Abstract

1) Contribution: Course aimed at addressing the documented enculturation process in engineering education, which leads to a cognitive dissonance in students between technical and social dimensions, immobilizing the latter. From a learning design perspective, resolving this cognitive dissonance requires the development of learning strategies targeted at achieving a conceptual change. We argue that the minimum needed prior knowledge for this change to happen is already present in students. 2) Background: Engineering education does not happen in isolated but social contexts and is, subsequently, inherently sociotechnical. Despite the growing recognition of the necessity to promote a broader comprehension of engineering identities, there is a disparity in the way curricula are effectively designed and implemented, if they are. The intricate nature of ethics within engineering, encompassing individual, institutional, and cultural dimensions, requires approaches that are both transformative and feasible. 3) Intended Outcomes: The course was designed following the ICAP (Interactive, Constructive, Active, and Passive) framework on cognitive engagement with a focus on mobilizing existing prior knowledge in both technical and social realms, and assessing its impact on students’ approach to learning and their identity as engineers. 4) Application Design: The examination of pre-and post-learning tasks embedded in the learning design indicates that the deliberate activation of students’ pre-existing knowledge in ethical, political, cultural, and social domains enhances their awareness of their cognitive dissonance. 5) Findings: The findings suggest that the course activates students’ pre-existing knowledge, fostering awareness of cognitive dissonance, and encouraging purposeful engagement with broader knowledge when tackling engineering challenges.
Engineering ethics mindset: fostering cognitive change in ICT studies

Aurelio Ruiz-García, Mireia López Álvarez, Davinia Hernández-Leo

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Index Terms—cognitive dissonance, enculturation, engineering education, engineering ethics, ICAP

I. INTRODUCTION

Since the last decades of the 20th century it is increasingly acknowledged that economic, social and political factors are combined inextricably with technological phenomena [1]–[3]. Given the profound social relevance of the engineering profession, ethics literacy is subsequently a growing demand for the basic skill set of the professionals, as explicitly assumed for other professional domains such as health [4], [5]. Activating an engineering ethics literacy (with a broad understanding of ethics, that spans the multiple ways by which technological artifacts affect individual and social aspects of our lives) becomes an essential element for engineers. This literacy is defined for this article as the capacity to collect and evaluate information that allows them to make critical and reasoned decisions, aligned with own and societal values, as well as with the social expectations posed in the profession under democratic principles, and take responsibility for them.

However, and despite increasing evidence of successful attempts to integrate certain ethical and societal subjects into engineering education, including recommendations for their inclusion in engineering degree programs (e.g. Value Sensitive Design approaches [6]), research indicates that its teaching remains notably unsystematic and frequently falls short in terms of effectiveness [2], [7], [8].

In the field of information and communication technologies (ICT), the need for this engineering ethics literacy is particularly pressing as regulatory initiatives increasingly call for the development of technological systems that align and comply with predefined ethical principles [9]. These considerations, however, are reported to be still far from being “prestige garnering work” within the community, or perceived by ICT professionals as falling within their agency, capability or responsibility to address [10].

The process of creating the professional identity of engineers begins during their education, when future engineers are
socialized into the cultures of the discipline. This en culturated process (“a place of initiation for the tribe of engineers” [11]) promotes the creation of a dominant view on what being a good engineer is, with its associated system of practices, meanings, and beliefs [12], [13]. Embedding an engineering ethics literacy in students involves, as a preliminary needed step, a restructuring of this perspective.

Specifically, this dominant view has long been characterized by a focus on technical expertise and a tendency towards depoliticization [14], [15]. The cultural identity of engineering, forged over time, is seen as a more rigorous and complex discipline than others in social domains. This perception commonly associates engineering with a masculine orientation, reserved for individuals excelling in mathematics and the physical sciences. This perception associates engineering with objectivity, overlooking subjective dimensions, and often neglecting broader societal issues [14], [16], [17]. This phenomenon persists even though public welfare is a crucial element of the engineering practice and its external prestige, considering its influential capacity in shaping the social and economic realms. Subsequently, there is an increasing acknowledgement that the traditional model, which places a premium on technical skills while downplaying the significance of societal and ethical concerns, falls short of meeting contemporary needs. The expected transformation of this prevailing culture carries profound implications as a central factor among the multifaceted challenges faced at individual, institutional, and policy levels [1], [2]. With the rise of more balanced approaches that advocate for cultivating the perspective of engineers as agents of social change [15], there is a call to improve the limited research analyzing the alignment of these desired learning outcomes with the effective design of the corresponding learning environments [18].

One of the reported effects in the learning of students due to this en culturization process, which is the focus of this article, is the cognitive dissonance by which students learn to separate “technical” and “social” competences along their studies [14], [19], devaluing the latter. As a result, the capacity of students to connect engineering efforts with public welfare gets diminished.

In terms of learning design, the critical need to address this cognitive dissonance among students does not entail merely adding new knowledge or skills to their existing base. Rather than assuming that the content is lacking or incomplete - by, for instance, incorporating courses with content related to legal, economic, or ethical issues - this en culturization process demands dealing with the existence of attitudes, knowledge and skills that enter in conflict with the promotion of engineering ethical literacy as a critical element in the professional practice of engineering. This type of learning is described in the literature as conceptual change. Conceptual change involves a learning that changes prior misconceived knowledge to correct knowledge [20], [21]. In this context, it refers to a conceptual change that targets the en culturated beliefs which interfere with the engagement with an engineering ethics literacy that links both realms, technical and social, towards the continuous and consistent consideration of social historical and contemporary phenomena in their role as engineers. This conceptual change implies, first, to raise their awareness of the new complexity views on the problems, as a needed previous step towards improvements in their ability (i.e., complementing their traditional quantitative problem strategies with their capacity for qualitative understanding and explanation). Furthermore, it also requires the engagement of students with the learning task, by mobilizing richer perspectives, including the vocabulary used to assess engineering problems with their knowledge on social and ethical issues - knowledge that students may not typically mobilize during their problem-solving activities along their engineering studies.

This article acknowledges that challenges stemming from individual, structural, and institutional factors pose significant hurdles for a comprehensive redesign of the way engineering degrees are both conceptualized and executed [2]. Yet, in response to the need to embed engineering ethics literacy in undergraduate programs while these broader aspects are tackled, this article presents the design of a course focused on the ethical and societal impact of ICT for last-course engineering students at the School of Engineering at Universitat Pompeu Fabra in Spain. This course, developed through evidence-based methods, is designed to heighten students’ awareness of their cognitive dissonance. It is designed with the purpose of not only shedding light on student’s cognitive dissonance, but also to provide guidance for students to effectively address and navigate such discordance, both within the confines of the course and in the broader educational and professional contexts they will encounter through their lives.

II. Course design

A. Course details

The elective subject "Social change, technological change" was carried out in the third quarter of the 2021-2022 academic year, involving third-year students from the Bachelor’s degrees in Mathematical Engineering in Data Science (3370), Audiovisual Systems Engineering (3375), Computer Engineering (3377), and Telecommunications Network Engineering (3379) of the Universitat Pompeu Fabra (UPF) in Barcelona, Spain. The analyzed sample is composed of 39 students (valid cases, consenting participation in the research), with 44% being female and 56% male, distributed across the respective degree programs as illustrated in the following figure. It is noteworthy that, on average, approximately 28.5% of enrolled students in these degree programs were female during that particular year. This observation points out a distinctive distribution of participants in this subject, given the possibility to select from a pool of elective subjects.
In order to help develop an enculturation process, the course material followed the ICAP (Interactive, Constructive, Active and Passive) framework on cognitive engagement [26].

According to the ICAP model, engagement behaviors can be categorized and differentiated into one of four modes of cognitive engagement: passive (receiving and storing information, for their activation in the following phase), active (store, activate and link information, to embed new information with activated prior one), constructive (generating new inferences from activated prior and new knowledge) and interactive (dialoguing, knowledge construction from mutual and reciprocal generative actions) [26]. The ICAP model suggests a higher level of engagement results in improved learning outcomes, if suitable methods are mobilized for them.

The design of the course evolves from the passive review of their existing prior knowledge by students, to the active retrieval of previous knowledge and their scaffolded integration, and, finally, to constructive and interactive reflection. In more detail:

First, students are invited to become aware of this dissonance, as a preparatory step towards its consideration in their current and future activities. In this initial passive learning mode, the objectives of the course were framed under the overarching question of the course: “what characterizes a good engineer?”.

As the transition to the next phase, students carried out the two learning tasks used as research instruments: an initial survey on their attitudes with respect to multiple areas of contact between technological design and society, and the resources mobilized to justify them, and a collaborative computer-supported learning task, where they freely analyzed a specific engineering problem.

Second, once this dissonance is acknowledged, students move to an active mode, through an instructive task, to activate, enhance, connect and recall relevant prior knowledge needed to address their cognitive dissonance. Activating prior knowledge has been extensively found in the literature to be effective for learning in different instructional designs [27], [28]. In this case, they are expected to be able to retrieve and combine their prior knowledge (technical and social, including existing intuitive ideas) to start making a more profound analysis of engineering problems by their integration. This previous knowledge applies to general knowledge on history, philosophy, biology or sociology that they have acquired in their previous pre-university education, with a focus on contemporary history (industrial revolution, evolution of capitalism and welfare systems, civil rights, democracy, from colonialism to globalization, etc). This is conducted through intentional reviews with different case studies and examples around the question: “which are the potential connections between these topics and the technical subjects you took during your studies?”.

Third, during the constructive mode phase, it is expected that students can infer, through discovery tasks, new knowledge

B. Objectives

The objective of the course is to target the cognitive dissonance between the technical skills (acquired along their engineering studies) and the social competences (acquired along their lives, including their pre-university studies and their real-life experiences). That is, the main objective of the course is not to focus on the provision of new content, but in the activation of existing prior knowledge on social and ethical issues, currently disconnected, with the objective of provoking a conceptual change in the way students collect and evaluate information related to technological design, as the needed previous step in getting and activating an engineering ethics literacy. The ultimate objective is the engagement of students with their learning processes in the rest of their studies and their future lifelong learning, considering the complex socio-technical role of engineering when researching, designing, implementing and evaluating ICT systems that interact at human and social levels [22].

The role of prior knowledge (including correct and incorrect, implicit and explicit, concepts, skills or beliefs, and their relations) is well established in neurocognitive, psychological, and educational research on learning [23]. The fragmentation of this knowledge can explain learner’s struggles, and becomes a central goal in learning design [24], [25]. The pre-existing frameworks (prior knowledge, attitudes, beliefs, and values) acquired during their studies, and that students bring to the course, shape how they approach and value different types of knowledge. This has an influence in their understanding of the profession and its alignment with shared societal values. This may involve helping students align their technical knowledge with their understanding and prior knowledge of social sciences or humanities, and of the common good and shared values. As a result, students should end the course being more aware of this dissonance and more engaged with applying their existing ethics literacy (or gaining more, as needed) to their engineering problems to enrich their professional analysis.

C. Structure

![Students distribution by sex and degree](image)

**Fig. 1.** Students’ distribution by sex and degree.
from the previously activated one, through individual reflections on case studies and their own development plans as engineers. This section builds on further iterations to the initial question ("what characterizes a good engineer?") and their reflections about the alignment of the education received so far with their evolved understanding of this question. Through different discovery tasks, this phase serves as a preparation for their participation (in the role of teachers, or as learners) in the next activities in the interactive mode. Getting exposed to different modalities of teacher-driven in-class debates, combined with previous individual reflection activities on the topics of debate, provides them with different models to lead their next interactive activities.

Fourth, they are expected to elaborate, share and lead the reflective thinking of their peers, moving to interactive modes. In this part, pairs of students take the responsibility of getting deeper in one specific topic, of distilling which are the important concepts that all engineers should be aware of around that topic, and of conducting a lesson that, at least, puts their colleagues in an active mode of learning (and, ideally, in an interactive one), including the preparation and distribution of a previous preparatory learning resource (a podcast or video). All students participate in this interactive phase with two roles: on the one hand, by leading one interactive task and, on the other, by participating in the activities proposed by their peers. The objective is to advance in a deeper understanding of individual facets of the interplay of technology and society by contrasting one's and group’s reflections in different topics (including general regulatory aspects, broadly-spread technologies such as algorithmic use in areas such as social media and government, or controversial domains such as facial recognition or genetic modification).

Finally, the students consolidate their learning through two final activities: i) the repetition of the initial survey and collaborative activity (the research instruments) and, ii) the preparation of a final essay addressing the original question. “What characterizes a good engineer?”, reflections on the education they have received so far and their future plans for lifelong professional learning.

Moving along the ICAP model is expected to increase the overall engagement and the awareness of students, allowing them to gradually consider and activate the diversity of previous knowledge and motivations that may exist in the course. For the purpose of this article, we focus on analyzing ‘awareness’ and ‘active engagement’ involving their participation with course materials in two tasks presented at the beginning and end of the course. It is expected that students, in the second presentation of the task, can show higher engagement (more participation), as well as awareness (the activation of relevant prior knowledge and the emergence of new competences that signal the desired conceptual change in making critical and reasoned decisions).

A. Research instruments

Among all the learning activities previously described, we focus the analysis on two activities repeated at the beginning and end of the course: (i) pre- and post-course surveys, and (ii) pre- and post collaborative computer supported learning activity. In addition to the ability to compare the same task at two different time points in the course, none of these tasks is part of the evaluation, but just as part of the preparation of students during the course, and are optional. The optional nature facilitates the assessment of engagement in a real setting, and its lack of evaluation reinforces that students are less motivated to answer what they consider to be expected by the teacher, but their considerations as part of their learning process.

A.1 - Task 1: Pre- and post-course surveys

Surveys were administered at the beginning and at the end of the course. Along the survey, the students rate their opinion on 60 questions which include general views on general social and political issues (i.e. “all citizens should have the same quality of health assistance guaranteed”), social and political issues linked with engineering (i.e. “Use of predictive policing systems by the police”), regulation (i.e. “Regulating technological innovation hinders its progress, so it has to be avoided”), specific technological areas such as facial recognition or conditioning, and, finally, their own attitude and behavior as citizens (i.e. “I am aware of all the possible uses to be given to my data”). In each section, the survey included an additional section allowing participants to optionally justify their responses. The original responses, initially provided in Catalan and Spanish were subsequently translated into English to streamline the analysis. These open-ended questions seek for students to optionally justify their responses provided in the quantitative section, while also encouraging the sharing of comments or pertinent examples related to the five dimensions (or themes) covered in the survey.

A.2 - Task 2: Pre- and post-course computer-supported collaborative activity

Pyramid scripts represent a collaborative learning approach designed to engage students at various social levels in problem-solving activities. PyramidApp [29], a web-based tool, facilitates the deployment of Pyramid pattern-based Computer-Supported Collaborative Learning (CSCL) activities. Through PyramidApp, students can collaborate at different stages of the learning process, following a structured sequence. This sequence starts with the individual contribution by the participants to the real scenario posed, with different interactions where groups rate, discuss and reformulate contributions to reach a final one. Specifically, the group was requested to make policy recommendations about the potential of technology in education, analyzing current and future trends in educational technologies and their use. For the purpose of this article, the individual data provided by the students at the beginning of the collaborative task is analyzed to assess conceptual change.
B. Measuring conceptual change

The fundamental premise of the disengagement process fostered to transcend the enculturation system is that, after completing the course, the students enhance the complexity of their reflections and opinions regarding the topics discussed during the subject. Furthermore, they are expected to exhibit an expanded vocabulary and a tendency to adopt more polarized opinions and attitudes.

Therefore, to operationalize these concepts and understand how these notions manifest in practical terms, the research undertakes an exploration of engagement and awareness.

B.1. Student engagement is a complex construct with multiple definitions. For the purpose of this article, we focus on the cognitive engagement dimension, defined as “thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills” [30] as a central aspect in tackling the targeted cognitive dissonance. For this purpose, we use two measures of student’s optional justification to the choices made in the different questions presented in task 1, to evaluate the lexical sophistication (or richness) of discourse [31], [32]. This lexical sophistication contemplates (i) the length of the texts (density of words), as an indicator of the willingness and ability to reflect, retrieve and use information, reflecting engagement; and, (ii) the lexical richness which refers to the diversity and linguistic complexity of the text (use of technical terms, advanced words, greater vocabulary repertoire) since vocabulary knowledge is linked to conceptual knowledge [33], and since “one of the major determinants of the vocabulary used in writing production is the vocabulary size of the writer” [34].

The most repeated nouns and adjectives have been detected in both questionnaires, both manually and with the use of software [35] (http://contawords.iula.upf.edu/) developed by UPF.

B.2. In terms of awareness, the analysis focuses on identifying the amount of prior, non-technical knowledge, and competences, mobilized for the execution of task 2. Only individual reflections have been considered in the analysis. The qualitative analysis has been performed by a person unrelated to the design of the research but knowledgeable about the subject. This process has been further reinforced by a blind peer review, serving as a double-checking system to validate the systematic application of codes.

The results intend to corroborate if more awareness arises among students, when given a real societal scenario they can relate to. For this purpose, the individual responses provided at the beginning and end of the course are analyzed, through three different lenses:

i) General competences: General competences towards ICTs and their implications have been classified following a proposal based on the UNESCO model of key competencies for sustainability to achieve the SDGs through education [36] and the Council of Europe Reference Framework of Competences for Democratic Culture [37]. Both frameworks describe the key competences which are considered to be crucial for the development of a conscientious, democratic and active society that seeks to protect human rights and that is able “to enable individuals to live independent lives and to take part as active citizens in all spheres of modern, rapidly changing societies. […] Many of the competences people need to be employable – such as analytical ability, communication skills and the aptitude to work as part of a group – also help to make them active citizens in democratic societies and are fundamental to their personal development.” [37].

Taking these frameworks as a reference, the grouped answers of students have been classified according to the following list of competences:

1. Does not show competences.

2. Democratic values: takes into account values such as human rights, human dignity, diversity, democracy, justice, equity, ethics, social and civic awareness, respect, tolerance of ambiguity and self-responsibility. (E.g., “education and health are necessary public services for everyone”, “technology shouldn’t be a substitute for human beings”, “we need to overcome the digital divide, it’s a matter of fairness.”).

3. Systematic thinking (systems thinking) and problem solving (problem-solving): the ability to analyze complex problems and systems, observing the relationships between different items and thinking of solutions. (E.g., “face recognition poses advantages in countries like the US due to the use of guns, but in other countries, like European ones, it could lead to increasing inequalities and marginalization of poorer neighborhoods”, “regulating social media is the only way to solve addiction issues”).

4. Anticipation: ability to evaluate multiple possible, probable and desirable future scenarios, and assess consequences and risks. (E.g., “I am aware that information is collected about me. I also believe that all this information will be used in the future to treat me in one way or another in society.”).

5. Normativity: commit to norms and values, as well as regulation, in the event of conflicts of interest, contradictions or uncertainty. (E.g., Regulation does not prevent technological advance, it only shapes it so that this advance goes hand in hand with society and its ethics.”).

6. Collaborative strategy and personal skills: show the ability to learn from others, empathy, sensitivity, collaboration, conflict resolution. (E.g., “I understand the usefulness of tracking people with a record, but where do we draw the line? I put myself in the shoes of someone with a minor crime who has lost his "privacy" and knows that will be "persecuted" when on the street for the rest of its life.”).

7. Critical thinking: ability to question norms, practices and opinions, including one's own values, as well as those of the
world (politics, legislation, human rights, culture, economy...) (E.g., “Monopolies are bad if power is used in a negative way to society and seek the monopoly owner's own benefit. But if the power is used beneficially, it can be a very good thing.”, “Even algorithms help save time, a racist one should never be used.”).

8. Self-perception, self-awareness and self-responsibility (self-awareness): reflect on one's own role in society. (E.g., “When social media platforms ask for our consent to collect our data, we simply give it, whether out of laziness, ignorance or not knowing more ethical app alternatives, which there are.”, “I don't care that companies collect my data, I have assumed that they do and I don't care”, “I know the risks and that's why my social networks are not linked to each other and I always use a pseudonym.”).

The mentioned cognitive dissonance in engineering through the global enculturation process is reinforced by the focus of engineering studies in a specific set of these competences. Engineering education has been historically oriented towards scientific and market-driven orientations [38], with an emphasis on systematic thinking (competence 3 above), anticipation (competence 4) and, increasingly, collaborative and personal skills (competence 7).

For the analysis of pre- and post answers, the answers are analyzed to identify whether new competences shown are shown in the post answers, under the assumption that the competences shown in the task at the beginning of the course are already available and mobilized by students when analyzing an engineering problem. The focus, subsequently, is to identify which new competences are developed and emerge in their problem-solving task.

ii) Attitudes: The general attitudes shown by students have also been classified in different levels of awareness according to the classification for algorithm awareness proposed by Anne-Britt Gran, Peter Booth & Taina Bucher [39]: the unaware, the uncertain, the affirmative, the neutral, the skeptic, and the critical.

1. Unaware: This category pertains to individuals who exhibit a complete lack of awareness or knowledge concerning the social impact of ICT and its various applications.

2. Uncertain: Within this group, individuals display attitudes towards ICT usage that range from neutral to positive. However, they express a perceived deficiency in their knowledge on the subject.

3. Affirmative: Participants falling under this category exhibit overall positive attitudes towards the general use of ICT.

4. Neutral: Unlike the "Unaware" group, individuals in this category possess a degree of awareness and knowledge regarding the social impact of ICT. Nonetheless, they maintain a neutral stance.

5. Skeptic: This group is characterized by individuals who predominantly harbor negative attitudes towards ICT usage. However, they may exhibit a certain level of indecision or possess limited knowledge on the topic.

6. Critical: Those classified within this category demonstrate a high level of awareness and possess extensive knowledge on the subject. They primarily hold negative attitudes towards ICT usage. Furthermore, they are capable of providing concrete examples and exhibit a forward-looking perspective regarding the future social implications of ICT usage.

iii) Concepts: Content analysis of the concepts, both in terms of advantages and disadvantages, that students mobilize as they respond to task 2, conducted at the beginning and end of the course. This analysis aims to discern the shifts, developments, and nuances in the students' conceptual frameworks.

IV. RESULTS

Firstly, with regards to engagement and participation in the task (B.1), the length of the texts (B.1.i) increases by a total average of 51% in the post-survey (from an average of 84.5 words per student to an average of 168 words per student). Answers by category are almost doubled in the post-survey when it comes to personal and general attitudes, showing greater participation.

Fig. 2. Engagement (participation) based on answers given per each of the categories of the survey.

On the other hand, focusing on lexical sophistication of discourse (B.1.ii), it is observed how lexical richness and complexity increase since there are sets of new words that appeared towards the end of the course: automatic content recommendations, affinity, preferences, polarization of society, humans, people, transparency, bureaucracy, agility, discrimination, optimization, data collection, personalized content, digital divide, vulnerability, injustice, ethics, equity, collective freedom and monopolies.

Secondly, looking at the general competences towards ICTs and their ethical implications (B.2.i), towards the end of the course students show a greater critical and analytical thinking as well as a broader self-perception, awareness and own responsibility regarding social and ethical implications of
technology.

![Acquired competences after the course](image1)

**Fig. 3.** New competences shown after the course

With respect to the attitudes (B.2.ii) identified in their answers, the group evolves from showing a varied heterogeneity of attitudes towards coalescing into a highly homogeneous cohort. There is a prevailing inclination towards a more critical stance, with a tendency to underscore negative facets of technological design. It is interesting to note that this would be aligned with the results in the original study by Anne-Britt Gran, Peter Booth & Taina Bucher [39] suggesting that citizens with the higher awareness of algorithms (and correlating with higher education levels) were more associated also to the critical type which emerged after the course.

![Comparison of awareness shown before and after the course](image2)

**Fig. 4.** Comparison of awareness shown

Thirdly, through the content analysis (B.2.iii) the individual responses to the Pyramid App activity (A.2), it is observable an evolution in students’ perspectives. The students identify some new advantages and disadvantages at the end of the course with regards to ICT usage in education but, more importantly, their answers suggest that they undertake more nuanced analysis, with a higher consideration of the domain-specific characteristics of education, such as its general social role, or its impact in the future prospects of citizens in contemporary societies. This suggests a more sophisticated capacity to engage with the task at the end of the course (technology in education, as such, has not been a topic of discussion in the course and, therefore, this sophistication cannot be directly attributed to more knowledge acquired during the course on the topic).

New dimensions appear in two aspects. On one hand, 13.6% of students recognize the potential of technology in education to foster greater awareness among students about a positive and healthy use of ICT in their lives. In other words, the use of technology in education can serve as a valuable tool to encourage more critical thinking surrounding its applications, if sought explicitly. On the other hand, 4.5% of the answers now also contemplate job losses and the potential replacement for teachers. Existing discussions expand, encompassing not only the potential positive aspects that more personalized education can offer (70.4% highlight this fact after the course, compared to the 46.8% at the beginning) but also blending the very positive view about the potential of technology to improve accessibility, inclusion and equality (72.34% of responses in the initial survey). This initial positive view transitions into a still positive one (indicated in 52.3% of answers at the end), but with a significantly growing concern among students regarding the potential individual inequalities in education which can result from incorrect technological development and adoption (72.7% of answers report this aspect after the course, with only 27.7% mentioning it initially). Additionally, the proportion of students explicitly expressing negative concerns about the pursuit of personalization (for instance, related to potential isolation or the loss of the collective and social elements that education as a system already has) slightly increases, from 8.5% to 11.3%. Concerns in other areas experience slight growth, such as environmental effects (rising from 38.3% to 45.5%), social effects perceived negatively, like social dissociation or loss of the human factor (increasing from 51% to 56.8%) or the positive potential in terms of efficiency (from 12.8% to 18.2%) or new teaching possibilities offered by technology (29.8% to 38.6%). As a result, the combined answers incorporate novel dimensions

Figure 5 presents a compilation of the results of the analysis, which suggest a general and broader enhancement in the sophistication and engagement of students as they approach the assigned tasks across different dimensions, suggesting a global positive evolution in their involvement in the given assignments.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Categories</th>
<th>Indicator</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1 - Task 1: Pre- and post-course surveys</td>
<td>8.1: Engagement</td>
<td>i) Student engagement: length of texts.</td>
<td>Participation and length of justification increases in all dimensions of the survey (Figure 2), suggesting a higher engagement with the task.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) Student engagement: lexical richness.</td>
<td>New sets of words and ethical concepts are mobilised in their justifications in the survey.</td>
</tr>
<tr>
<td>A.2, Task 2: Pre- and post-course computer - supported collaborative activity</td>
<td>8.2: Awareness</td>
<td>i) Student awareness towards ICTs and their ethical implications</td>
<td>New competences are mobilised, especially related to critical and analytical thinking, and self-perception, awareness and responsibility.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) General attitudes.</td>
<td>Shift towards indicators that show critical attitudes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) Content analysis of the concepts that students mobilise in the task.</td>
<td>Several existing concerns by some students at the beginning of the course greatly increase among peers, while some new concerns (especially related to potential inequalities driven by technology) emerge.</td>
</tr>
</tbody>
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**Fig. 5.** Summary of results
V. CONCLUSION

Embedding ethics in engineering studies presents challenges at multiple levels, including individual teachers’ attitudes and knowledge, the lack of systematic learning designs or assessment methods, or larger institutional aspects such as budgets or the already density of engineering curricula. In line with abundant scholars in the domain (for instance, [15]), this study begins with the premise that a critical element is to tackle the general identity issues of the profession. On a cognitive level, tackling a more comprehensive understanding of the profession involves addressing the cognitive dissonance between the technical and social dimensions exacerbated during engineering education. This cognitive dissonance acts as a bottleneck for any approach, or as the root for some undesired effects noted in the engineering ethics literature. These effects manifest in the limited consideration of social dimensions, often confined to specific courses focusing on topics such as privacy or legal aspects, which reinforce their “serial” consideration, emerging only in the design process (if they do) after technical aspects have been resolved.

The role of prior knowledge is known to be essential in any learning process. We argue that, in order to address this dissonance (that is, to provoke a learning which is of a conceptual nature), students already possess sufficient general knowledge and competences associated with the social dimension of the profession, but they get ignored. Subsequently, the focus to foster the desired mindset needs to be put on activating this existing knowledge (on socio-technical contemporary and historical issues), and not necessarily adding more (while, of course, it is expected to be gradually enriched as part of the process). This activation requires, first, making students aware of its relevance for the learning objective. Once activated (and only in that case), they can get engaged in addressing the implicit core hypothesis that leads to their robust misconception about engineers’ identity, a misconception that is reinforced by their lived experience during education.

For this learning objective to occur, we tested if a gradual student engagement process, following the categorization of the ICAP model, can optimally (in a short 10-week course) direct students in the process, towards more sophisticated views of the socio-technical nature of their role, when they address an engineering problem. The analysis of the activity of students in real-class, not evaluated tasks in terms of awareness and engagement suggests that such learning design can advance in this direction and, especially, empower students’ agency to further improve it by autonomously applying this view during the rest of their studies and their professional lifelong learning. The elective nature of the course may imply a potential self-selection bias among students, as those who may be already inclined to consider social elements, or even already (explicitly or implicitly) aware of the cognitive dissonance, may be more likely to enroll. This self-selection process could influence the composition of the course cohort, potentially impacting the generalizability of the findings to the broader student population within the discipline.

This pragmatic, evidence-based approach may be particularly valuable in situations where the practical impediments to undertake more profound transformations at the level of studies are significant. Specially, different adaptations using the basic key principles may be easily implemented with engineering students in their first year. The aim would be to equip them with resources that help them become "shielded" from cognitive dissonance induced by the enculturation process. This approach naturally guides them toward adopting more balanced perspectives throughout their educational journey.

As this interest and imperative to articulate a more comprehensive understanding of the engineering profession and, consequently, its education is likely to grow, a crucial aspect for future research lies in developing the adequate methodologies, approaches, and tools at engineering schools, and their enactment. These approaches will enable the evaluation of competences that are often neglected in the engineering domain, and for which current professionals, academics, and policymakers may still lack the resources to effectively assess. Thus, there is a pressing need for research efforts aimed at creating robust evaluation mechanisms for these often-neglected aspects within the field of engineering.

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