stereotypes still affect (sometimes in non-deterministic ways, see for example [42], [43], [44], [45]) how engineers are perceived from large portions of the populations (for example, women or ethnic minorities) and whether they decide to commit to an engineering training and/or academic programme. Also, there is a matter related to the inherent question of what technology and engineering are and how they have been developed, exist and evolve the way they do.

In the following Figure 2, a new, still simplified life-cycle, derived from the above arguments, for embedding and pursuing employability skills, is therefore proposed.

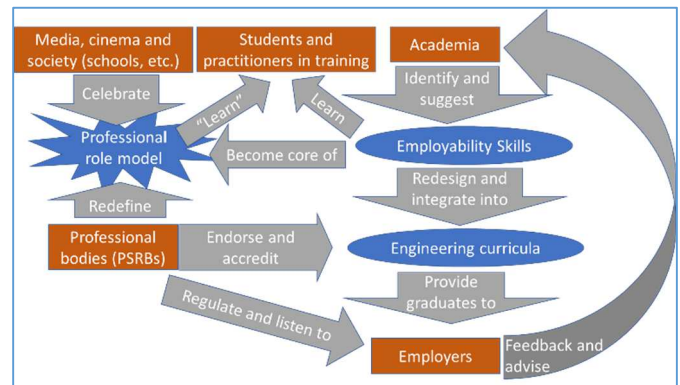


Fig.2. Simplified new life-cycle as proposed after taking into account lessons derived from the Social Learning Theory

Also, authors of this paper would argue that a crucial reference to socio-technical systems is needed, to ensure any future debate approaches the dialectical relationship between technical and non-technical factors by the lenses of epistemologically robust perspectives. One of them is offered by the theory behind the so-called socio-technical systems, as first originated from the seminal paper by Trist and Bamforth [46]. The idea that every technology should be considered as a socio-technical system revolves around four crucial principles, representing the best manifesto engineers might want to adopt to define their own professional identity: responsible autonomy (of the pair-based work group), adaptability (of the small group to the [underground] situation), whole task (in the relation between the small team and the “undifferentiated collectivity” and by considering the increased “mechanised complexity”), and meaningfulness of tasks (and the importance of “recognition of the nature of the difficulties”).

From a socio-technical systems viewpoint, creativity is not merely a result, but a process that encompasses the dynamic interplay of individuals, organizational structure, tasks, and technology [47]. The above implies (or should imply) that any technology, as well as any reflection about it, should be developed and operationalised not in a vacuum, but in a complex social environment, which it is engineer’s responsibility to understand, analyse and eventually consider as a whole when a certain solution is designed, developed, deployed and eventually assessed.

V. CONCLUSION

So far, the employability agenda has been pushed forward mostly by a limited but well-determined set of actors (HEIs, employers, professional bodies and learners and/or practitioners in training), so to have it built-onto and integrated-into the engineering curriculum.

A renewed effort is now expected to reform stereotypes and to include also non-technical skills as core to the engineer professional identity and to bring social perception closer to facts and data [48], [49]: those who embrace and better develop an interest (or better a passion) for engineering, by being exposed to the possibility to “practise” engineering at an early stage, and by processing social models of the

associated professional role that better encompass both technical and employability skills, are usually those who better succeed in their academic endeavours, in their quest for a better job in the labour market and, in last instance, in providing a positive impact to society.

This is therefore where we would advocate not only professional bodies and employers (and business organisations and associations), but also governments, all educational institutions, from schools to universities, and -crucially- the media and the entertainment industry, to put all their weight on and invest more effort: in ensuring that society -as a whole- develops a more comprehensive understanding of what engineers (and STEM graduates) do, by generating and supporting narratives and social models that encourage from an early stage all people to “open the black box of technology” [50] and fully appreciate how this can and will be the outcome of a broad spectrum of skills (technical and non-technical) that exist in a socio-technical ecosphere.

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