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Improving and Assessing Self-Awareness of Undergraduate Mechanical Engineering Students: A Case Study from Chile*

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The Covid-19 pandemic, the rise of artificial intelligence and major societal changes have meant disruptive changes in how to achieve education everywhere and at all educational levels. Increasing uncertainty and complexity motivate a reevaluation of the role of engineers in the future society and what skills will matter more in the work market and society. Such a context has inspired and/or forced a series of changes in active learning strategies. This paper describes a course-level learning hybrid methodology that has been implemented in a mechanical-engineering curriculum. The methodology combines concepts from three bodies of knowledge: *cultural materialism*, *social cognitive learning*, and *transactional distance theory*. A blend of activities is proposed to enhance the active learning of students. Through in-class collaborative problem solving, the provision of spaces for reflection and exploration of self-awareness, and a project work that culminates with an open seminar, the aim is to develop technical and the so-called XXI century skills, in particular, self-awareness skills. Such an approach would better prepare students for the ongoing uncertainties and future professional and interpersonal situations. The case study shows promising results that have been documented through self-perception and self-efficacy surveys from students and alumni. The proposed method helped students to achieve the learning outcomes of the course, increased their engagement, and allowed them to exercise their self-awareness as a complement to their development of technical skills.

Keywords: transactional distance; social cognitive theory; active learning; 21st century skills; self-awareness

1. Introduction

Humanity is currently facing a period of rapid and disruptive changes, with various perspectives and interpretations of reality available. One of the main challenges is to develop a comprehensive understanding of the diverse changes occurring at different levels and timescales [1]. However, it is clear that the global economy is rapidly evolving and becoming more interconnected and complex than ever before, driven by technological advancements. In this context, service markets and international trade are taking precedence over industrialization, which has significant implications for education [1, 2]. Educational demands are closely linked to changes in industries and technologies, with services requiring more flexible and horizontally-structured organizations, while industrial and agricultural processes are based on standardization. To navigate these changing dynamics, it is essential to develop adaptive and innovative approaches to education that can effectively address the new demands of a rapidly-evolving global economy.

In turn, this increases the need for social and cognitive skills [3]. In some countries, there is also discontent associated with health and education services and the imminent threat of low complexity jobs by automation and the rise of artificial intelligence [4].

Engineering, both as an academic and a professional field, can contribute to generating pathways for developing countries, more so in the context described above [5]. The leap to a complex and more equitable economy depends mainly on human capital capable of generating innovations that enable sustainable growth based on the real economy [6]. Young engineers can support the development of the solutions and services required by this endeavor. In such a context, this article discusses an intervention on a senior course in mechanical engineering. The main objective is to complement technical skills with 21st-century skills, with a special focus on developing self-awareness. The election of this skill acts as a lever for many skills that are and will be in more need in the future.

1.1 Emerging Countries and their Road to Modernity

Using the cultural materialism framework [7, 8], it is possible to assume that the changes in the economy

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must have a concomitant change in the ideologies that support the identities and relationship systems of peoples and individuals. In this conceptual context, it can be observed that the changes from agricultural and industrial societies to a global services economy are accompanied by changes in the hierarchical class systems. Such changes create conflict in professional hierarchies, gender, and social class. We set our case study in Chile. It exemplifies situations that occur in other parts of the world. Chilean society has not been an exception in the modernization process but shows some peculiarities that are worth mentioning to justify the urgency of the need for educational changes.

The Chilean tertiary education system was developed in the context of a national strategy for industrialization fomented and led by the state. Compared with the Anglo-Saxon system, characterized by a broad spectrum of topics and the election of majors and minors, the Chilean curricula are still longer and highly specialized. Topics such as entrepreneurship, innovation, or social skills are often neglected, assuming the student does not need other skills than the technical requirement of the operative work. In an economy and educational system mainly controlled by the government bureaucracy, critical thinking is not a desirable trait. Such a context is not auspicious to develop social skills and critical or creative thinking [9].

As sustained by the cultural materialism approach [7, 8], the economic engines are crucial to the educational system and permit a better understanding of their pitfalls and opportunities for development. Continuing with our case example, the accelerated development of Chile in the last 40 years was the result of three main processes triggered by a neoliberal model: the development of the primary sector (e.g., exports of cooper, cellulose, and fruits); the expansion of the services industry (e.g., health, life insurances, and retirement plans); and the deregulation of other industries (e.g., Universities, telecommunications). Most of the new economy was controlled by family offices, with scarce use of information technologies and modern managerial systems [10]. Mostly in the last 20 years, there was progressive incorporation of both elements to gain organizational efficiency, flexibility, and efficacy [11]. Such endeavors exposed different skill gaps in many professionals (including engineers), especially related to an entrepreneurial culture, teamwork, and creative thinking [12]. At the same time, the economic development boosted expectations and discomfort in an important part of the population [13]. For our example: the Chilean higher-education system is accused of setting conditions that lead to the excessive creation of for-profit (and low-quality) institutions [14]. The excessive offer of tertiary education in several professions produces educated people that local job markets cannot absorb and also has caused an increase in underemployment and debts from students and/or their families [15]. These and other gaps triggered the social outbreak during 2019 [16]. It was shortly followed by the worldwide pandemic in 2020, the Russian-Ukranian conflict in 2022 and the accelerated AI developments of 2023.

The above-described context inspires this work. The uncertainty that countries face resonates with the necessity of forming engineers with enhanced skills, better prepared for Volatility, Uncertainty, Complexity, and Ambiguity (VUCA).

1.2 Transitioning into a New Era in Engineering Education

An element that complements the social changes that all countries face is the adaptation to Industry 4.0. Emerging countries need highly specialized human capital with a fresh mindset towards creating social capital and consciousness for the environment and local communities [2]. On the other hand, globalization demands an interconnection between higher education and science, technology, and innovation [17]. This means that an essential step to facing educational gaps is redefining priorities in academia. Nowadays, universities function more like complex knowledge ecosystems that interact with many other environments [18]. Such interconnectedness brings increased diversity and transformation to education. Part of it was in plain sight during the pandemic: the traditional classroom is blurred and a number of conceptions about the University are becoming obsolete. Traditions and beliefs delay the development of new connections, ways to educate, and research [18].

Another essential dimension of education that is in transformation is the set of skills that engineering programs are developing. Students must be prepared to make rational decisions in VUCA professional situations. For that, technical and professional skills are fundamental; engineers must be able to apply specialized technical knowledge while working with multidisciplinary teams. Moreover, they must understand the impact of their solutions in a global and societal context that will be continuously changing [19]. The scenario inspires students to understand the situations in longer planning horizons, with enhanced flexibility to adapt, and strong in their emotional and mental balance [20]. Teaching in the XXI century needs to facilitate students to know themselves and have a comprehensive worldview on an extended horizon. Questions such as the purpose of their life or who they are or who they want to be, must be present during their formation [21]. Students should

become aware of their strengths and weaknesses, which will be essential elements of their professional identity [22].

1.3 Need to Integrate Frameworks

COVID-19 forced institutions to implement emergency remote teaching. Online Learning (OL) created spaces to decouple learning from the synchronic experience and increased the possibility to learn anytime, anywhere [23]. However, this demands both students and teachers to "learn to teach and learn online" [24, 25]. Such a scenario inspired us to integrate the concepts of Transactional Distance Theory (TDT) [26], Social Cognitive Theory (SCT) [27], XXI-century skills framework, and Active Learning (AL) [28]. We justify these choices in section 2. Accordingly, the following hypotheses were proposed: (i) Applying a balanced blend of online AL methods reduces transactional distance, increasing the learning engagement of the students. (ii) The proposed method allows students to practice and increase their critical thinking, communication, and Information Media and Technology (IMT) skills. (iii) Applying standard personality instruments, exploring appropriate support material and brief group reflections raise the self-perception levels regarding self-awareness.

The rest of the paper is organized as follows. Section 2 presents a literature review related to the proposed method, which is described in Section 3. Section 4 details the case study and discusses its results. The methodology is evaluated in section 5.

2. Literature Review

As mentioned in section 1, several learning theories are integrated into our approach. SCT presents itself as a conceptual base that allows the observation of reciprocal interactions between students as active subjects evaluating and ori entating their behaviors in relation to their relevant environments. AL provides an operational frame, and the 21st-century skills model identifies the critical domains that must be addressed. TDT shows its usefulness to evaluate the educational process considered here, which is delivered partly or entirely in a distance learning environment. TDT promotes minimizing transactional distance and thereby maximizing learning outcomes in distance learning. TDT considers four aspects: (i) student-student distance, (ii) student-teacher distance, (iii) student-content distance, and student-technology distance. The integration of the above-mentioned theories allowed us to set a framework for our work from the beginning and provide coherence and meaning to the tools and methodologies that are explored (Fig. 1).

Fig. 2 represents the different skills that the 21st century demands. This is an adaptation of "The 21st Century Knowledge and Skills Rainbow" [29]. IMT skills are required to face the technological and online reality we live in, such as learning how to read with a critical view and exploit IMT [29, 30]. These are complemented with the 4Cs: Critical thinking, Communication, Collaboration, and Creativity. They all respond to the demand for high levels of expert thinking and complex communication. On the left hand of the rainbow, skills for life and career (SLC) are addressed. Among them, we find self-awareness, which acts as an enabler for other interpersonal skills that may be sheltered under the SLC umbrella. Students need to develop flexibility and adaptability because they will need to adjust and adapt to professional circumstances that will show VUCA attributes. At the same time, they need to improve their self-initiative and self-efficacy and to be able to work independently and manage goals and time [29, 31]. The rainbow also considers sustainability as core. This topic is represented in the "3R" (Reduce, Reuse and Recycle) keystone. Future engineers must have in mind this perspective when solving problems and designing engineering systems [2]. Finally, self-awareness is the skill that education is more in debt. Students must know about their motivations and goals. They should be aware of their competencies' strengths and weaknesses [22]. References [32, 33] describe frameworks to develop self-awareness as a possible foundation to develop a higher level of the other skills mentioned.

One of the pillars of our framework concerns AL. By using a mix of AL strategies, we are able to attract a long diversity of students' interests, motivations and talents [28]. Also, supporting remote education requires that the responsibility of learning fall more on students, which aligns with the development of self-regulation that AL promotes [34]. On the other hand, digital tools allow students to review the content whenever they can and at their own pace, so Flipped Learning appears as an attractive option [35]. Finally, the combination of entertainment and learning of Game-Based Learning (GBL) resembles the digital nature of the current students at the same time that achieves educational objectives [36]. GBL provides immediate feedback and lets students know that they are making progress. Challenges allow them to become more interested and engaged in the learning process. GBL can be used to develop conflict solving and cooperation skills [37]. All these are examples of AL strategies but there are many more such as Problem Based Learning (PBL), Project Oriented Learning (POL) and many others.

Both TDT and SCT are highly relevant in this

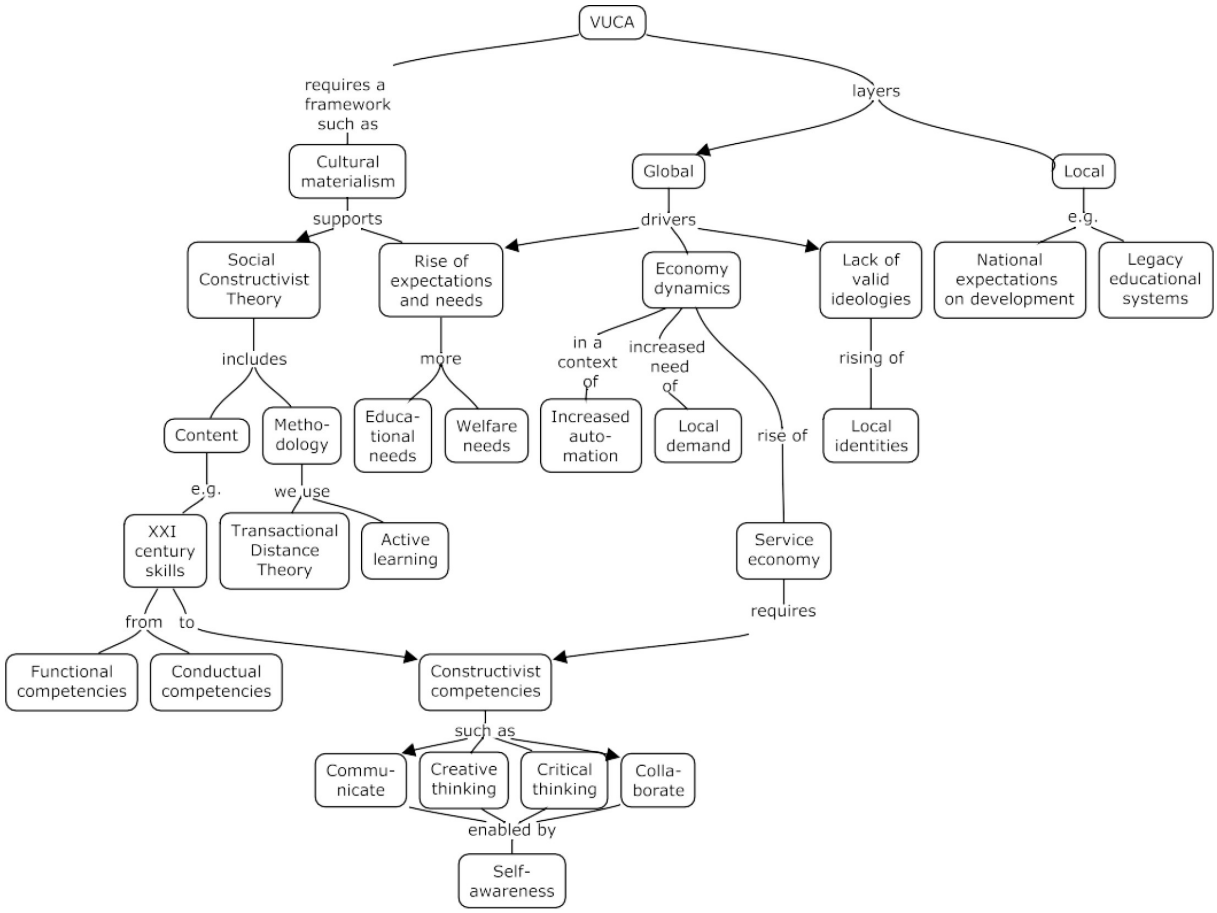


Fig. 1. Overview of the methodology.

Fig. 2. Customized 21st century skills arch. Adapted from [29].

rapidly changing educational and learning scenario. OL offers space for theories that serve to complement SCT and which were not thought for virtual contexts. TD is a social constructivist model that shares some foundational principles with the social learning approach [38] and serves to build the base for online Vicarious Learning (VL). The OL and the asynchronous experience may negatively affect the educational distance. Although creating a high-quality interaction between students and teachers is one of the objectives of the AL, it is essential to complement it with a more prominent conceptual framework about educational distance. TDT analyzes the behavior between teachers and students when separate. TDT focuses on three dimensions: *structure*, *dialog*, and *autonomy*. *Structure* is associated to the set of activities planned by the teachers, traditionally called "lessons", and how teaching and content are organized in the courses and programs. *Dialog* refers to how teachers or students interact with other students when using communication technologies in the task of creating knowledge. Finally, *autonomy* is added to include the learner's side in this theory. The students may require more or less to manage their learning depending on the context. Also, TDT considers the importance of social interaction in remote learning. Increasing dialog and more space for interaction reduce the distance between participants [26].

SCT [27] also refers to people learning from their interactions with others in a social context. SCT states that there are two basic modes of learning. People learn by experiencing the effects of their actions and through the study of social models [39]. Moreover, to expand their knowledge and competencies, learners can do it through observation. Virtually, all learning from direct experience can be achieved vicariously by watching other people's actions [27]. That vicarious experience

plays a fundamental role in learning; when students observe others they think are similar to them in terms of capabilities complete a task, they believe they can achieve it too, and therefore, they work to make it happen [40]. Some examples of the relationship between VL and virtual educational environments are shown in ref. [41]. They gathered recordings of students and tutors engaged in task-directed discussions. Students who watched this material showed a more critical assessment of their own contribution to the debate. In [42] undergraduate students observe tutorial videos where their peers tackled open-ended and conceptually challenging problems led by their professor. Students who watched the tutorial videos felt more engaged and found positive accessing additional learning information. Finally, Pleines [43] study vicarious participation using small-group tutorials for language classes in a pandemic context. Students found VL suitable as they could learn at their own pace by processing the information for longer and in different ways. Affective and motivational benefits are also reported.

3. Method

An AL strategy requires a balanced selection of elements to attain the proposed learning goals. In this work, we propose amalgamating 21st-century skills (Fig. 2), SCT and TDT in a comprehensive active learning strategy. These tools are selected considering some of the keystones of the 21st-century skills rainbow, focusing on developing self-awareness as SLC, 4Cs, IMT skills, and of course professional skills.

Aiming to develop self-awareness as SLC for the 21st-century workplace, a set of sequential micro-learning activities may be organized. Each activity can consist of three moments: application of selected personality instruments (in the classroom), followed by an exploration of attractive support material (at home), and a final in-class reflection of results from the instruments and the revised material (in the classroom). With this method, students may find the opportunity to compare themselves to their peers and reflect on the different proposed personality traits, inviting them to explore self-awareness. To develop self-awareness we propose using several instruments. Each of them allows students to evaluate themselves in a variety of areas. Table 1 describes the tools explored in our case study. Its selection had to do with exploring instruments well-grounded in theory and also expanding the scope of personality exploration as much as possible while limiting its number to a reasonable amount. Our selection is: (i) dominant personality traits (extroversion, agreeableness, conscientiousness, emotional stability, and openness to experience); (ii) grit; (iii) ways of processing information (rational and experiential); (iv) conflict management style (assertiveness and cooperativeness); (v) growth mindset (perception of flexible intelligence) and (vi) empathy. This list may be easily extended and/or modified.

Table 1. Summary of self-awareness instruments of the case study

Trait	Instrument	Sub-scales
Big five	Ten-Item Personality Inventory [47]	5
Grit	Grit-S [48]	2
Processing information style	Rational-Experiential Inventory [49]	2
Conflict management style	Thomas-Kilmann test [50]	2
Growth mindset	Implicit self theory [51]	1
Empathy	Read the Mind in the Eye [52, 53]	1

Critical thinking is developed using an inductive approach that exploits PBL and POL. PBL can be one of the core activities applied throughout the term in every week of the course. For example, in our case study, students solve problems synchronously with the help of their teacher and their peers. In this virtual mode of PBL, called ''champions'', students share their screens and solve the proposed cases in some data analysis tool, such as Excel. Its importance lies in the fact that with continuous AL practice and exposure, they can learn the essential technical competencies of the course more effectively, while at the same time increasing their collaboration skills. Collaboration is a vital aspect of the approach and is considered key to reducing *transactional distance* among students. This aspect occurs in both synchronous and asynchronous forms. As an example, different games and activities may be carried out along the term to enhance interactions and teamwork in the synchronous classes. In these instances, challenge problems are proposed. Small student teams must solve them, interacting among themselves using *breakout rooms* in the video-conference platform. This dynamic may also be explored with collaborative tools such as Kahoot and Socrative. One of the main game-based activities of our case study is the ''Olympics'', where students compete to see which teams achieve the podium through play and collaboration. Asynchronous collaboration is explored via VL. The videos of every class and other resources may be made available for students to watch whenever they want. If students can't or don't want to participate in the synchronous classes, they can learn passively with the VL approach of watching his/her peers solve problems.

Communication is mainly addressed by POL,

which culminates in an open seminar where the groups present their experience and results. Students have to identify a problem, delve into it, and generate practical and innovative solutions to face it. This process requires a deep understanding of the content, creativity, and deliberation. The public seminar is the final instance where students present the project outcomes they worked on during the term. The audience is diverse and professional and puts students to the test.

Regarding IMT, professional skills, and 3R, they are developed almost in many activities of the course as it is based on PBL and POL. The problems students face require the use of IMT tools such as Python and Excel. The problems are oriented to decision-making in operational contexts which improve practical professional skills. Among the lists of projects, a number of them deal on sustainability issues.

3.1 Assessment Strategy

The evaluation system is composed of a mix of formative and summative assessments. A pool of formative assessments may be implemented to obtain feedback on students' learning process. Formative assessments, such as quizzes, may be applied to measure the understanding of basic concepts before starting the class. The summative assessment system is composed of four components: (i) POL is evaluated through presentations and a final Open Seminar; (ii) special quizzes are taken by students to measure their knowledge in specific lectures and/or videos previous to the class, which help to open and deepen the discussion; (iii) synchronous partial exams measure individual knowledge and acquisition of competencies, motivated to reduce cognitive workload and potential cheating. To reduce anxiety, these partial exams may offer the alternative to the students of changing one of their worst questions and replacing it with another question they have to solve in a special instance; (iv) a final synchronous exam represents the last instance of evaluation, focused on the same objectives and characteristics of the partial exams, intending to summarize all the learning gained during the course.

4. Results

4.1 Stakeholders Assessment

The integrated methodology described in the previous section was implemented in a mandatory course in the terminal stage of the curriculum of Mechanical Engineering at Universidad de Chile. The course is focused on operations and life-cycle management [2]. To measure their impact on students' learning, a research study was conducted during the Spring term of 2020 (fully online due to pandemic restrictions), which was mainly focused on XXI-century skills and the development of self-awareness. A series of different surveys and interviews were conducted to gain a quick assessment and adapt the strategy during the term. The class was composed of 20 students. The sample number of every survey and interview varied according to students' availability. To complement this work and the views of the course's students on the usefulness of skills for the workplace, 12 mechanical-engineering alumni were interviewed as part of the study.

Self-perception of learning was evaluated with a pre/post survey, where the first one was applied during the third week of the semester and the post questionnaire during the eleventh week. It consisted of a series of propositions related to acquiring different technical (Operations Management skills, IT skills, professional writing and communication skills) and self-awareness skills (personality traits, empathy, identification of strengths and weaknesses) developed in the course. The instruments used a five-point Likert scale that ranged from "strongly disagree" to "strongly agree" and was applied by using Google Forms. ANOVA analysis was conducted to find significant differences between pre and post answers.

Transactional distance was measured to identify the gaps that could be obstructing students' learning in different dimensions (student-student, student-teacher, student-content, and student-technology). The questionnaire was adapted from Weidlich [44]. The set of items used to evaluate each one of the dimensions is listed in Appendix A.1.

A conclusive self-made survey was given to students at the end of the term to evaluate the course. Topics such as academic workload, satisfaction with the active modality, and transactional distance were the main ones considered. The survey consisted of a series of propositions that use a five-point Likert scale from "strongly disagree" to "strongly agree". To complement this output, open questions from the end of the term survey applied by the University through its learning management system *U-Cursos* were analyzed qualitatively to have a solid understanding of students' perceptions and evaluation of the course. These questions aim to find the strengths and weaknesses of the course and served to build conclusions and find or reaffirm the main issues and benefits.

Given the importance of students' views and opinions on their learning process, two series of semi-structured interviews were made via video conference with different groups a few weeks after the end of the term. The first group was composed

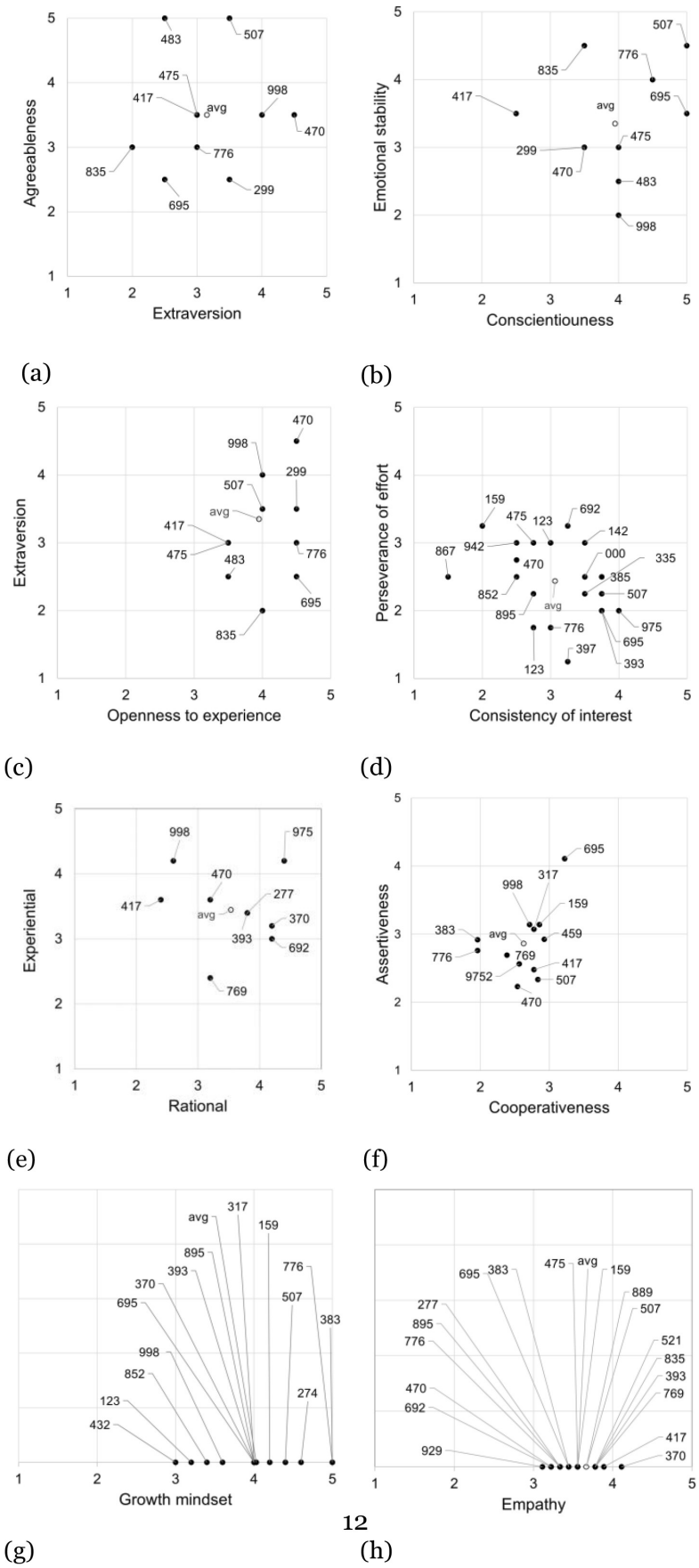


Fig. 3. Self-awareness results. Each point corresponds to a student's responses to a given dimension.

of five students of the course, who responded to an e-mail invitation. This activity was directed to gain a deeper knowledge of the utility and effectiveness of the AL elements incorporated into the modality and their obtained skills. The second group was integrated by 12 Mechanical Engineering alumni. Their interviews aimed to find which skills are more important in the job market and check the importance of self-awareness. These interviews were divided into two parts. In the first one, each interviewee answered a five-point Likert-scale questionnaire about the perceived usefulness of certain skills in the workplace and how they considered these skills to be developed and enhanced during the undergraduate curriculum in the courses they took. The second one was conformed by an open-ended set of semi-structured questions that were also made to obtain a deeper understanding of the opinion of the graduates. The list of skills selected were adapted from [33, 45, 46]. Appendix A.2 describes details of the interview process.

4.2 Self-awareness Exploration

Fig. 3 shows different results (as they were shown to students) in the reflective part of the micro-intervention. Every three-digit code represents a student. Each one of them know their own personal code. For each instrument, students could identify their coordinates and compare them with their peers and the average student. In the in-class discussion, the group talked about the general characteristics of people who are on one side or the other of each criterion and how it may affect personal and professional life. Before the discussion, the professor made a presentation of the general concept evaluated with each instrument and the scales in which each meta-scale can be decomposed. For example, the dominant personality traits can be explored as extroversion, agreeableness, openness to experience, and emotional stability.

4.3 Student Surveys

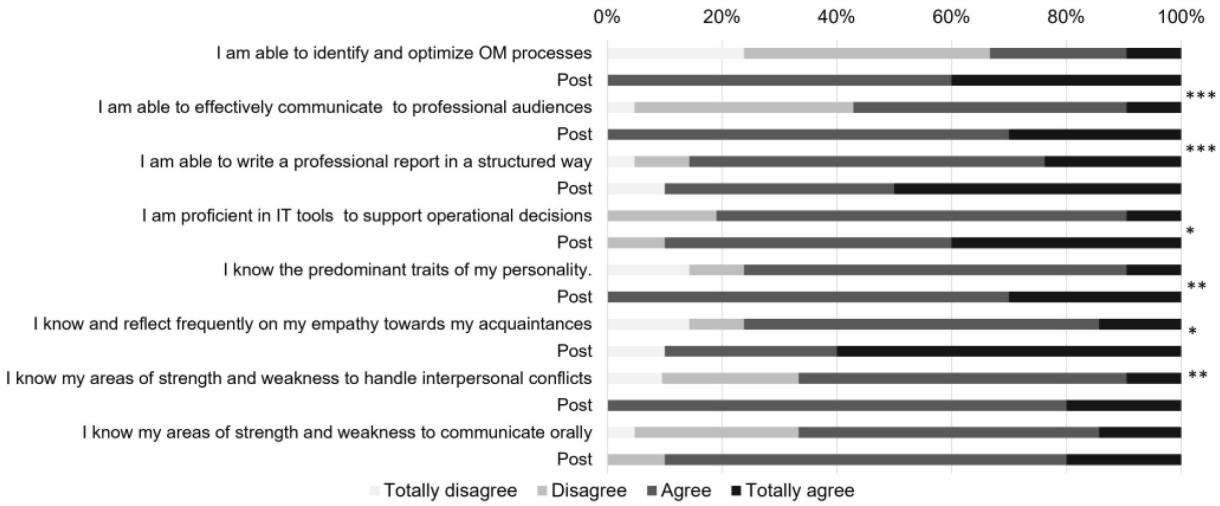
4.3.1 Self-perception of Learning

To measure the impact of the pre-post changes the answers were codified from 1 (Totally disagree) to 4 (Totally agree) and T-Tests were performed. Fig. 4 distills the results from the pre-post test and Fisher Tests. The most significant difference is that after the course all students consider that they master decision-making skills associated with operations management (main learning outcome) ($p < 0.01$). Also, most students agree that they can write a structured professional document. They also declare improvements in their IT skills ($p < 0.1$).

Regarding self-awareness skills, most students agree or strongly agree that they were able to recognize and reflect on their empathy ($p < 0.1$) and to identify areas of strengths and weaknesses related to oral communication.

At the beginning of the course, 40% of the students strongly disagreed or disagreed that they were able to communicate to a large professional audience. In the end, all students agreed or strongly agreed that they mastered this skill ($p < 0.01$). The progress can be associated with the methodologies used in the course, such as POL and the Open Seminar.

After the course, there is an increase in the ability to recognize dominant personality traits and identify areas of strengths and weaknesses related to



$*** : p < 0.001, ** : p < 0.05, * : p < 0.1$

Fig. 4. Pre/post test. Pretest results above, post test below for each proposition. In the right, significance levels in the Fisher Test

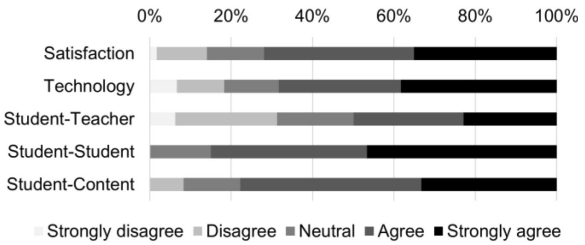


Fig. 5. Survey 1. Transactional distance. Distributions for the 4 TD scales and overall student satisfaction. The survey was adapted from [44].

interpersonal conflicts ($p < 0.05$) and oral communication. The results of this survey show evidence of accomplishment of the course's main objectives..

4.3.2 TDT Survey

Fig. 5 shows the distributions of the answers to the first survey. For details, see Appendix A.1. The highest transactional distance is obtained among students and the teacher (TDST) and the lowest between student-student (TDSS). The low TDSS allowed us to have a better classroom climate, while the results of TDST motivated the search for ways to decrease it.

The main measure taken by the teacher was to review the students' class attendance and contact those who had not attended for some time. The contact aimed to make the students feel that the teacher is concerned about them and their learning and that their absence does not go unnoticed. This resulted in some of these students returning to attend synchronously.

4.3.3 Active Modality Evaluation

Fig. 6 shows the results of the survey taken during the final week of classes. It is observed that most of the students prefer the modality of this course compared to those traditionally used.

This shows a decrease in the TDST from the previous survey, so the measures taken by the teacher had an effect on the students' perception.

Students valued the flexibility of this course, received the evaluation system well, and considered that the academic load was affordable. Furthermore, they mentioned that as the semester progressed, they were leaving aside this course to concentrate on other courses. Thus, it can be noted that students have a high academic load in their courses, but in this one, the overall load seems to be appropriate.

4.3.4 End of Term Survey

At the end of each semester, the University conducts a survey for students about the courses they participated in through U-cursos. Below are some of the opin ions left in this survey.

> "(The methodology) Given that it is a new learning method. I think there will always be people reluctant to new methods, they will feel a little uncomfortable, but it's just a matter of time before they embrace it . . ."
>
> "The teacher's methodology is highly effective for learning in a course like this. The academic load was not excessive but at the same time, the learning was quite continuous and incremental. He also made available a generous amount of his time to help the students."
>
> "I think that the self-awareness part was very interesting and innovative."

Although at the beginning some students mentioned having difficulties with some of the active methodologies proposed, they were able to adapt and take advantage of them for their learning. It can also be seen that, at the end of the term, a few students considered, as a positive trait, the teacher's concern for their learning. This speaks of a decrease in TD.

4.4 Post Term Interviews

4.4.1 4.4.1 Interviews with Students

In April 2021, interviews were conducted with 5 students via video call. The following are some of their comments made by them on the different modalities used in class and their experiences in the adaptation process.

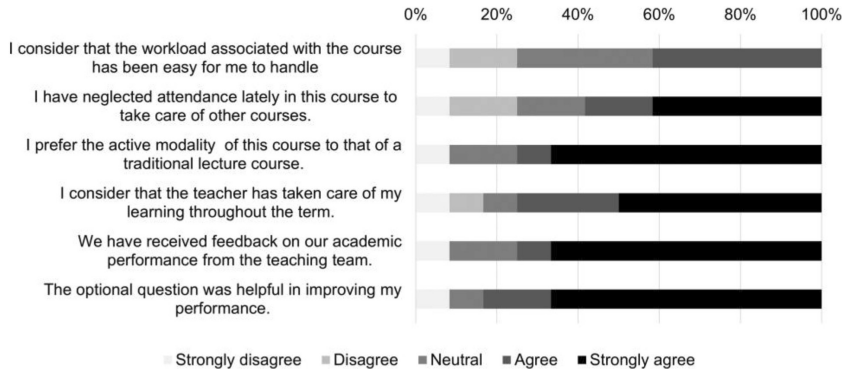


Fig. 6. Active modality evaluation. $N = 12$.

"(At the Olympics) If I didn't speak, the group would still be progressing towards the solution . . . the instance made me feel very motivated to lead."

"I think that the new modality that the teacher implemented is much valuable, yet, I feel that some elements of the traditional theory-based modality were missing."

"Being a champion is a bit stressing, you have to be active and engaged all the time, yet, I felt very good with my classmates and teacher."

"I learned a lot of Excel. It has many tools for data analysis, and now I manage many of them."

"The public seminar was a great experience. Very challenging, since we have to present results up to the challenge"

"My grandmother is on a treatment that requires going to the hospital three times a week . . . when the pandemic started I had to start accompanying her often. I had to miss classes often . . ."

"My dad lost his job right before the pandemic. He had found an opportunity, but they decided not to hire more people because of the social context. There were difficult months for my family and me."

Students understand and appreciate the active learning modalities, yet for some of them, it is not easy to adapt. A few of them show a certain resistance to active methodologies, as they are different from what they are used to. They have to participate and study autonomously, and they are not used to it. In spite of that, many feel comfortable with the classroom environment, their classmates, and the teacher. They also show signs of developing other skills, such as leadership and collaboration. Students have had to adapt to new modalities in a complex national and global context. This has an impact on their personal lives, making the adaptive process more complicated.

4.4.2 Alumni Survey

In May 2021, 12 alumni were interviewed. For a number of items, interviewees had to answer based on the following statements:

- I think it is a useful skill in the workplace ("Work usefulness").
- I think the skill was addressed and taught during my undergraduate courses ("Addressed in the curriculum").

Interviewees had to answer whether they agreed or disagreed with these statements, on a scale of 1 to 5, going from strongly disagree to strongly agree.

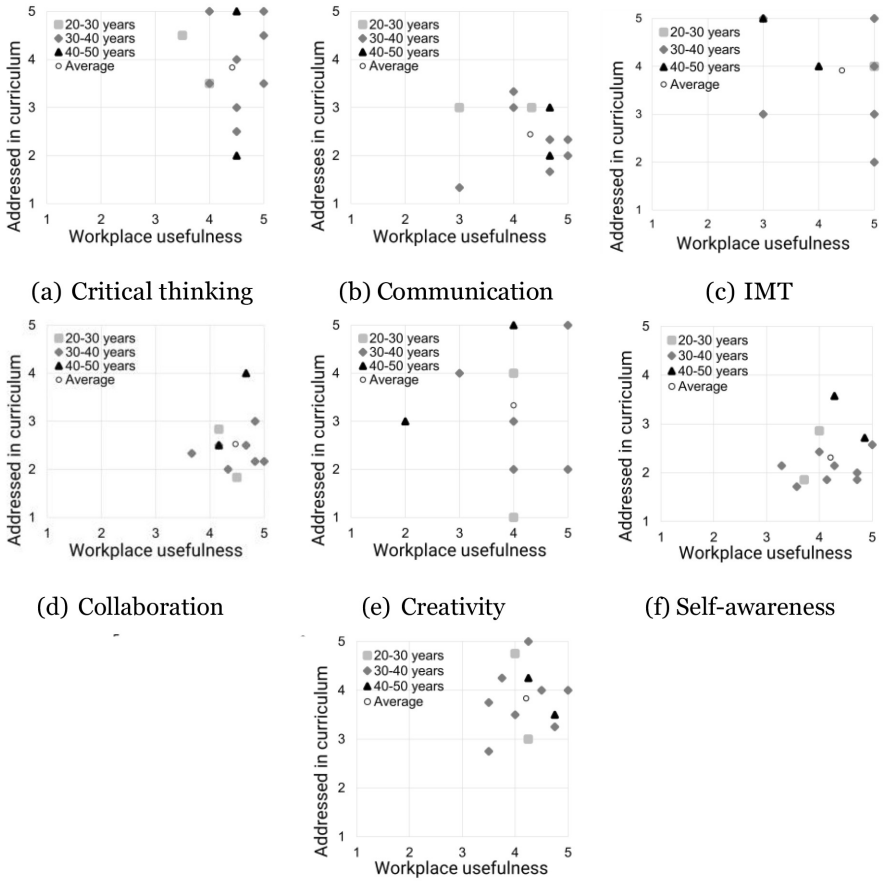


Fig. 7. Results by skills category obtained from interviews with graduates.

The items of each group (Critical thinking, Creativity, Collaboration, Communication, Professional skills, ITM skills and Self-awareness) are listed in Appendix A2. Fig. 7 shows the results obtained. The graphs show the average value assigned by each interviewee to the different categories, separated by age range. The separation was made to see if there were notable differences depending on the interviewed person's age, but no clear trend was found. The skills mentioned in the interview are useful at work. On average, professional skills have the best balance, in terms of being correctly addressed in the curriculum and being use ful in the workplace. There is also a consensus that Self-awareness skills are not vastly covered in the curriculum, but are declared to be very useful in their current jobs. The behavior in communication and collaboration is similar to the described above (although the second one has a big dispersion). On the other hand, critical thinking, IMT and creativity skills are considered very useful and correctly addressed according to their usefulness in the workplace, but with opportunities to improve their approach in the curriculum.

Fig. 8 presents the condensed results obtained for each skill, with the average score for every question (detail can be found in Appendix A.2). In particular, time management skills are presented as the most useful in the workplace, followed by the capacity to work in teams and to coordinate and plan tasks. On the other hand, research and information seeking skills are the most well addressed in engineering school, followed by critical thinking and technical skills. The least useful for the workplace is the capacity to evaluate peers, while the skills to know your predominant personality traits

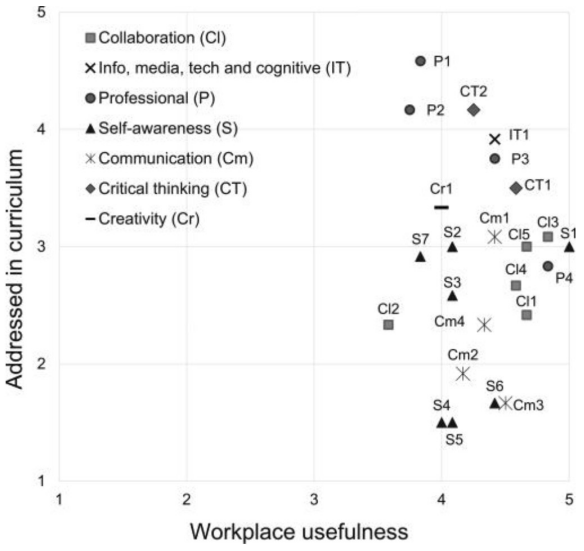


Fig. 8. Results by skill obtained from the interviews with graduates.

and to know your level of empathy are the least taught in the university.

Quotes from the interviews with the alumni are presented to show some of the recommendations and opinions they provided for the mechanical engineering curriculum.

> "(An engineer's education) requires a lot of teamwork, managing relationships with peers, leadership, planning, and learning to relate to others."
>
> "It would be helpful if teachers started teaching on how to identify the strengths of other people, and how to delegate tasks."

According to the above, the graduates think that there is a debt in the application of knowledge during the career and in the development of generic skills. Additionally, their answers show the relevance of the development of self-awareness. Regarding this type of competencies, all the interviewees agree with developing them during undergraduate studies.

4.5 Analysis

To end this section, the following is a brief analysis of the most important results. (i) Students had the opportunity to compare themselves with the rest of their peers on several self-awareness elements. That gave them the chance to get a deeper understanding of themselves. Post-test shows that students valued that opportunity. In particular, all the students agree or strongly agree with the question about knowing their strengths and weaknesses to handle interpersonal conflicts better, which involves empathy, flexibility, and critical thinking. (ii) In the first survey, the student-teacher was the highest transactional distance. The direct relationship with the teacher motivated to look for concrete ways of decreasing them. (iii) It was possible to find an AL blend that motivated students (75% preferred this modality). It was not easy to adapt to it, but students evaluated that it was not too demanding. Moreover, students recognized that self-regulation and organization were required to take advantage of this teaching initiative. (iv) The strategies introduced students to technical topics like the OM processes while learning the importance of life and career skills. (v) Students highly valued new ways of teaching. For example, 80% were happy with the use of anxiety-reducing optional questions. They also valued that the teacher cared about their stress and anxiety. (vi) Alumni opinions reinforce that IMT, professional and critical thinking skills are developed correctly in the Faculty, but as expected, there is a debt with self-awareness, collaboration and communication skills. They consider these skills the least devel-

oped in their studies, while at the same time consider them very useful in the workplace. In summary, the AL blend was well received and valued. And it is achieved to install topics that are relevant for students and alumni.

5. Discussion

5.1 Main Findings

Recognizing the limitations of our case study, the exploration with the alumni survey and interviews are in line with our expectations regarding the importance of developing XXI century skills for the current and future work market. They are not taught appropriately in the current curricula. The micro-interventions to develop self-awareness, 4Cs, and ICT skills are seen as a successful experiment. The self-perception survey shows a significant increase in self-awareness. The alumni survey confirmed their interest in developing different kinds of skills for the present and future workplace. It provides excellent motivation for research in the near future. Yet, the exercise of developing self-awareness in the students is only an exploration that needs further investigation. The results of the pre/post self-perception show positive signs regarding the value of the exercise for them. Despite the brevity of the effort to develop XXI century skills in our case study, we observe that students changed the self-evaluation of their performance in several critical aspects that are important for the future work market.

5.2 Relations with Previous Research

The integration of TD and SCT in a common framework provides ample avenues for future developments. The scenario of 2021 suggests that hybrid learning is here to stay. Merging and updating existing frameworks seems to be a reasonable bet. To the author's knowledge, no such intent has been proposed in the literature. Gained insights require further investigation, and considering potential already reported in fresh literature [30, 54].

It is evident that CO-19 and the rise of AI boost changes in education. Yet, changes have been exacerbated in Chile by its societal moment. The case study, being very limited, supports that students were open to trying new learning tools and that learning goals were achieved.

5.3 Implications and Applications

From the evidence provided in the case study, it seems reasonable to explore the use of the proposed approach to enhance student learning in Engineering Education. The exploration of skills for life and career with a small number of resources and developing SLC at different courses and at different levels in the curriculum. Increasing students' self-awareness and engagement is also a way to respond to the new deal that Chilean society is living. The chosen AL blend induces students to be protagonists of their own learning, which is similar to what has happened with citizens and their increasing demands. Being an active part of the changes is an element that will not dissolve easily. The critical thinking that students have developed and the more complex view of their role as future engineers are tools for them to join a labor market in which society has established that it cannot continue with abuses and inequalities.

5.4 Future Work

The proposed framework may be extended to a program level, beyond the course that is studied in the case study. Tighter synchronicity between engineering education and the labor market would help to continue the improvement of the proposed framework. An example is the development of entrepreneurial skills, which offers increased flexibility in the VUCA labor world. The second level of analysis is to understand how young engineers with high levels of social and cognitive skills integrate into heterogeneous professional/non-professional teams were communication skills, the need to foster intellectual stimulation in other team members, and to build coalitions are challenged [55, 56]. To mention a relevant figure, 68% of Chilean adults with finished tertiary education possess levels 1 or 2 (out of 5) in literacy [57].

6. Conclusions

The ongoing social and technological dynamics in Chile and the world show us that teaching future engineers traditional learning outcomes is not enough. Countries need conscious leaders and citizens. This puts the bar higher for engineering education programs. In that line, we present a flexible course-level methodology to face an increased need to adapt teaching-learning in the context of disruptive technological and social changes. We illustrate our approach in a senior course of mechanical engineering at Universidad de Chile. This case summarizes an integration of learning frameworks that were integrated into the volatile online environment faced during the development of the work. Results show achievement of the main learning goals with a purposeful reduction of the transactional distance between students and the content, the teacher, their peers, and the used IT. We explored self-awareness skills as a way to reduce transactional distance and prepare better students for the VUCA job market (and society)

they will face soon. The move from face-to-face to online learning may be facilitated by custom-blending different strategies that are already available in the literature.

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Appendix

A1. The Transactional Distance Instrument

Table 2. First survey. Transactional distance student-content (TDSC)

#	Item
1.	This course emphasized synthesizing and organizing ideas, information, or experiences.
2.	This course emphasized our reflection about the value of information and modelling in engineering.
3.	This course emphasized applying theories and concepts to practical problems or in new situations.

Table 3. First survey. Transactional distance student-student (TDSS)

#	Item
4.	I get along well with my classmates.
5.	I feel valued by the class members in this online class.
6.	My classmates in this online class value my ideas and opinions very highly.
7.	My classmates respect me in this online class.
8.	The class members are supportive of my ability to make my own decisions.

Table 4. First survey. Transactional distance student-teacher (TDST)

#	Item
9.	The instructor pays no attention to me (R).
10.	I receive prompt feedback from the instructor on my academic performance.
11.	The teacher has been helpful for my learning in this course.
12.	The instructor can be turned to when I need help in the course.

Table 5. First survey. Transactional distance student-technology (TDTECH)

#	Item
13.	I feel competent in using Excel to model problems of operations management.
14.	I feel competent in researching information and finding bibliographic resources for my course project.
15.	I feel that Excel has been useful for my learning in this course.
16.	I experienced frustration using Excel in this course.
17.	I feel comfortable using Excel for modelling.

Table 6. First survey. Student overall satisfaction (S)

#	Item
18.	This course has met my expectations.
19.	I experienced and learned new things in this course.
20.	The content covered in this course is interesting.
21.	I would like to take more courses like this one.

A2. Alumni Interview

The content of the interview conducted with alumni is presented below.

Personal information

1. What is your name?
2. What career did you study?
3. What year did you finish your degree?
4. What age range are you in?
   (a) 20–30
   (b) 30–40
   (c) 40–50
   (d) 50–50
   (e) 60 or older
5. Have you complemented your university studies?
6. What is your current occupation?
   (a) Company
   (b) Industry
   (c) Position
7. Is this your first job since you graduated?
8. If not, what other areas have you worked in?

Skills

The interviewee should respond based on their experience about how useful each one is on the work and if it was adequately covered in their education. The following are the statements to be answered and the scale on which they have to answer them:

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4 Agree
5. Strongly Agree

- I think it is a useful skill in the workplace (“Work usefulness”).
- I think the skill was addressed and taught during my undergraduate courses (“Addressed in the curriculum”).

The instruments used were combined and 24 skills that were related to the present study were selected. These abilities are part of the categories of the 21st century skills arch in Fig. 2.

Critical thinking

1. Capacity to identify relevant information.
2. Capacity for critical thinking.

Creativity

1. Skills to generate new ideas.

Collaboration

1. Motivating and supervising others.
2. Capacity to evaluate peers.
3. Capacity to work in a team.
4. Skills to build and maintain working relationships.
5. Capacity to listen to other people's opinion.

Communication

1. Presentation skills.
2. Skills to persuade others.
3. Negotiating skills.
4. Capacity to recognize strengths and weaknesses in oral communication.

Professional

1. Research and information seeking skills.
2. Technical skills.
3. Problem solving skills.
4. Capacity to coordinate and plan tasks.

Information, media and technology

1. Knowledge and skills in technological tools.

Self-awareness

1. Time management skills.
2. Capacity to be flexible.
3. Skills of self-evaluation.
4. Capacity to know your predominant personality traits.
5. Capacity to know your level of empathy with others.
6. Capacity to recognize strengths and weaknesses in interpersonal conflict resolution.
7. Capacity to recognize strengths and weaknesses in written communication.

Open-ended questions

1. What skills did you develop during your studies that you use most today?
2. What skills and/or knowledge did you have to learn on your own?
3. Do you think it would have been better to learn these skills during your studies or are they things that are better learned throughout your profes sional life, as needed?
4. In terms of technical skills, does your current job demand more or less of you than what you were required to do at university?
5. And in terms of generic skills? E.g. empathy, teamwork skills, leadership, etc.
6. Regarding expectations, is your current job a far cry from what you thought you were going to do when you were in university?
7. Has it been easy or difficult for you to adapt to the workplace? Why?
8. If it was difficult, what did you do to adapt (bridge this gap)?
9. In your experience, what do you think are the most important skills to develop properly in your field as a mechanical engineer?
10. Do you think those skills are the same ones that will be required in the future?
11. In conclusion, do you feel that your career provided you with the knowledge and skills necessary to develop optimally in the workplace? Answer for each category.
    (a) Collaboration
    (b) Critical thinking
    (c) Effective communication
    (d) Creative thinking
    (e) Self-awareness
    (f) Professional
    (g) IMT
12. What improvements would you propose to the Mechanical Engineering department
    chair? Mention 2.
13. Is there anything we have not asked that you would like to comment on?