Bringing Visibility to Transversal Skills in Engineering Education: Towards an Organizing Framework

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Presented at the European Society for Engineering Education (SEFI) Annual Conference, 19-22 Spetember 2022, Barcelona

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ABSTRACT

Professional engineering work occurs in dynamic, complex contexts that require engineers to leverage various skills beyond their technical competencies to work productively with different stakeholders. Problem-solving is not merely a technical endeavor; educators and practitioners have long realized the synergistic connection between technical proficiency and complex personal and interpersonal competencies, such as critical thinking and communication skills.

Since the 1990s, the topic of transversal or professional skills has been a common thread in engineering education literature. Engineering accreditation bodies such as Accreditation Board for Engineering Technology (ABET) and Commission des titres d'ingénieur (CTI), and engineering curriculum models such as the conceive-design-implement-operate (CDIO) have highlighted the importance of various transversal skills in professional engineering work. Today, there is a general agreement among engineering educators and scholars about the value and benefits of transversal skills. What is less clear is which specific skills should be considered transversal and how those skills can be categorized and defined. Efforts in settling these issues ultimately help engineering programs to have a clearer picture of which skills are (and are not) well integrated and assessed in their curricula.

This concept paper discusses a framework for categorizing transversal skills. We build on the relevant literature and the ongoing educational practices in prioritizing transversal skills at the École polytechnique fédérale de Lausanne (EPFL) to bring visibility to essential graduate skills and attributes, including those that are often underemphasized.

Keywords*: Transversal skills, engineering education, organizing framework, curriculum development*

1. INTRODUCTION

Desired outcomes in engineering curricula for students' learning are often categorized into two groups: technical and transversal or professional competencies (we use the terms interchangeably in this paper). Broadly speaking, the technical competencies are among widely accepted desired attributes for engineering students. Accreditation bodies such as the Accreditation Board for Engineering Technology (ABET) and Commission des titres d'ingénieur (CTI), and popular models in engineering education, for instance the conceive-design-implement-operate (CDIO) approach, point out to outcomes that demonstrate more or less similar attributes regarding technical competencies, among them, emphasis on

scientific and technical knowledge and ability to apply knowledge to solve engineering problems, or ability to plan and carry out experiments (ABET, 2021; Crawley et al. 2014; CTI, 2017). Despite engineering educators' familiarity with these competencies, defining specific outcomes, teaching strategies, and ways to assess the outcomes and their respective competencies are the focus of ongoing work in the scholarship of teaching and learning.

Our focus in this paper is on the second group of competencies, transversal skills, which has been a matter of debate. Since the 1990s, the topic of transversal skills has become a common thread in engineering education literature. The emphasis on these competencies in particular was motivated by reports calling for broader education and the observation of inadequate preparation of engineering graduates for work settings (Crawley et al. 2014; Shuman et al. 2005). In the U.S., for example, documentation of misalignment between the level of preparation of undergraduate students in attributes necessary for professional settings, such as communication and teamwork, led to the major changes in ABET requirements on students' outcomes, ABET Engineering Criteria 2000 (Prados et al. 2005; Shuman et al. 2005). Today, engineering programs are more intentional to incorporate various professional skills and competencies, often motivated by changes in student learning outcomes identified by accreditation bodies. Nevertheless, while there has been increasing attention to the importance of professional competencies within engineering education community, the lack of consensus about the breadth and depth of competencies addressed in educational settings as well as ambiguities in guidelines specified by accreditation bodies, for instance on ethics (Junaid et al. 2021), created a complex picture for building a common ground centered around transversal knowledge, skills, and attitudes.

Considering the diversity of the competencies and the complexities in defining them, we believe developing a framework for categorizing is critical for educators to have a clearer picture of which skills are (and are not) well-integrated and assessed in their curricula. This study was motivated by the recent strategic efforts and ongoing educational practices around transversal skills at the École polytechnique fédérale de Lausanne (EPFL) and aims to develop a framework that can bring visibility to essential graduate skills and attributes. This will also help to refine emerging approaches to teaching transversal skills, including the use of tangibles.

2. EFFORTS IN PRIORITIZING TRANSVERSAL SKILLS AT EPFL

With the recognition of the primacy of transversal skills for students, diverse educational initiatives have prioritized different skills in the curricula at EPFL. Notably, teachers are asked to select specific transversal skill learning objectives, for each course, from a list of 32 skills— adopted since 2013. These skills are categorized into five broad themes: (1) communicate, process, manage, and generate information; (2) personal effectiveness; (3) project management; (4) working in the society; and (5) working in groups and organizations; for more details

see Kovacs et al. (2020). Some skills point out general statements that focus on behavior or performance, for instance, “write a scientific or technical report” or “collect data”; others emphasize specific processes, for instance, “communicate effectively with professionals from other disciplines”.

As thinking and experience within the EPFL community around transversal skills for engineering students evolved, a working group was set up in 2021 to review our current needs, objectives and resources in order to coordinate the teaching of transversal skills at different educational levels. The working group includes professors and members from several units, among them the Teaching Support Center (CAPE), the Language Center, and the representatives of the Student Association, and is led by Associate Vice President for Student Affairs (Hess, 2021). The working group envisions creating possibilities for EPFL students to develop the necessary skills for highly competent architects, scientists, and engineers.

In the first phase of their work, the group identified a list of competencies and the subjects that address those competencies, as well as a list of high-priority skills that should be taught at different educational levels (BA, MA, and PhD). Table 1 presents the list of transversal skills identified for bachelor students concerning five major themes: communication, interpersonal, intrapersonal, organizational, and enterprise. The group arrived at a consensus on some particular high-priority skills for bachelor level; for instance, giving oral presentation (communication skills), collaborating (interpersonal skills), and learning from feedback (intrapersonal skills).

In addition to the efforts described, there has been a growing interest and commitment to doing research and professional development with respect to transversal skills at EPFL. One such recent initiative is the 3T Play[1] (transversal skills, technical universities, tangible objects) that aims to design interventions for teaching transversal skills using tangibles. The project is a collaborative effort between several units at EPFL, including the College of Management of Technology (CdM), the Center for Learning Sciences (LEARN), CAPE, and the Discovery Learning Program (DLP). The current study is an initial attempt to converge the ongoing efforts and create a common framework for designing the 3T Play Project.

[1] https://learn.epfl.ch/wwd_learn/3tplay-tangible-objects-for-developing-transversal-skills-in-technical-universities/

Table 1. List of transversal skills at bachelor level identified by the working group at EPFL

Broader categories	**Skills**
Communication	- Giving oral presentations - Writing reports - Listening actively - Mastering at least two foreign languages
Interpersonal	- Collaborating - Taking the perspective of others - Managing conflict
Intrapersonal	- Learning from feedback - Regulating emotion - Evaluating oneself - Planning learning goals - Managing priorities
Organizational	- Setting objectives - Managing time - Choosing appropriate methodology
Enterprise	- Working with other professionals - Determining relevant societal issues - Applying relevant ethical, legal, and safety goals

3. TOWARDS AN ORGANIZING FRAMEWORK

There are some similarities among different lists of transversal skills proposed by accreditation bodies and/or adopted by various institutions. For example, they often highlight various communication and collaboration skills, which are widely recognized and frequently addressed in engineering education (Cruz et al. 2020). Such recognition implies that there is more emphasis on integrating these competencies. Importantly, there is less conceptual ambiguity in defining such skills and establishing evidence for their improvement. The differences, though, resonate with the diversity of attributes that have been addressed in the engineering education literature (Crawley et al. 2014; Passow and Passow, 2017; Rosén et al. 2019). They further speak to a degree of specificity in defining particular skills and competencies.

We picture a categorization on the basis of specific competencies rather than domains of competencies. That is defining domains of competencies, such as interpersonal skills, may in fact add another layer of complexity in developing a framework. Further, there are interrelationships among various competencies and as such, creating explicit boundaries around different groups of skills is not consistent with the reality of day-to-day practice, which is particularly problematic when considering interactions between personal and interpersonal knowledge, skills, and attitudes. For example, CDIO syllabus v.2 (Crawley et al. 2014) distinguishes between personal and professional attributes and interpersonal skills. The former includes categories such as “systems thinking” and “ethics, equity, and other responsibilities” and the latter includes “teamwork” and “communications”. While it would be perfectly reasonable to prioritize specific skills, within each category, in an educational setting, downplaying the importance of interactions between the two

reproduces the predominant practices in engineering education that lacks consideration of broader social factors.

In addition, a useful framework of transversal skills should foreshadow criteria and indicators one could consider in addressing each group of competencies. There might be a diversity of interpretations about the specificity of particular skills; some point towards general descriptions and criteria for addressing the competencies, while others get to a more detailed description of each group of competencies. Moving towards a detailed description of skills and prescribing the attributes may, in fact, simplify the very nature of transversal skills and limit faculty members in operationalizing the skills in their classrooms. The goal is not to copy specific outcomes, as it is the case with learning outcomes identified by accreditation bodies. Here, it is important to distinguish between competencies and the primary emphasis of educational activities. One teacher may prioritize and assess critical thinking for a given intervention, while another may focus on collaboration and teamwork.

Now, the question is what skills and competencies should be considered in building a framework. Our goal is not to provide an exhaustive list of skills but to prioritize an initial list of broader themes and emphasize the interactions among them, which can help us identify specific criteria and indicators. There is a consensus about the importance of collaboration and communication skills for professional engineers. The abilities to effectively work and interact with stakeholders and individuals with different backgrounds are often integrated into engineering curricula. In addition, in agreement with theoretical and empirical works around transversal skills, we posit any set of proposed skills should prioritize fostering students' moral values. We use ethical reasoning as an umbrella term to describe skills for moral deliberation process, among them, considering and evaluating different perspectives, and insight into intended and unintended consequences of courses of action.

The last two broad categories we propose are thinking and management skills. By thinking skills, we mean reflective ways, cognitive, emotional, and social, by which we approach and engage in problem-solving and the process of inquiry. It emphasizes the skills needed to deal with ambiguity and uncertainty, which is the very nature of real-world problems. While different frameworks specifically address indicators of thinking skills, for instance, critical thinking, these competencies have remained underemphasized in engineering education. Not only is there less clarity about these skills, conceptually, but they are often treated fundamentally as problem-solving in ways that reinstate the status quo of technical rationality. Lastly, by management skills, we refer to the ability to organize taskwork or a change process individually and as part of a group.

As we move to spell out broader categories of transversal skills, it gets more clear that specific skills may interact. Considering such dynamics, we propose a different framework to organize various transversal competencies. We envision a more holistic representation of transversal skills considering overlapping relationships between five general themes: thinking skills, ethical reasoning, collaboration (teamwork), communication, and management skills. Readers may imagine a Venn

diagram presenting relations between different themes. Such illustration emphasizes five broad themes of transversal skills that have been highlighted as critical graduate attributes for engineering students.

We intentionally avoid treating interpersonal and intrapersonal skills as broader categories to organize professional skills and therefore drawing boundaries between various skills on such a basis. We posit that competencies that are often defined at the individual level, such as critical thinking and ethical reasoning, interact with interpersonal communication and the dynamics of relationships between individuals. While this claim might seem obvious to the readers, its practical implication demands moving beyond the picture of thinkers as merely isolated individuals. Further, the interactions among the various skills, for example the overlap between ethical reasoning and thinking skills, demonstrate how interventions focusing on one may influence another. Treating imagination as the primary constituent of thinking skills and ethical reasoning, for instance, and providing opportunities for students to practice at imagining (Jalali and Matheis, 2017; Jalali et al. 2022) may work to simultaneously develop both. Put differently, the overlap between the themes can also be considered a guide for designing classroom interventions. The description of all reciprocal interactions is beyond the scope of this concept paper.

4. DISCUSSION AND CONCLUSION

This work-in-progress paper presented an initial work towards developing an organizing framework for transversal skills. While technical and transversal skills are important for professional engineering practice, transversal skills are often not adequately taught and learned (Graham, 2018; Kovacs et al. 2020; Sarrade et al. 2021). Kovacs et al.'s review identified that while some transversal skills are addressed relatively frequently, others are rarely addressed (Kovacs et al. 2020).

Our future work considers exploring the categories of transversal skills developed in other technical universities and next to the two lists developed at EPFL. In addition, we intend to examine the state-of-the-art in the categorization of transversal skills to clarify the discourse on differences among skills and categorizations. The outcomes help us reflect further and refine the initial framework of transversal skills proposed in this paper and define specific indicators. Further, there is an empirical component in working with teachers once we put forward the framework. It is essential to explore how it can be used in different settings and how its specificities, such as relationships between skills, are translated into practice.

The model proposed in this paper is an attempt to simplify the complexities around transversal skills and facilitate communication with a range of stakeholders, primarily engineering instructors. Our goal is ultimately to develop critical indicators for each theme, informed by the literature, and clarify the key synergies or overlaps between different groups of skills, which will improve understanding of what each attribute/competency is and what it entails. It also provides a springboard for successfully implementing these competencies in practice.

Recognizing the need to converge different approaches at EPFL into a coherent list for transversal skills, we aim to reduce the ambiguities around transversal skills and bring more visibility to these essential skills for faculty and students. We hope that the current study serves as an invitation to discuss how we can better communicate, further develop and implement a somewhat different model of transversal skills in our institution and potentially beyond.

ACKNOWLEDGMENTS

We would like to thank the anonymous reviewers for their review and helpful comments. Special thanks to Natascia Petringa for provindg feedback on the paper.

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