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Design Thinking as an Approach to Guide a More Humanized Learning Process in Engineering Teaching

Evandro Minuce Mazo[1], Renelson Ribeiro Sampaio[1], Cristiano Vasconcellos Ferreira [2]

[1]Centro Universitario SENAI CIMATEC, Salvador, BA, Brazil.
[2]Universidade Federal de Santa Catarina, Campus Joinville, Joinville, SC, Brazil.

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***Abstract*— Changes in digital transformation have been increasingly accelerated. Consequently, educational institutions face a significant challenge in preparing individuals for the current and future job market. These institutions must support students in developing transversal skills that can meet the demands for work and social life. Thus, the objective of this study is to present a learning model that combines the challenge-based learning methodology with the design thinking approach as a strategy to conduct a more humanized learning process and promote the development of transversal skills. This study was conducted with 23 students pursuing mechanical engineering. The learning model was well-rated by the students, and the development of transversal competencies were evaluated.*

I. INTRODUCTION

According to (Mendonça, de Andrade, & Neto, 2018), digital transformation has been breaking paradigms in companies, business models, education, and society, owing to the considerable innovation in information and communication technologies such as cloud computing, Internet of Things, and artificial intelligence.

According to (Borgatti Neto, 2007), we are experiencing a transition from a mechanistic paradigm to a different paradigm of complexity. According to (Snowden & Boone, 2007), complex contexts are disordered, no apparent cause-and-effect relationship exists, and the path forward is determined based on the integration of emerging patterns. In this scenario, a comprehensive understanding of the context is a condition for establishing changes in an environment of growing uncertainty. Thus, owing to the technological revolution, which imposes a significant cognitive challenge, the transformation of thinking from a mechanistic, linear, and fragmented pattern to a more complex, integrative, and collaborative pattern in a network is crucial.

An important consideration by (Noweski et al., 2012) is that scientific, business, and social organizations lack skills and competencies for the 21st century; however, the educational system is still focused on cognitive skills, despite recognizing the need to develop new values and social attitudes that can meet the demands of work and social life.

This condition allows a student to move with greater security from their academic life to work life, both in relation to their first work and future experiences.

Educational institutions need to maintain pace with the changes in the world, evolve quickly to be more relevant, and ensure that everyone learns competently. Consequently, it is necessary to rethink the curriculum, methodologies, role of the teacher, and connection with society and organizations, awaken students' autonomy, interest, and an empathetic and reflective look at the context, and stimulate the development of transversal and attitudinal skills through the connection of students with different learning experiences.

Learning models must be applied to make the process more contextualized, experimental, and reflective, to contribute to the development of transversal skills.

The aim of this study is to present a learning model that combines the challenge-based learning (CBL) methodology with the design thinking (DT) approach and shows how this can strategically guide the learning process.

The concepts adopted for transversal competencies, DT approach, and CBL methodology are shown. The proposed learning model, its application, and the results achieved are described.

II. TRANSVERSAL SKILLS

In the case in which the definitions of competencies have multiple characteristics and no general established consensus exists, as observed in relation to transversal competencies, in this study, we will refer to the model of (Silva & Teixeira, 2012), which is supported by the reference de (Moreno, 2006) define transversal work competencies as attitudes, capacities, and skills of the individual that contribute to effective performance in different work situations, being transferable from one context to another throughout life.

Based on the models of (Moreno, 2006) and (Silva & Teixeira, 2012), the following transversal competencies were included in this study: empathy, collaboration and teamwork, written communication, oral communication, problem-solving, organization of the work, creativity, and autonomy. However, it is worth noting that, as discussed by (Moreno, 2006), it is difficult to know the extent to which soft skills can be developed. In this work, the premise is that using learning practices that contribute to the exercise of transversal skills is a way to generate awareness and enhance the development of those skills.

III. DT APPROACH

DT is a process of investigation and development of a solution, the result of critical and creative thinking, centered on the needs of the user, which integrates a holistic and innovative look, based on a new approach to problems in obtaining information, analysis, and, consequently, solutions based on knowledge generated from an integrative perspective. Therefore, this approach occurs in the stages of designing a solution, which contributes importantly to the educational context. (Brown, 2008; Dunne & Martin, 2006).

According to (Buchanan, 1992), the DT process is divided into two distinct phases: The understanding and definition of the problem and the solution to the problem. The understanding and definition of the problem is an analytical sequence that determines all elements of the problem and specifies all the requirements of a successful solution. The solution to the problem is a synthetic sequence in which the various requirements are combined and balanced against each other, generating the concept and proposal of a solution that meets the expectations of users. The DT approach must be made broadly, understanding, at first, the problem and the context in which it is inserted and later, reflecting on the solution.

It is possible to find in the literature different terminologies for the DT, such as a process, an approach, a method, a system, and a way of thinking. In this work, we consider DT as an approach. To meet the DT approach, the solution to a problem must meet and balance the following criteria: being desirable by the user, economically and environmentally viable, and technologically feasible. In addition, it must meet the following principles: centered on the man, with a collaborative, interactive, and iterative approach (Aranha & SANTOS, 2016; Buchanan, 1992; Dunne & Martin, 2006; Martins Filho, Gerges, & Fialho, 2015; Razzouk & Shute, 2012).

As regards problem-solving, it is important to emphasize that the DT approach originates from the DT that flourished in the1960s and finds a fertile field to solve the perverse problems, as addressed by (Dorst, 2015; Rittel & Webber, 1973).

According to (Rittel & Webber, 1973) DT is an adequate approach for dealing with perverse problems. Perverse problems are a class of social system problems that are poorly formulated, where information is misunderstood, many customers and decision-makers have conflicting values, and the ramifications of the system are completely misunderstood. Moreover, it highlights that most of the problems addressed by designers are perverse problems, as well as many contemporary problems and challenges. In summary, it is observed that the investigative and reflective look at perverse and open problems demands the competence of empathy, understanding the context and the user, which is facilitated by the ability to ask the correct questions, which is essential for the training of reflective professionals who will act in the 21st century.

DT has diversified and evolved in recent decades. It was first introduced by Richard Buchanan in 1992, and is no longer an approach used only by a designer but is equally being used in the business environment, education, etc. (Buchanan, 1992) highlights that DT works as a mental model of how a problem is approached. It shifts the focus of how a problem is approached, from the focus of the creator to the focus of the user, as a process that focuses on the user and their needs, seeking to understand, empathetically, what generates value. Empathy and full understanding of the context are the greatest strengths of the DT approach.

The DT approach is divided into cycles or stages, with different authors adopting different nomenclatures to name these stages. In this work, the following nomenclatures and stages are used: empathy, definition, ideation, experimentation, and evaluation (Charosky et al., 2018; Marin, Hargis, & Cavanaugh, 2013). Fig. 1 shows the major steps of this approach.

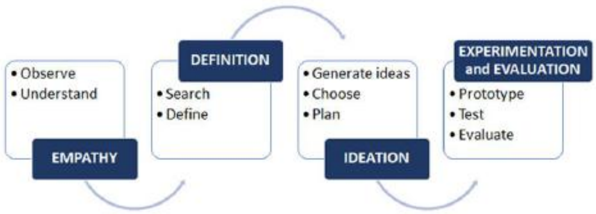

Fig. 1: DT approach. Source: Author (2020)

In the empathy stage, the objective is to generate an understanding of the problem (formulate the problem) and qualify the challenge to be overcome, based on the needs of the user. At the definition stage, the objective is to research and define the requirements and characteristics that need to be met and functions that need to be performed by the solution. The ideation stage aims to generate ideas about possible solutions that will be used for the development of a prototype and solution construction. Finally, the experimentation stage aims to test the prototype, obtain feedback, evaluate the learning process, develop the solution, and publish the results obtained.

Finally, the DT provides a process of reflecting on an action, contributing to structuring the teaching-learning process that involves everyone, students, teachers, and target audience (users of the solution), in a high-level process of understanding the context (problems and challenges), and development of adequate solutions that adhere to the reality under study (realistic solutions), guided by deductive, inductive, and CBL (Dunne & Martin, 2006).

IV. CBL METHODOLOGY

The first efforts to build a CBL methodology were published in 2008 through the initiative called Apple Classrooms of Tomorrow (ACOT). This initiative was an effort that collaborated with the education community and aimed to identify the basic principles for 21st century schools, as well as helping schools move closer to creating a more appropriate type of learning environment to increase the engagement of new generations with schools (M Nichols & Cator, 2008).

According to (Santos, 2016), CBL was built on the practice of problem-based learning (PBL), a model where students work with real-world problems in collaborative teams. CBL, however, goes further, as it encompasses the PBL concepts and the need to develop and test a prototype, which requires students to materialize the solution, thus developing their entrepreneurial capacity.

CBL is a multidisciplinary educational approach that encourages students to collaborate with other students and teachers to seek solutions to real-world problems. To work with CBL, students need a clear understanding of the problem, those involved and the challenge, they study the subject, research, debate, develop solutions, and put them into practice (Ferreira, Flório, & Iaralham, 2016). CBL advocates those students must learn with intense support and participation from teachers and experts, confronting students with a relevant and open problematic situation, where a real solution is required; Consequently, the student must develop a deeper knowledge of the topics they are studying to apply them to the solution of the problem.

CBL is a pedagogic approach that actively involves the student in a real situation, a challenge from society, related to the context where the student belongs; therefore, this student is emotionally involved, which implies understanding the problem and the implementation of an innovative solution (de Monterrey, 2015).

CBL takes advantage of the interest of the students in giving practical meaning to education, the development of transversal skills that are extremely significant to the context, such as collaborative and multidisciplinary work, decision-making, advanced communication, ethics, and leadership (Malmqvist, Rådberg, & Lundqvist, 2015).

According to (Johnson & Brown, 2011; Santos, 2016), CBL helps to improve several areas of knowledge. Ninety percent of teachers reported significant improvements in areas such as leadership, collaboration, flexibility, creativity, problem-solving, and innovation. Furthermore, 75% of teachers cited an increase in student engagement.

The authors (M Nichols & Cator, 2008) describe the CBL methodology in components, which we describe in this paper as steps, which are key to the CBL process. It starts with a big idea and moves on to the following steps: definition of the essential question, the definition of the challenge, reflecting on the guiding questions, definition of the guiding activities, identification of the necessary resources, development of the solution, implementation and evaluation of the solution, and finally, reflection and documentation of the results achieved, and the solution development process. According to (Mark Nichols, Cator, & Torres, 2016) the challenges can be of different types: nano challenge, mini challenge, challenge, and strategic challenge, and this depends on the time, focus, and intensity of the intended learning experience, as well as the scope of use of the CBL, that is, if all the stages of the CBL will be used or only parts. In fig. 2, based on the proposal of (M Nichols & Cator, 2008), a scheme that represents the framework of the CBL methodology is illustrated.

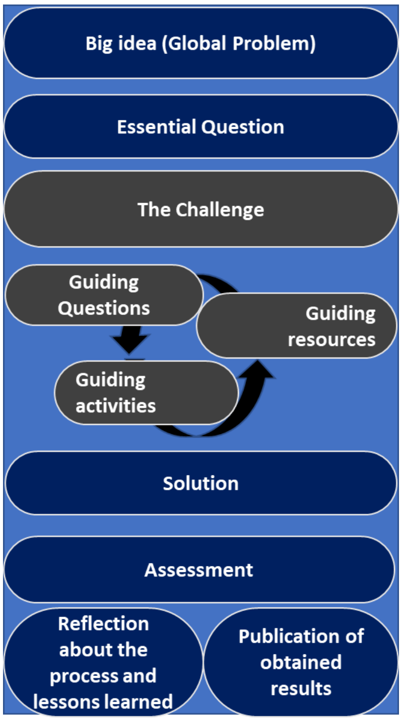

Fig. 2: framework of the CBL methodology. Source: Author (2020)

In the learning model proposed in this work, which is the result of a doctoral research, the definition of the challenge is associated with assistive technologies and works as a strategy to engage the student in the learning process and develop a solution that aims to address real pain, where the performance of a student can make a difference. According to (Nichols et al., 2016) challenges create a sense of urgency and stimulate action; thus, the selection of challenges is strategic to generate meaning in the learning process.

V. LEARNING MODEL (APRENDESIGN)

The proposed model, called APRENDESIGN, seeks to conduct the learning experience to stimulate the interaction of the students with the environment through a reflective process, guided by pragmatic reasoning.

The proposition of APRENDESIGN is based on assumptions, which are described as follows:

- Assumption 1 – Solving real challenges requires the enhancement of collaboration between the different actors involved in the learning process: students, teachers, experts, problem-solving users, and other stakeholders (Calvo Centeno, Galván Vallina, Gutierrez Duarte, & Rodríguez Gómez, 2019; Malmqvist et al., 2015; Membrillo-Hernández et al., 2019; Pathak, 2018).
- Assumption 2: The development team must devote time to understand the challenge before embarking on a solution through an interactive and iterative process, as recommended by DT (Buchanan, 1992; Noel & Liub, 2017).
- Assumption 3 – Working with real challenges contextualized with the reality of the student increases engagement and improves the learning process, according to (Johnson & Brown, 2011; Santos, 2016).
- Assumption 4 – The learning experience must promote an investigative process based on reflection and pragmatic reasoning, according to (Dewey, 1933; Schön, 2000).

Based on these assumptions, a learning model that combines the CBL methodology with the DT approach is proposed, as illustrated in Fig. 3.

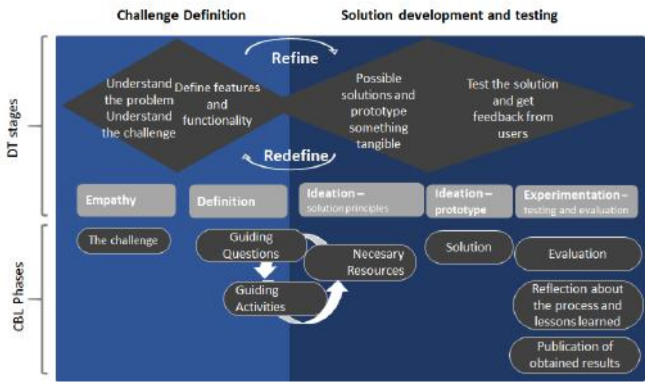

Fig. 3: APRENDESIGN - framework of the proposed learning model that combines CBL with the DT approach. Source: Author (2020)

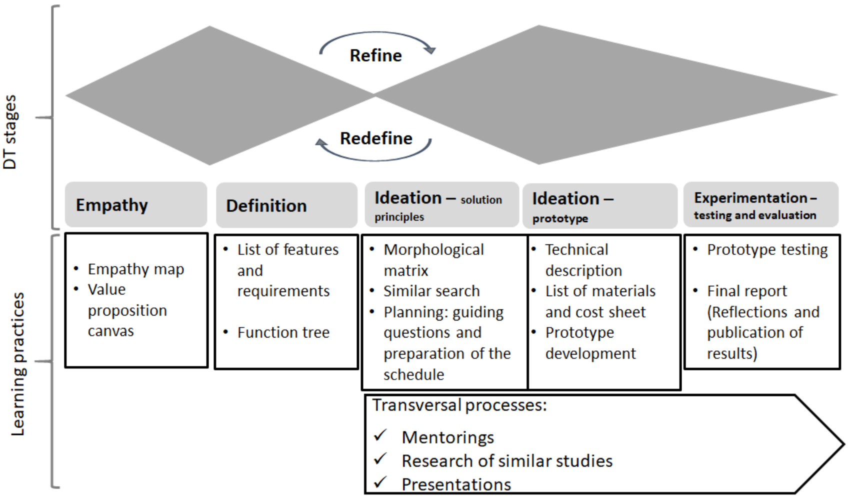

Fig. 4: details of the learning practices used to develop the solution (projects). Source: Author (2021)

The model is organized at the top with DT stages and the bottom with CBL stages. On the left side, a space for the understanding and definition of the challenge (empathy and definition) exists and on the right side, the solution development and testing (Ideation, Experimentation, and Evaluation), having as relevant points, the solution to be developed from the perspective of the user, contributing to the humanization of the learning process. Furthermore, it is worth noting that the DT approach helps to provoke different perspectives to build a more plural and complete process, adequate to the challenges imposed by the complex environment we are living in today. Model description based on DT stages.

- Empathy stage: it aims to generate an understanding of the problem (formulate the problem) and define the challenges to be overcome, as well as generate meaning and student engagement with the project development process and learning.
- Definition stage: seeks to understand the requirements, features, and functionalities that the solution (prototype) should meet. The most important aspects of this stage are questions, not the search for a solution, and this deserves a lot of attention from the teachers, as it is common for students to go to the solution without properly understanding the problem to be solved.
- Ideation stage – solution principles: it aims to generate ideas about solution principles to provide a solid foundation for the development of a technically viable, user-desirable, and executable solution.
- Ideation stage – prototype: It aims at building a solution that meets the expectations of the users, that is, the construction of the prototype.
- Experimentation stage – testing and evaluation: The objective is to test the prototype, obtain feedback, and then evaluate the learning process and the development of the presented solution. It is also part of the result publication stage.

At the end of this process, a prototype must be developed, tested, and evaluated as a solution to the problem presented.

In APRENDESIGN, the DT organizes and guides the learning process, as a guiding thread, in stages (empathy, definition, ideation, experimentation, and evaluation), whereas the CBL methodology instrumentalizes the process through stages (challenge, guiding questions, guiding activities, necessary resources, solution, evaluation, and publication of the results obtained and reflection on the learning process), supported by the use of learning practices, which guide, from the understanding of the challenge, development, and solution testing to fulfill all stages of DT.

As a gap in the DT approach, a need to use methods and tools to instrumentalize each stage of the approach exists, as the DT presents the concept of what to do, through its stages but does not detail how to do it and this led to the birth of CBL. In addition, through CBL, the learning process is oriented toward solving a real challenge and through the stage of the definition of the guiding questions, as the students define what is necessary to learn to solve the challenge, generating meaning in the learning process.

The operationalization of the learning model is supported using learning practices, which guide the understanding of the challenge and development of the solution, to fulfill all stages of DT, as shown in Fig. 4.

The Fig. 4 describes the learning practices used in each stage of the CBL to perform the stages of DT, as well as the strategies to monitor and guide the teams as regards the development of the project and prototype, through mentorships and presentations, which occur after the definition stage.

The learning practices are presented and exercised through workshops, which are structured as teamwork, assisted by teachers, lasting 2-3 hours for discussion, understanding, and structuring of relevant information for the development of the project. Mentorships are the moments where teachers guide the teams as regards the deliveries of each workshop, prototype development, and support of the structuring of the presentations. Here, it is also important to work on the engagement of students with the learning process and project development.

The presentations are moments where the teams formally present, to a group of guiding professors, the results achieved so far. Presentations are thermometers for students and teams to critically assess the progress and quality of projects under development, in a high-level process of reflection on the project development process and the quality of deliverables. Similar studies have also been conducted, which is a benchmarking process aimed at seeking references and inspiration for the development of the solution.

VI. EVALUATION SYSTEM

To assess the impact of the proposed learning model on the development of the project and the development of the transversal skills of students, an evaluation system comprising student and teacher assessments was developed. A graphical representation of the evaluation system is shown in Fig. 5.

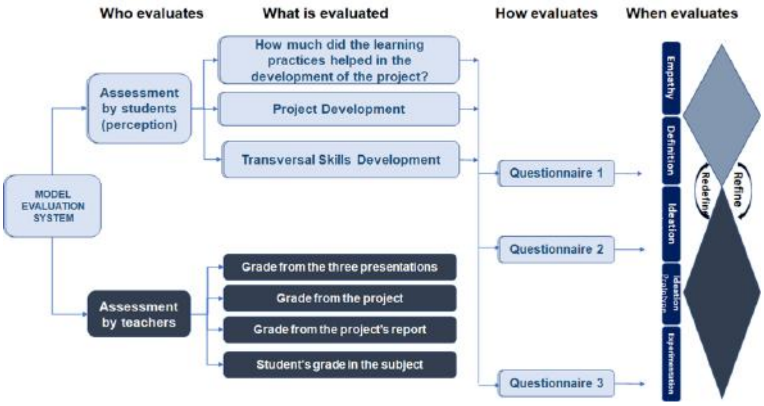

Fig. 5: representation of the APRENDESIGN evaluation system.

Source: Author (2021)

Learning practices – Used to conduct the project in the context of mechanical engineering.	**Learning Outcomes** - Results (impacts) achieved in the perception of students and evaluation of teachers, during the development of the project.
• Value Proposition Canvas • List of features and requirements • Function tree • Mentorship • Initial presentation • Morphological matrix • Planning: guiding questions and preparation of the schedule • Research of similar studies • Intermediate presentation of the project • Technical description • List of materials and cost sheet	• Level of problem understanding and solution definition • Level of the solution conceived by the team • Quality of time and resource management by the team • Level of interest in using the learning model in other subjects • Level of satisfaction with project delivery • Initial presentation grade • Intermediate presentation grade • Final presentation grade • Grade of the final project report • Grade of the project “Mechanical Engineering Challenge" •Grade of the introductory mechanical engineering subject

• Prototype development • Final presentation of the project	

Fig. 6: learning Practices versus Learning Outcomes

Student assessment was performed using three self-assessment questionnaires. The evaluation of the professors was a set of grades attributed to the three presentations given during the semester, the project developed, the final report of the project, and the grade referring to the subject of Introduction to Mechanical Engineering.

The questionnaires used to assess learning practices, project development, and the development of transversal skills were applied thrice per semester using the Google Forms tool; it always occurs after the presentations of projects, which are represented in Fig. 6. A Likert scale was used to assess the questionnaires, in which scale 1 corresponds to the lowest score and scale 5 corresponds to the highest.

To structure the data analysis and evaluation model, a comparative framework is presented between the learning practices used and the impact of the use of these practices in the project development and in the development of transversal skills by students. Fig. 6 shows a proposed structure in a way that describes on the left side the questions contained in the questionnaires relating to the learning practices used during the development of the project, and on the right side, the questions contained in the questionnaires and other evaluation items relating to the intended learning outcomes.

It is noteworthy that, through the data analysis based on learning practices versus learning outcomes, when it comes to correlation, the scenarios that may occur are:

- Positive correlation: the higher the learning practice scores, the higher the learning outcomes.
- Negative correlation–an indication that the practices are not adequate or the way these practices are applied should be reviewed, as the intended results are not being achieved. It is important to emphasize that the opposite also deserves attention, as it may indicate that, independently of the practices, the learning results occur, and this demands an analysis of the process.

Further, it should be noted that the performance of this assessment from the perspective of teachers, with the active participation of students as subjects impacted by the learning process, is relevant because it allows us to evaluate whether the intended learning objectives, from the perspective of teachers and students, are being met.

VII. APPLICATION AND RESULTS OF THE APRENDESIGN

APRENDESIGN was applied in the discipline “Mechanical Engineering Challenge,” which was formed by Mechanical Engineering students from SENAI CIMATEC, mostly students in the 1st semester. SENAI CIMATEC is one of the major technologies and innovation complexes in Brazil that currently comprises a technical school, university center, and a technological center.

The subject project, “Mechanical Engineering Challenge,” which focused on solving real challenges of assistive technologies, was developed in partnership with the *Centro de Reabilitação das Obras Sociais Irmã Dulce* (CER/OSID), a psychomotor rehabilitation center, reference in Salvador-Bahia.

At the beginning of the semester, CER/OSID representatives presented several demands for assistive technologies that contributed to the independence and inclusion of patients. Based on these challenges, students organize themselves into teams, with an average of five participants, and then begin the development of the project. Each team refined their essential questions and defined the challenges they would work with. In the proposed model, the qualifications of the essential questions and challenges are performed by the teams with the support of the professors and proponents of the challenge. After the challenge definition, the teams proceed with the definition of the requirements, features, and functionalities that should be presented as a solution. Subsequently, the principles of solutions that will be adopted are defined, and the preparation of technical description and the development of the prototype.

Fig. 7 shows an image that represents solutions developed by the teams in 2019. Owing to the COVID-19 pandemic in 2020, the prototype test could not be performed. As previously mentioned, this work is part of doctoral research, and the application and evaluation of APRENDESIGN has been done since 2018.

The survey data refer to the application of the proposed learning model in the “Mechanical Engineering Challenge” project class, held in the 2nd semester of 2020. The class comprised 25 students, 23 of whom responded to the survey. In addition to testing the proposed learning model, the objective of this evaluation was to evaluate the impact of the model on the development of projects and transversal skills.

Fig. 7: assistive technology solutions developed by students participating in the project that adopted APRENDESIGN as a strategy to guide the learning process.

Source: Author (2019).

Based on the research, it is worth noting that all learning practices that constitute APRENDESIGN were well-evaluated by students, with an overall average grade of 4.50, on a scale from 1 to 5, where:

- Grade 1 means the learning practice helped very little.
- Grade 2 means the learning practice helped a little.
- Grade 3 means the learning practice helped
- Grade 4 means the learning practice helped reasonably well.
- Grade 5 indicates the learning practice helped very well.

Table 1 Represents the statistical evaluation of each learning practice evaluated, with the value proposition canvas, technical description, presentations, and function tree being the best-evaluated learning practices.

Table 1: Description of the average grade, median, mode, and standard deviation of learning practices evaluated by students

Learning practice evaluated	**Average Grade**	**Mode**	**Median**	**Standard Deviation**
Value proposition canvas	4.74	5	5	0.45
List of features and requirements	4.52	5	5	0.51
Function tree	4.57	5	5	0.59
Morphological matrix	4.48	5	5	1.12
Planning: guiding questions and preparation of the schedule	4.22	4	4	1.30
Research of similar studies	4.39	5	5	1.22
Technical description	4.65	5	5	1.28
List of materials and cost sheet	4.39	5	5	1.28
Mentorship	4.46	5	5	1.04
Presentations	4.58	5	5	1.03

When the students were asked why the learning practices helped in the understanding of the challenge and development of the project, they responded as follows:

- The learning practices helped us to understand the challenge as they helped us to reorder our thoughts.
- All learning practices used by the team helped in the progress of the project. In view of the relationship difficulties owing to the pandemic, the practices served as a communication guide.
- The learning practices facilitated the visualization and understanding of the project, such as where we should start, how to do it, what are the goals, and how to develop a quality project, aiming at an improvement of the quality of life of patients.
- They helped us to better see the problem and the needs of users, which was important in the precise development of the project.

- The learning practices used in the "Mechanical Engineering Challenge" helped us to understand the challenge and the need for the project; from these practices, we had to have more empathy with the project and the beneficiaries of the project.
- The learning practices gave an even greater immersion to our project, migrating our theoretical knowledge to a more practical area; thus, we could get an idea of how our walkway will help in the daily lives of patients.

In the case of the project development, the evaluation was generally satisfactory, and on average, the grade given by the students for the understanding of the problem by the team and the definition of the solution was 4.08 (clearly identified the need and reasonably understands the characteristics and requirements demanded by the solution); the quality of the solution designed by the team was 3.35 (the team has already identified the solution principles; however, we still need to better understand how the entire project will work), the ability to plan and organize the work for the development of the project was 3.39, (the team knows what they have to do and can better plan what they need to learn to develop the project and the principles of chosen solutions), the degree of satisfaction with the delivery of the project was 4.09, with high satisfaction, it was considered that they met the expectations of the user. When students were asked about their interest in using the learning model in other subjects, the average score was 3.96 (a vast majority of students expressed their interest in using the learning model in other subjects); these data are represented in Fig. 8. Therefore, it can be said that APRENDESIGN helped in the development of the project and was well-evaluated by the impacted students.

In addition, when the students were asked if they would use the learning model in other subjects and their reasons, they responded as follows:

- Helps in the matter of interest, students have more fun and seek to learn more about the subject.
- It would be used in certain disciplines for greater engagement and understanding of the content present in the discipline.
- This is a more dynamic way of learning.
- Learning is more interesting when it is dynamic.
- Because, in this way, we have a follow-up that helps us to achieve our objectives, principally through mentorship.

From the testimonies of students during project presentation, the importance of connecting the project with the real challenge presented by CER/OSID is observed, which involves and engages students as it represents demand from the society where the role of engineering can make the difference. It is often highlighted by students that social projects (assistive technologies) mobilize teams and encourage students to get involved, both in understanding the needs of users and in the search for solutions that can make a difference in the lives of people; this process has been very relevant to humanize engineering education, as well as providing an approach that highlights the need for a more attentive and curious look to broadly understand the role of engineering in the search for solutions to social challenges.

In addition to the assessment of learning practices and project development, the students assessed the development of transversal skills, and the assessment was very positive. The development of all transversal skills that make up the learning model was well-rated by students on a scale of 1 to 5, where.

- Grade 1 means the transversal competence has not been developed.
- Grade 2 means the transversal competence has been poorly developed.
- Grade 3 means the transversal competence has been satisfactorily developed.
- Grade 4 means the transversal competence has been well-developed; and
- Grade 5 means the transversal competence was well-developed with a positive emphasis.

The three transversal skills that obtained the best scores, on average, were respectively empathy (average grade 4.46), oral communication (average grade 4.39), and problem-solving (average grade 4.34). The competencies with the lowest grades, given by the students, were respectively time organization (average grade 3.93), written communication (average grade 3.94), and autonomy (average grade 4.08). It is observed that even the competencies less highlighted by the students obtained a very expressive score, all above 3.93, that is, 78.6% of the maximum score. Fig. 9 shows the notes described earlier.

In addition, the deepening of the analysis of the results and with the aim of correlational analysis, based on figure 8, is presented in Table 2. The left side comprises the grades given by the students, referring to how much the learning practices used helped in the development of the project. The right side comprises learning results based on the perception of the students and the evaluation of the professors. It is noteworthy that the items vary at each stage of the project because different learning practices are used, and the learning outcomes also vary. Through this analysis, it is possible to establish a correlation between how much learning practices contribute to the development of the project.

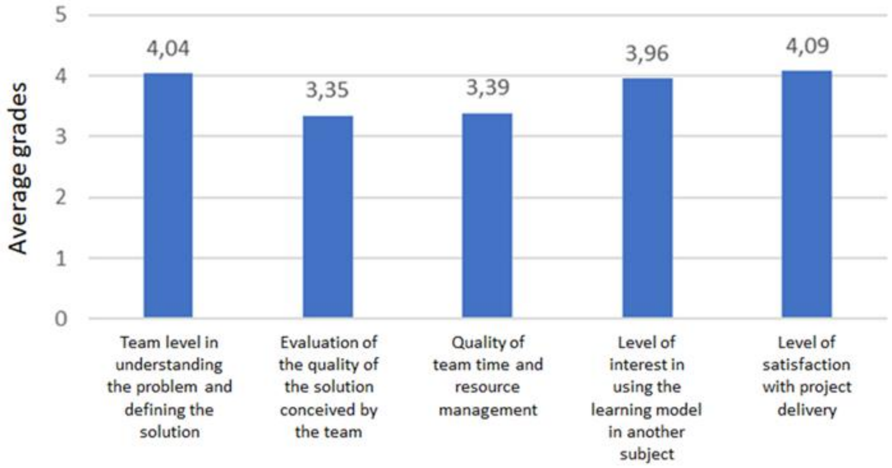

Fig. 8: Students evaluation regarding the project development

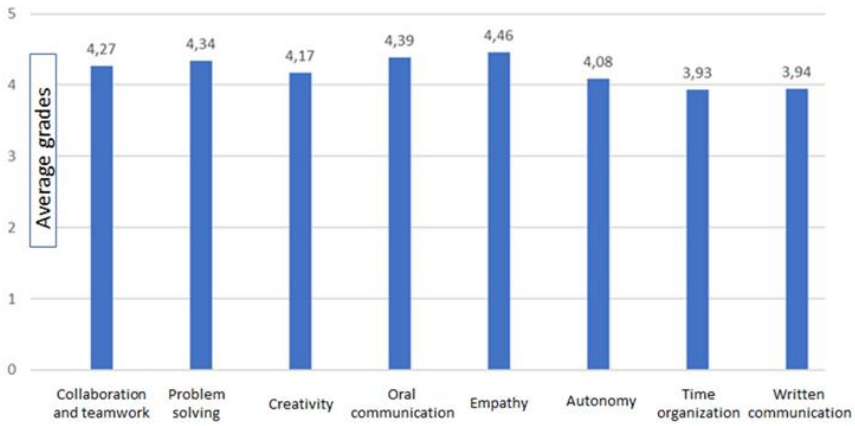

Fig. 9: Average grades based on the perception of the transversal skills development of students

This analysis of the values (subtotal) of each column contributes to a reflection on the part of teachers, to verify whether the use of learning practices should be reconsidered in terms of content or the way it has been applied, making it possible to identify which practices or learning outcomes are more in need of attention, becoming a reference to direct the necessary efforts.

To structure an evaluation proposal to assist in the analysis of the results in Table 2, on the next page, the following level of correlation between learning practices and the learning outcomes achieved by students was adopted:

- If the difference between the subtotal value of learning practices and learning outcomes is less than or equal to 10%, a good correlation exists between the practices and the results achieved; that is, it is considered that the practices lead to results.
- If the difference between the subtotal value of learning practices compared to learning outcomes is greater than 10% and less than 20%, a medium correlation exists; that is, it is considered that a promising result exists in terms of practice that leads to learning outcomes.
- If the difference between the result of the subtotal of learning practices compared to the learning results is greater than 20%, this result is of low correlation; that is, it is considered that the result is vulnerable and lacks attention on the part of the teacher to analyze what should be adjusted in practice or in the method to achieve a greater correlation.

Note that the aforementioned values are an indication and may vary based on the class profile in terms of knowledge and experience.

Based on the results presented in Table 2, it is possible to verify the alignment between the learning practices used, in comparison with the quality of project development, in the perception of students and teachers. The correlational analysis of the intermediate stage draws attention; the difference between the subtotal of practices and results is 0.78 or 17.7%, and the difference in the other stages is smaller. In the first stage, it was 0.45 or 9.8%, in the final stage it was 0.49 or 10.8%, and the difference in the consolidated result was 0.58 or 12.9%, driven by the result of the intermediate stage.

This result may indicate that the intermediate stage lacks a more refined analysis; to identify the reasons that led to this difference, when compared with the other two stages, as mentioned earlier, it should be evaluated whether the practices were not adequate or if they were applied inappropriately to achieve the intended result.

For the result in question, the reflection pointed to the need to improve the application of the morphological matrix and planning: guiding questions and elaboration of the schedule; consequently, workshops 3 and 4 were remodeled and the conduct was adjusted to improve the articulation between workshops, using the morphological matrix as input for the planning of the guiding questions and preparation of the schedule.

Finally, through the evaluation system, it was possible to verify that the learning practices used by the proposed model were well-evaluated by the students, all with a grade higher than 4.22, out of a maximum of 5, contributing significantly to the development of the project. It was also possible to verify that, according to the students, during the development of the project, all the transversal competencies evaluated were well-developed, with the lowest average score of 3.93, out of a maximum of 5. Another highlight is the high interest of students in using the proposed model in other disciplines.

Table 2: Correlational analysis between how much the learning practices used helped in the project development compared to the quality of project development

2020S2 – Initial Stage			
Learning practices	Grades	Learning outcomes (Project development)	Grades
Q3: Value proposition canvas	4.74	Q9: Team level in understanding the problem and defining the solution	4.04
Q4: List of features and requirements	4.52	• Initial presentation grades average	4.22
Q5: Function tree	4.57		
Q6: Mentorship	4.44		
Q7: Presentation	4.61		
Subtotal	4.58	Subtotal	4.13
2020S2 - Intermediate Stage			
Q2: Morphological matrix	4.48	Q9: Level of the solution conceived by the team	3.35
Q3: Planning: guiding questions and preparation of the schedule	4.22	Q10: Quality of time and resource management by the team	3.39
Q4: Technical description	4,44	• Intermediate presentation grades average	4.13
Q5: Research of similar studies	4.39		
Q7: Presentation	4.48		
Subtotal	4.40	Subtotal	3.62

2020S2 – Final Stage			
Q2: Technical description	4.65	Q7: Level of interest in using the learning model in other subjects	3.96
Q3: List of materials and cost sheet	4.39	Q9: Level of satisfaction with project delivery	4.09
Q5: Mentorship	4.48	• Final presentation grades average	4.38
Q6: Presentation	4.65	• Final report grades average	3.90
		• Project grades average	3.96
		• Average student grades in the introductory mechanical engineering discipline	4.00
Subtotal	4.54	Subtotal	4.05
Semester average	4.51	Semester average	3.93

VIII. CONCLUSION

A learning approach that promotes a more contextualized, experimental process, guided by pragmatic reasoning and a real challenge, presents better conditions to contribute to the learning process and the development of transversal skills. In this context, the DT combined with the CBL methodology has an important approach to contribute to the development of relevant competencies for 21st century actors. In addition, it is worth noting that working with socially appealing challenges has considerable potentials to engage and involve students in the process, as well as generate a special motivation that contributes to the improvement of empathy and consequently humanizing the process of project development. The evidence of the presented approach can be seen in the results of this research, which shows, in the perception of the students, how much the proposed model helped in the development of the project and contributed to the development of transversal skills. Based on the teachers, it shows the positive evaluations of the quality of deliveries and maturity of the projects during the semester.

The contribution of the evaluation system, based on learning practices used compared to the learning results achieved allows the teacher, during and at the end of the process, to evaluate and reflect on the impact of each practice used, subsidizing information to improve the learning process.

In the management of the learning process, teachers can identify and develop learning practices that lead to more successful futures for all students, which is possible through continuous assessment and with the effective participation of students, active subjects of the process, on the pertinence and adherence of the learning practices used and how much these have supported the development of projects and transversal skills, which can help the teacher to identify which practices and approaches should be reviewed such that the intended learning objectives can be achieved.

It is also worth noting that the model was designed to be applied under normal conditions of social relationships; however, owing to the pandemic, the test was performed under adverse conditions owing to social isolation, which occurred because of the Covid-19 pandemic, and some reflections are presented. The lack of eye contact makes it difficult for students to emotionally engage with the challenge, reducing the bond created between students and potential users of the solution, which makes it difficult for the students to understand the problem and the context.

To date, the study has been performed with a limited sample; thus, new applications are indicated, with different groups, to improve reflections and records on the proposed learning model and its use. The correlation between learning practices and learning outcomes should be considered, that is, what difference between practices and results may indicate that the correlation is strong, medium, or weak.

Finally, the proposed learning model can be applied in different learning contexts, different types of projects with different student profiles, and consequently, it is necessary to assess which learning practices are the most appropriate to instrumentalize the process and support in reaching the intended learning objectives. Based on this statement, it is highly recommended to use this model in other contexts to improve the understanding of the impact on project development and on the development of transversal skills.

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