DISTINCTLY HUMAN - STUDENTS' PERCEPTION OF TRANSVERSAL SKILLS IN ENGINEERING CURRICULUM

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ABSTRACT

Through their participation in accreditation procedures, engineering educators are well versed in documenting transversal skills addressed by individual courses and across programs. But to what extent do students perceive support for the transversal skills that interest them? The student perspective is important to assess the curriculum as experienced by students but also because students' perception of what is taught is related to what they actually learn. Recent reports from our institution found that course documents fell short of institutional goals for transversal skill development and what graduates wanted skill development. While changes are still being implemented, this survey investigates students' current experiences. We asked 244 Bachelor and Masters engineering students about the transversal skills they encountered in the fall 2023 semester. Guided by the CDIO syllabus, we coded students' open-ended responses about the transversal skills they were most interested in developing and those for which they received the least support to develop. All three categories of transversal skills were found in students' responses, while disciplinary or technical skills were completely absent. This shows that transversal skills are understood by students. Skills from the category Interpersonal skills: Teamwork and Communication were cited most often both for interest (46% of responses) and for lack of support (45% of responses). The CDIO syllabus categories of Personal and professional skills and the Innovation process were also well represented. Using chi-squared tests with a resampling approach, our findings indicate that students do not perceive adequate support to develop the skills they prioritise. Our study suggests that the increased attention to developing engineering students' transversal skills is not yet sufficient. Frameworks and resources that support teachers to incorporate skill development in their courses are an important element in ensuring students receive the explicit and scaffolded instruction they need to develop these important skills.

KEYWORDS

Transversal skills, Perceived curriculum, Engineering education, Standards: 3, 12

INTRODUCTION

Current and future engineering students are tasked with challenges that will require them to master skills beyond the technical skills that traditionally represent an engineer's toolkit. They are expected to accomplish lofty and difficult targets such as the goals for sustainable development proposed by the United Nations (UN, 2015), or the Grand Challenges for Engineering proposed by the National Academy of Engineering (NAE, 2017). In this changing landscape of the engineering profession, engineers are expected to deal with complex societal and environmental issues while working in multidisciplinary teams and often in global contexts. Addressing global challenges like climate change, sustainability, and ethical issues will require a broad skill set that includes transversal skills such as ethical reasoning, global awareness, and the ability to work across cultural and disciplinary boundaries. Students are aware of the importance of developing transversal skills for their future careers (Direito et al., 2014; Donald et al., 2019) and also concerned about their current skill level (Direito et al., 2012; Lermigeaux-Sarrade et al., 2021). This paper uses the CDIO curriculum to categorise the transversal skills that most interest students and those students think they need most assistance to achieve their desired proficiency.

It is difficult to overstate the importance of transversal skills. In addition to being an important aspect of the engineer's toolkit, the development of transversal skills has been shown to predict students' success in later life (Heckman & Kautz, 2012). Additionally, employers increasingly emphasise the need for graduates who are more than just technically competent but also adept at communication, collaboration, and creative problem-solving (Craps et al., 2022; Patacsil & Tablatin, 2017; Robles, 2012; Succi & Canovi, 2020). However, multiple studies have highlighted the lack of work-readiness in current graduates (Busteed, 2014; Hirudayaraj et al., 2021; Patacsil & Tablatin, 2017). Studies that explored alumni perceptions of their engineering education found that while most were highly satisfied with technical and research skills, they were much less satisfied with the transversal skills they had gained and reported needing to fill in professional gaps especially in transversal skills such as 'project management', 'communication', and 'organisation' (Brunhaver et al., 2018; Kovacs, Capdevila, et al., 2023).

Transversal Skills in Contemporary Engineering Curricula

It is widely accepted that a comprehensive engineering education, that ensures that engineering graduates are "ready to engineer" (Crawley et al., 2007), should develop transversal skills along with developing knowledge and skills relating to core disciplinary concepts in engineering (Kolmos & Holgaard, 2019; Passow & Passow, 2017; Winberg et al., 2020). Recognising this, the development of professional or transversal skills is required by multiple engineering accreditation bodies both in Europe (Commission des titres d'ingénieur, 2023; European Network for Accreditation of Engineering Education, 2023), and at the international level (Accreditation Board for Engineering and Technology, 2023).

Focus on interpersonal and intrapersonal skills also forms an important part of the CDIO syllabus (Crawley et al., 2007). These skills, along with disciplinary knowledge and skills, are considered to be the building blocks necessary to thoroughly train engineering students. The 2.0 version of the CDIO syllabus highlighted the importance of ethics and equity as important components of intrapersonal skills (Crawley et al., 2011). This version also extended the CDIO ("Conceiving, Designing, Implementing, and Operating Systems in the Enterprise, Societal and Environmental Context") aspect to include leadership and entrepreneurship.

Despite the widely acknowledged importance of transversal skills, curricular uptake and change has been slow. A recent study at our institution (a mid-sized western European university) analysed course documents to ascertain the degree to which transversal skills were integrated into the curriculum, and found that the teaching of transversal skills fell short of institutional goals and accreditation ideals (Kovacs et al., 2020). In response, the institution launched several initiatives to address the issue and assist both teachers in transversal skill integration and students in transversal skill development.

The 3T PLAY Trident Framework for Teaching Transversal Skills

One of the major initiatives is the 3T PLAY project which focuses on providing resources to assist teachers in technical universities develop students' transversal skills using tangible objects. A major output from this project is the 3T PLAY trident (Fig. 1). This framework assists instructors to identify the three important aspects for the design of activities developing transversal skills - i.e. **Knowing** (what is the skill, why it is important, and what strategies can be employed), **Experiencing** (engaging activities that intentionally leverage the skill), and **Learning from Experience** (explicit reflection prompts to help students transfer what they learned to their next project). The improved understanding of the skills students perceive needing more support to develop provided by this paper is relevant for instructors and institutions to decide which skills should be the focus of such activities.

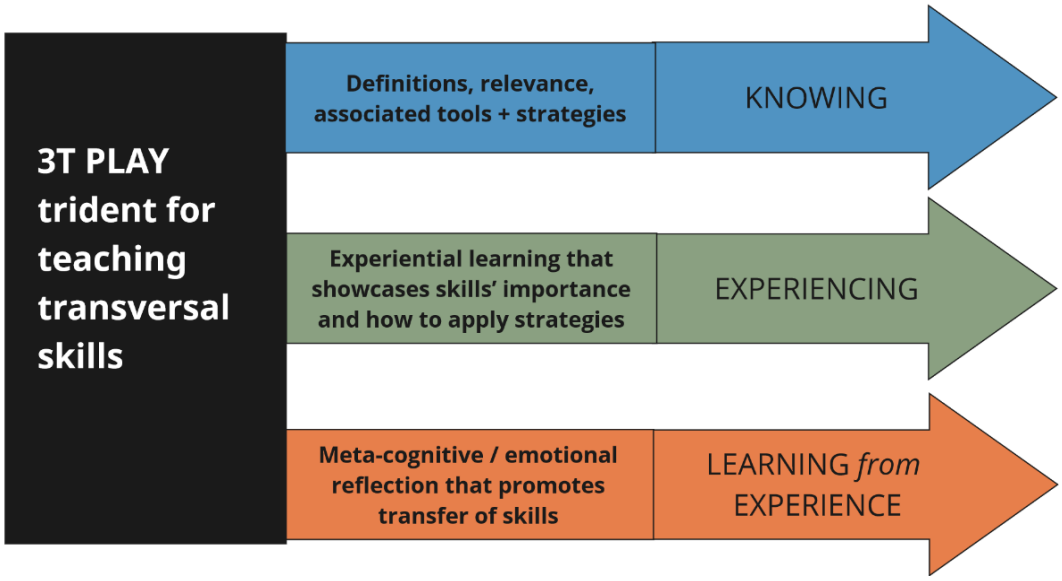

Figure 1. The 3T PLAY trident framework.

Research Questions

The context of our institutional efforts to develop transversal skills reflects the experience of many engineering schools. As mentioned above, our institution implemented several strategies including requiring instructors to state the transversal skills addressed by their courses. Additionally, our recent accreditation process required documentation of transversal skills addressed by individual courses and across programs. Although transversal skills are now an explicit part of the "planned curriculum" (Kovacs, Milosevic, et al., 2023), this study focuses on the "experienced curriculum".

Specifically, we ask:

- Which groups of transversal skills from the CDIO framework do students prioritise most highly?
- Which transversal skills do they perceive needing additional institutional help in developing?

METHODOLOGY

Settings and Participants

The data was collected in a mid-sized European engineering institution. To improve academic outcomes in the first-year large enrolment courses, the institution has implemented several initiatives, including a training program for student teaching assistants who will be employed in these courses. These student teaching assistants, henceforth referred to as students, are typically senior Bachelor's and Master's students who are required to attend pedagogical training workshops. The survey was administered during one such training. The benefit of this opportunistic data sampling is that it provided a diverse sampling of students from across the institution.

Data Collection & Analysis

While the survey had additional Likert-style questions, this study focuses on two open ended questions that asked students:

- What are the 2 transversal skills that you are personally most interested in developing? (coded as Personally interested)
- What are the 2 transversal skills that you think EPFL students get the least support to develop? (coded as Least support)

This qualitative approach avoided limitations to assessing students' perceptions by imposing a list of skills and enabled a robust examination of students' conceptions of what 'transversal skills' should be developed in their programs. 217 students responded to the prompt about skills they were personally most interested in developing (n of responses = 447), and 200 students responded to the question about skills they got the least support in developing (n of responses = 440). Students' responses were terse, consisting of 2-3 words or a brief phrase and were coded using qualitative content analysis (Schreier, 2014) using *a priori* codes taken directly from the subsections of v2.0 of the CDIO syllabus (Crawley et al., 2011).

We used a chi-squared test of independence to evaluate whether responses that students listed as having 'least support' were also those in which they were most interested in developing. We quantified the strength of the relationship between the two categorical variables using Cramer's V. Because each student's response included multiple skills (multiple codes), the data contained hierarchical structure that the standard chi-squared test cannot account for. We therefore used a resampling approach to generate 1000 datasets that each contained one skill (code) from every student's response to the question about 'least support' and one skill (code) from their response to the question about which skill they were most interested in personally developing. We performed the chi-squared test on each of these 1000 resampled datasets, using 10000 Monte Carlo simulations for each test to calculate a p-value. We also calculated Cramer's V for all 1000 resampled datasets.

RESULTS

Students' Responses Clearly Map onto The CDIO Syllabus

We found that the skills students mentioned mapped very clearly onto the sections and subsections of v2.0 of the CDIO syllabus (Fig. 2). These skills related to subsections of Section Two (Personal and Professional Skills and Attributes - shown in blue), Section Three (Interpersonal Skills: Teamwork and Communication - shown in yellow), and Section Four (Conceiving, Designing, Implementing, and Operating Systems in the Enterprise, Societal and Environmental Context – The Innovation Process - shown in red).

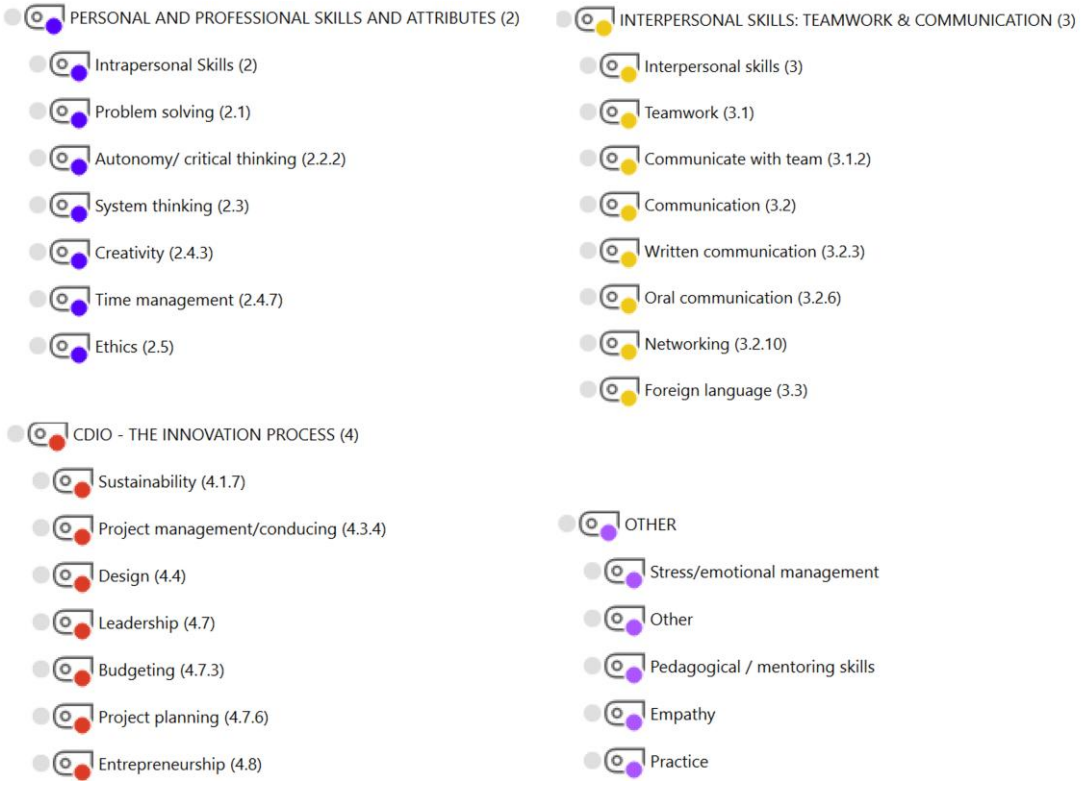

Figure 2. Coding scheme based on v2.0 of the CDIO syllabus (Crawley et al., 2011). Section and subsection numbers that correspond to the CDIO Syllabus for each code are given in the brackets.

The skills which could not be directly mapped onto the CDIO syllabus were put into the "Other" category (shown in purple). These included stress/emotional management, pedagogical/mentoring skills. Additionally, two students cited 'empathy' in response to both the prompts. Students' responses did not include any ideas that would have been coded under Section One of the CDIO syllabus (Disciplinary Knowledge and Reasoning).

Students Prioritise Interpersonal Skills

Our data clearly shows that students prioritise Interpersonal skills: Teamwork and Communication (CDIO syllabus Section Three); this category both has the overall combined responses for both the prompts (46% and 45% of total responses for Personally develop and Least support respectively, Fig. 3), and contains the individual subcategory most frequently

cited for interest and lacking (Fig. 4). Within this category, students named “Communication”, “Interpersonal skills” and “Teamwork” as the skills that they would both like to personally develop and receive least institutional support in developing.

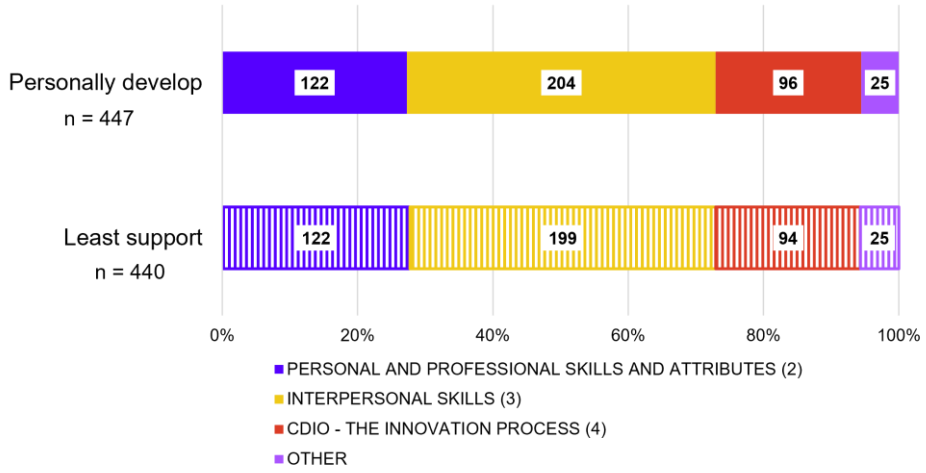

Figure 3. Relative frequencies of the groups of skills that students reported wanting to personally develop (solid-coloured bars) and getting least institutional support in developing (stripped bars). Absolute frequencies are listed in the figure.

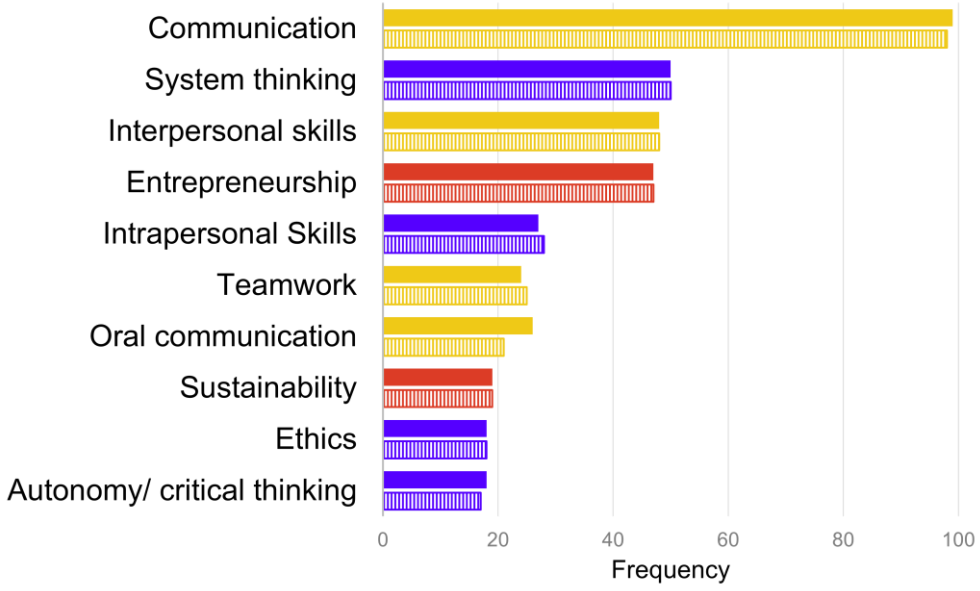

Figure 4. Number of responses for each of the top ten skills that students reported receiving least institutional support in developing (striped bars, total n of responses = 440). Solid bars indicate the number of students that said they wanted to personally develop (total n of responses = 447) that skill. The colours map on to the sections of the CDIO syllabus as seen in Figures 2 and 3.

Our data indicated that the next highest priority for students (27% and 28% of total responses for Personally develop and Least support respectively, Fig 3) were skills related to Personal and Professional Skills and Attributes (CDIO Syllabus Section Two), with special emphasis on "System thinking" and "Intrapersonal skills". "Ethics" and "Critical thinking" (Fig.4). And finally, the skills of "Entrepreneurship" and "Sustainability" from Section Four of the CDIO syllabus also appeared in the top 10 list of skills that students both wanted to personally develop and reported receiving least institutional support (Fig. 4).

Students Perceiving Needed Additional Institutional Support to Develop the Skills they Prioritise

We found strong evidence that students are most interested in developing skills for which they believe they had the least support. Our analysis showed that the codes in the responses to the two prompts were not independent according to the chi-squared test of independence ($p < 0.0001$ in all 1000 resampled datasets). We also found that the association between the responses was very strong (mean Cramer's V = 0.65 [95% intervals of 0.60, 0.70], Fig. 5).

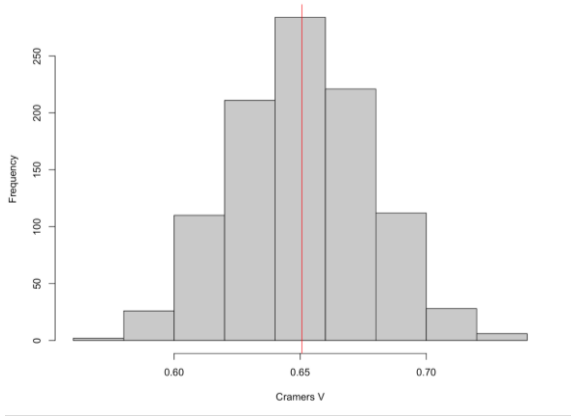

Figure 5. The distribution of Cramer's V values across the 1000 resampled datasets. The vertical red line indicates the mean value of 0.65.

DISCUSSIONS AND CONCLUSIONS

We chose to ask open-ended questions (qualitative data) in this study for two major reasons. First, we would not have been able to account for all the possible transversal skills in a quantitative framework. Second, and more importantly, we wanted to ascertain students' perception of what they considered to be transversal skills and investigate any propensity to confound transversal skills with disciplinary skills or knowledge.

Our data showed that the CDIO framework is useful for teachers to reflect on the transversal skills that are present in the course. It is particularly interesting to note that students did not cite disciplinary or technical skills when asked about transversal skills. This shows that institutional messaging about transversal skills has been successful in creating shared language and understanding with students.

It is interesting that "Entrepreneurship", "Sustainability" and "Ethics" are skills that students prioritise. While these were not included in the first version of the CDIO syllabus (Crawley et

al., 2007), they were included in the updated version of the syllabus based on reflections on the evolving roles of engineers (Crawley et al., 2011). Our data indicates that students have experienced the same evolution in thought processes as the syllabus designers and afford increased importance to these skills. It was additionally interesting that two students included empathy on the list of skills they prioritise. Developing empathetic engineers is indeed desirable, and engineering educators have proposed a model to foster the teaching and learning of empathy as a skill in engineering (Walther et al., 2017).

Importantly, our data shows that students both value transversal skills and would appreciate additional support in developing these skills. Previous studies found students have low self-efficacy for transversal skills (Direito et al., 2012). At our institution, in a study that explored Master's students' self-efficacy, almost a third of the respondents indicated having insufficient mastery in transversal skills like project management (Lermigeaux-Sarrade et al., 2021). They are clearly interested and ready to take advantage of additional support that is provided to them, and therefore teachers can expect to get warm welcome to integrating these aspects. Teachers should therefore leverage this opportunity to experiment and develop activities to respond, as they will benefit from good engagement. The CDIO syllabus in general, and the data from this study in particular, will help teachers identify and prioritise the skills they would like to focus on.

While teachers appreciate the importance of transversal skills and have explicitly included them in their engineering course syllabi (Kovacs et al., 2020), they see barriers to integrating them in their teaching and expect students to develop these skills simply by engaging in activities where they are needed (Isaac et al., 2023). This is especially evident in the fact that even though "Communication" was one of the skills that was listed with higher frequency in course syllabi (Kovacs et al., 2020), it was also the skill that was mentioned most often by the students as being a priority and as getting least support in developing.

Our study suggests that the increased attention to developing engineering students' transversal skills is not yet sufficient. Previous work suggests that this will require providing more support for teachers on how to incorporate opportunities for skill development in their courses to ensure students have the explicit and scaffolded instruction they need (Isaac et al., 2023; Kovacs, Capdevila, et al., 2023; Picard et al., 2022). We therefore present both the 3T Play trident framework (Fig. 1), and the associated activities developed by the team (See: Isaac & de Lima, 2024a, 2024b in 3T PLAY, 2024) to help teachers operationalise the development of these skills in their classrooms.

FINANCIAL SUPPORT ACKNOWLEDGEMENTS

We would like to thank Dr. Mridul Thomas for statistical advice. Funding for this research was provided by the LEGO foundation.

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BIOGRAPHICAL INFORMATION

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Jessica Dehler Zufferey earned her Ph.D. at University of Tübingen in the field of computer-supported collaborative learning (CSCL) with a focus on knowledge awareness. She held postdoctoral positions at University of Fribourg in university didactics, working on gender-neutral teaching, and at EPFL in the “Computer-Human-Interaction in Learning and Instruction” lab, working on technology-enhanced vocational training. After 4 years in a R&D role in the educational technology industry, she is now executive director of the EPFL Center for Learning Sciences.

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