

Development of transversal skills in mobility engineering students

Desenvolvimento de competências transversais de estudantes de engenharia da mobilidade

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ABSTRACT

The education of engineers in the field of mobility presents several challenges, particularly regarding the promotion of skills that go beyond specific knowledge. It is essential to also foster the development of transversal competencies, such as communication, creativity, and teamwork. In this context, this article presents the results of the “Development of Transversal Competencies (TCs) in Engineering Project”, which aims to identify the conditions that favor the enhancement of these competencies among engineering students. The study analyzed 12 TCs within a group of 23 Mobility Engineering students from the Federal University of Itajubá – Itabira campus. To support the development of competencies, the “PDCA of Transversal Competencies” practice was implemented. The results indicated that creativity, innovation, and proactivity were the competencies with the lowest frequency of execution. After participating in the project, 84% of the students reported improvements in their competencies, while 16% stated that they did not notice significant changes. The discourse analysis revealed the emergence of a student-subject in formation, whose professional awareness is based on the active search for content and experiences developed autonomously. This study proposes reflections on the importance of fostering students’ self-awareness and self-leadership, aiming to prepare them for practicing engineering with a high degree of professionalism.

RESUMO

A formação de engenheiros na área da mobilidade apresenta diversos desafios, especialmente no que se refere à promoção de competências que vão além do conhecimento específico. Torna-se fundamental estimular também o desenvolvimento de competências transversais, como comunicação, criatividade e trabalho em equipe. Nesse contexto, o presente artigo apresenta os resultados da aplicação do projeto “Desenvolvimento de Competências Transversais (CTs) na Engenharia”, que tem como objetivo identificar as condições favoráveis ao aprimoramento dessas competências entre estudantes de engenharia. O estudo analisou 12 CTs em um grupo de 23 estudantes de Engenharia da Mobilidade da Universidade Federal de Itajubá – campus Itabira. Para apoiar o desenvolvimento das competências, foi utilizada a prática “PDCA das Competências Transversais”. Os resultados indicaram que as competências com menor frequência de execução foram criatividade, inovação e proatividade. Após a participação no projeto, 84% dos estudantes relataram perceber melhorias em suas competências, enquanto 16% afirmaram não ter identificado mudanças. A análise do discurso revelou a construção de um sujeito em formação, cuja consciência profissional se baseia na busca ativa por conteúdos e experiências desenvolvidas de forma autônoma. O estudo propõe reflexões sobre a importância de estimular a autoconsciência e a autoliderança nos estudantes, visando ao exercício da engenharia com elevado grau de profissionalismo.



1. INTRODUCTION

The training of engineers in the current context requires more than just mastery of specific knowledge; it also involves the development of transversal competencies (TCs) such as problem-solving, teamwork, and emotional intelligence to deal with contemporary challenges (Schmal et al., 2020; Said et al., 2022; Pacher, Woschank and Zunk, 2023; Chans et al., 2025).

TCs, often referred to as soft skills, 21st-century skills, or life skills, are built over time and constitute a structuring axis of engineers' professional performance (Lopes, 2021; Martins et al., 2021). Given the relevance of TCs, curriculum guidelines, and educational policies in several countries around the world have recommended the adoption of active learning and skills development strategies, such as the Bologna Treaty in Europe (EHEA, 2020) and the National Engineering Curriculum Guidelines in Brazil (Brasil, 2019).

These recommendations reinforce the importance of Competency-Based Education (CBE), which has been implemented through strategies such as challenge-based learning (CBL) and project-based learning (PBL) (Leles, Zaina and Cardoso, 2024). In addition to these strategies, tools aimed at self-management of education and professional development, such as Individual Development Plans (IDPs), have been used to enable students to set development goals aligned with their professional trajectories and develop actions to achieve them (Kusters et al., 2020; Rubio et al., 2023).

Considering this scenario, the Mobility Engineering program at the Federal University of Itajubá (UNIFEI – Itabira campus) observed the need to articulate training in specific technical skills — such as designing and conducting experiments, interpreting results, and evaluating the economic feasibility, the operation and maintenance of transportation systems and projects — with the development of TCs, such as problem-solving, clear communication, teamwork, and self-improvement. These competencies are outlined in the Pedagogical Project Program (PPC, 2022) and reflect the understanding that working in mobility and transportation requires a complete and adaptable professional profile.

This paper presents the results of the “Development of Transversal Competencies (TCs) in Engineering Project”. This is the context for the practice presented in this paper, which was developed during the second semester of 2021. The initiative involved 23 Mobility Engineering students from UNIFEI – Itabira campus, who were invited to create and apply their IDPs, promoting a self-managed learning experience focused on the intentional improvement of TCs.

This paper is organized into five parts. Following this introduction, a literature review is presented. Next, the methodological procedures used are described. The fourth section presents the main results. Finally, reflections and contributions from this experience to strengthening mobility engineering education are discussed.

2. LITERATURE REVIEW

A literature review was conducted on TCs in engineering education, development strategies, and the role of IDPs in professional development. The statement Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Page et al., 2024) guided the review, although not all items on the PRISMA checklist were applied, as the purpose of the review was to support the research and not to be the ultimate goal of this study. Methodological details are described in the Methodology section.

During the project, numerical and textual data were collected via online forms administered by the professors. The project was registered on the Brazil Platform (CAAE: 61376922.70000.5094) and, in this case study, involved 23 students from the disciplines of “Administration,” “Transportation Project Management,” and “Logistics and Transportation” at UNIFEI - Itabira campus, in the second

semester of 2021. All students participated, without exclusion criteria, with the project integrated into the mandatory curricular activities. Despite the effects of the pandemic, methodological adaptations such as hybrid teaching were applied uniformly.

Figure 1 summarizes the results of the literature review, presenting the databases consulted (Scopus, Web of Science, and Lens) and the number of scientific papers originating from these searches. The following filters were used in the searches: publication period: 2019 to 2025; language: English; type of publication: journal articles; location of terms: abstracts. The search terms used were: 1) “development AND transversal AND competencies” AND “engineering AND education” and 2) “individual AND development AND plan” AND “engineering AND education”.

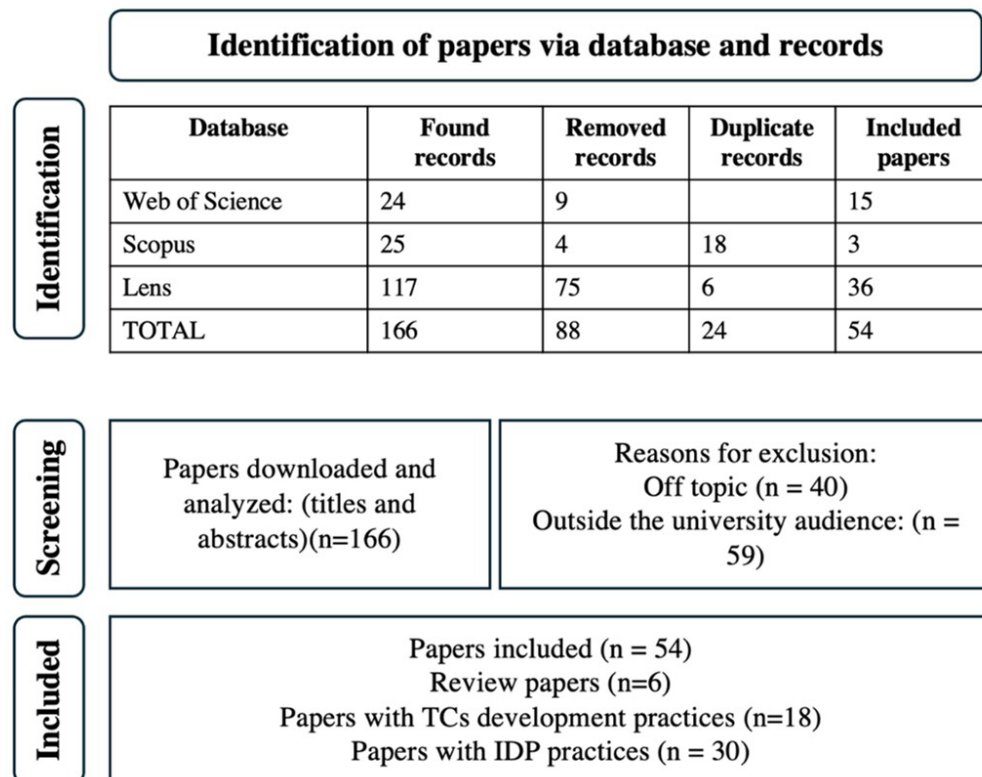


Figure 1. Literature review methodology: databases used and records found and included.

The use of the PRISMA 2020 statement, in the context of this paper, contributed to greater rigor, transparency, and systematization of the literature review process. The adoption of PRISMA principles enabled the organization of the steps involved in searching, selecting, and analyzing studies, favoring the reproducibility and credibility of the results. The papers included in the analysis will be presented in the following topics of this work.

2.1. Expected transversal competencies of engineers

In higher education, the challenges are complex and constantly evolving. In addition to imparting specific knowledge, institutions need to prepare students for a dynamic market by identifying the necessary TCs and developing professional development strategies adapted to new challenges (López et al., 2021; Pacher, Woschank and Zunk, 2023; d'Escoffier et al., 2024; Quesel et al., 2024).

According to Pacher, Woschank and Zunk (2023), TCs are useful in many areas of life. They are called transversal because they are applicable in different contexts, regardless of function, sector, or hierarchy (Ferraz, 2023). In the literature, different terms are used to designate them, such as soft skills (Borges and de Souza, 2024), life skills, generic skills (Schmal et al, 2020), general skills (Vázquez-Parra et al., 2024), essential skills, key skills (d'Escoffier et al., 2024), and 21st-century competencies (Quesel et al., 2024).

Analyzing the literature on the subject, several lists of TCs expected of engineers in training were identified. Table 1 presents the TCs mentioned in the literature consulted.

Table 1: Transversal competencies mentioned (literature consulted) and frequency of mentions

TCs	Authors																									Σ TC
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Effective communication	1	1	1			1	1		1	1		1		1	1	1	2			1	1	1	1		1	18
Collaboration		1		1			1		1		1				1	2	3		2	1	1	1	1		1	18
Problem-solving			1			1	1				1	1					1		1	1		1	2		1	12
Self-management	2					1		1									4	1		1					1	11
Critical thinking	1		1			1		1			1							1					2			8
ICT competencies										1						1	2	1		1			1			7
Adaptability			1		1				2					1										1		6
Analysis												1			1		1			1	1		1			6
Professional ethics											1					1				1			2		1	6
Systemic thinking				1	1										1	2			1							6
Entrepreneurship													1		1	1	1						1			5
Leadership			1						1					1									1			5
Lifelong learning									1								1						1		1	4
Management															3								1			4
Innovation						1				1			1			1										4
Modeling															2					1	1					4
Decision-making									1								1			1						3
Self-regulation	1							1																		2
Data science																	1						1			2
Foreign language																	1						1			2
Empathy with stakeholders																1								1		2
Interdisciplinarity				1																				1		2
Complex thinking																								1		1
Cultural awareness																	1									1
Creativity								1																		1
Equity																		1								1
Data management																				1						1
Negotiation																	1									1
Neurocompetence					1																					1
Organization	1																									1
Service orientation															1											1
Stakeholder representation															1											1
Resilience																1										1
Respect for diversity																								1		1
Σ author	6	2	5	3	3	5	4	3	7	2	4	4	3	2	13	11	20	4	4	10	4	3	16	5	6	149

Legend: [1] Amador-Rodríguez and Alvarez-Rodríguez (2023); [2] Cruz and Saunders-Smits (2021a); [3] Cruz and Saunders-Smits (2021b); [4] d'Escoffier et al. (2024); [5] Miranda et al. (2021); [6] Diliegros-Godines et al. (2021); [7] Félix-Herrán, Rendon-Nava and Nieto Jalil (2019); [8] García-Martínez, Cruz-Ramírez and Olais-Govea (2021); [9] Hernandez-de-Menendez, Escobar Díaz and Morales-Menendez (2020); [10] Lara-Prieto and Flores-Garza (2022); [11] Leles, Zaina and Cardoso (2024); [12] Llopis-Albert and Rubio (2021); [13] López et al. (2021); [14] Luna, Chong and Djurica (2024); [15] Maturana-González et al. (2024); [16] Neumeyer and Santos (2023); [17] Pacher, Woschank and Zunk (2023); [18] Quesel et al. (2024); [19] Ribeiro et al. (2024); [20] Rodríguez-Abitia et al. (2023); [21] Said et al. (2022); [22] Sánchez-Martín et al. (2020); [23] Seguí and Galiana (2023); [24] Vázquez-Parra et al. (2024); [25] Véchot, Olewski and Al-Qahtani (2022).

Considering the most cited TCs in the literature (more than 5 authors), interpersonal skills such as leadership, effective communication, collaboration, and professional ethics related to workplace interaction are observed. There are also intrapersonal competencies, such as adaptability, self-management, and continuous learning, which relate to the individual's internal management. In addition to cognitive competencies such as problem-solving, analysis, systemic, and critical thinking. Among these, the competency in information and communication technology (ICT) stands out, which is essential for dealing with digital technologies.

Given the variety of TCs mentioned in the literature, it is necessary to establish priorities to support students' self-development. Given this diversity, Pinto, Campos and Lima Jr. (2024) proposed prioritizing TCs for engineers based on an analysis of National Student Performance Exam (ENADE) regulations and pedagogical projects for engineering programs. These documents highlight the expected profile of graduates, justifying the need for the university to commit to the development of these competencies (Pinto, Campos and Lima Jr., 2024). This prioritization strategy makes the process clearer and more focused, in addition to being based on national references.

For this paper, the TCs indicated by Pinto, Campos and Lima Jr. (2024) were chosen, since the TCs development methodology proposed by these authors was used in this paper.

2.2. Process development of transversal competencies

Several institutions around the world have adopted competency-based education (CBE), focusing on the development of specific and transversal competencies, rather than just passing on content (Lowe et al., 2025). Although the development of TCs can occur empirically, without formal processes, the adoption of CBE allows for the improvement of teaching practice through intentional learning experiences. In this context, active learning strategies (ALSS) emerge as dynamics that favor the application and development of TCs.

The literature consulted identified ALSS aimed at developing specific and transversal competencies. Table 2 summarizes the ALSS, the context, and the authors identified.

Table 2: Active learning strategies mentioned (literature consulted), context, and authors

Strategies	Context	Authors
CBL	One-semester experience in solving industry problems - Mechatronics Engineering (Mexico)	Félix-Herrán, Rendon-Nava and Nieto Jalil (2019)
Use of gamification with escape rooms	Industrial Engineering Program (Spain)	Sánchez-Martín et al. (2020)
Multidisciplinary project	Final Course Project with industry (electric vehicles) (Mexico)	López et al. (2021)
CBL	Elective course (40 hours) using drones - Mechatronics Engineering and related fields (Mexico)	Félix-Herrán et al. (2022)
Collaborative learning and flipped classroom	Electrical Engineering course (Mexico)	Said et al. (2022)
Collaborative learning, PBL, and portfolios	Biomimicry and Sustainability course – first year of engineering programs (Mexico)	Amador-Rodríguez and Alvarez-Rodríguez (2023)
Forums, debates, flipped classroom, PBL, reading texts, digital platforms	Different areas of Engineering (Spain)	Seguí and Galiana (2023)
Gamification (digital game)	Project Management course in the Software Development course (Colombia)	Maturana-González et al. (2024)
PBL	Sustainable City Management Program (Portugal)	Ribeiro et al. (2024)

Among the ALSs mentioned above, the experiences conducted in engineering programs in Mexico are particularly noteworthy. All of these experiences come from the Monterrey Institute of Technology, which in 2018 implemented CBE and reformulated the curricula of engineering programs (Félix-Herrán, Rendon-Nava and Nieto Jalil, 2019; Félix-Herrán et al., 2022; López et al., 2021; Said et al., 2022).

In general, the authors identified that ALSs, in addition to promoting the development of TCs, benefit the educational process. CBL stimulated curiosity and the integration of emerging technologies (Félix-Herrán et al., 2022), while multidisciplinary projects favored the emergence of technological leadership (López et al., 2021). Strategies such as collaborative learning and the flipped classroom increase engagement and encourage autonomous learning (Said et al., 2022), and PBL reduced absenteeism and improved academic results (Ribeiro et al., 2024).

Gamification sparked positive emotions and encouraged interaction and competition (Sánchez-Martín et al., 2020). In addition, the use of portfolios, forums, debates, and digital platforms contributed to motivation, autonomy, and self-regulation of learning (Seguí and Galiana, 2023). Together, these approaches provided a more dynamic environment aligned with contemporary demands for engineering education.

In addition to occurring through the use of ALSs, the development of TCs can also be encouraged by reflective practices focused on self-development. In the latter case, the Individual Development Plan (IDP) stands out, a practice in which students set goals, perform self-assessments, and plan actions for their improvement (Chang and Saw, 2021; Mahdzir et al., 2021). The development of the IDP (Figure 2) involves initial reflection, mentoring, plan execution, and feedback sessions (Chang et al., 2021; Hardy et al., 2022; Mahdzir et al., 2021).

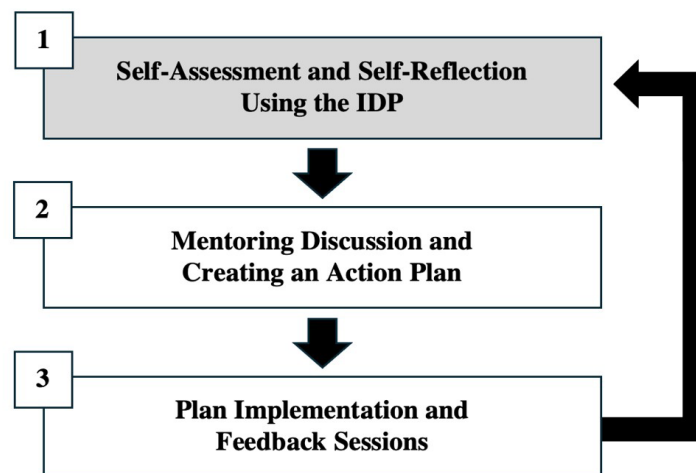


Figure 2. Individual Development Plan Process.

Source: Chang et al. (2021).

The Individual Development Plan (IDP) emerged in the organizational context (Mahdzir et al., 2021). In academia, it has proven effective in mentoring by promoting communication, encouraging accountability, and supporting goal setting (Zhang et al., 2020). For students, especially in STEM fields, the IDP contributes to career planning, increased retention, and strengthened autonomy (Chang et al., 2021; Hardy et al., 2022). According to McSween (2024), the IDP promotes self-knowledge and the identification of key competencies, facilitating alignment between advisor and advisee.

The literature presents uses of IDP in various audiences, such as children (Iniutina, 2024), educators (Mahdzir et al., 2021), teachers (Nakanjako et al., 2022), and, above all, doctoral and postdoctoral students (Chang et al., 2023, 2024). Table 3 highlights the experiences of adopting the IDP with undergraduate students.

Table 3: Experiences of using IDP in undergraduate education (authors, audience, and forms of use)

Authors	Audience	Ways to use the IDP
Gee, Schulte and Matsumoto (2019)	Pharmacy students	Adoption to help plan careers and track progress against accreditation standards.
Halpern et al. (2021)	Undergraduate students during the pandemic	Organization of online discussion panels followed by weekly reflection on goals, achievements, and obstacles.
Hardy et al. (2022)	Underrepresented minority students (UMS)	Use with mentoring (planning and tracking goals) and emotional and informational support.
Thompson (2022)	UMS in the field of aging and dementia	Training, interactive completion in small groups; ongoing reviews; discussion with mentors.
Holland (2023)	Students and postdoctoral fellows in research laboratories	Individual development with career goals, objectives, and identification of career objectives.
Edwards et al. (2024)	UMS	Weekly use for reflection on goals, obstacles, and achievements.
Keyes and Ames Fischer (2024)	Undergraduate students in urban planning	Use as a tool for career planning and reflection on development.
McSween (2024)	Undergraduate students in STEM	Integration into a professional development course with skills assessment, personalized goals.

The experiences in Table 3 illustrate the use of IDP in different contexts. As pointed out by Edwards et al. (2024), IDPs can be used weekly to reflect on goals, obstacles, and achievements, also functioning as a tool for empowering students in vulnerable situations (Hardy et al., 2022; Thompson, 2022). In addition, the IDP can support mentoring programs, professional development courses, and be complemented with vocational assessments (McSween, 2024).

Hardy et al. (2022), Thompson (2022), and Edwards et al. (2024) highlight that the IDP favors admission to graduate and doctoral programs. Other reported impacts include increased self-awareness (Gee, Schulte and Matsumoto, 2019), reduced identity-related anxiety, and emotional and informational support for persistence in goals (Hardy et al., 2022). These results indicate that IDP is an effective tool for career planning and comprehensive training.

Integrating the literature that addresses the development of TCs via ALSs and the literature that presents the use of IDP, it is possible to identify that these are complementary strategies for developing TCs. In the first mode, experience gives students the opportunity to train their skills and perceive their evolution, and this mode can be considered an indirect mode of TCs development. Through the use of IDP, it can be considered a deliberate mode of TCs development. This mode requires students to cultivate self-awareness and self-leadership, which are important elements for their training (Stewart, Courtright and Manz, 2019).

2.3. Identification of TCs for the case study

The project began with a survey of the cross-cutting skills mentioned in the graduate profile of the engineering programs offered by Unifei - Itabira campus. This survey was conducted based on an analysis of the 2017 National Student Performance Exam (ENADE) regulations for the programs in Production Engineering (PE), Mechanical Engineering (ME 1), Electrical Engineering (EE 1), Control and Automation Engineering (CAE), Environmental Engineering (EE 2), and Computer Engineering (CE) (Table 4). To access the graduate profiles of the Mobility Engineering (ME 2), Health and Safety Engineering (HSE), and Materials Engineering (ME 3) programs the analyses were made based on the pedagogical plans of these programs.

Based on this survey, a proposal was made for students to learn about these competencies and begin to develop strategies for their development. As Ferraz (2023) states, the development of transversal competencies involves theoretical knowledge and access to the meaning of each of these competencies. To this end, it is important that students have the opportunity to practice these competencies in their daily lives so that their attitudes can be consolidated with the perception of improvement in their profile.

Table 4: Documents consulted for the definition of TCs

Program	Document Analyzed
Control and Automation Engineering (CAE)	Inep Ordinance No. 487 of June 6, 2017. Published in the Official Gazette of June 8, 2017, Section 1, p. 32 (Brasil, 2017a)
Production Engineering (PE)	Inep Ordinance No. 491 of June 6, 2017. Published in the Official Gazette of June 8, 2017, Section 1, p. 34 (Brasil, 2017b)
Environmental Engineering (EE 2)	Inep Ordinance No. 483 of June 6, 2017. Published in the Official Gazette of June 8, 2017, Section 1, p. 31 (Brasil, 2017c)
Electrical Engineering (EE 1)	Inep Ordinance No. 488 of June 6, 2017. Published in the Official Gazette of June 8, 2017, Section 1, p. 33 (Brasil, 2017d)
Mechanical Engineering (EM 1)	Inep Ordinance No. 490 of June 6, 2017. Published in the Official Gazette on June 8, 2017, Section 1, p. 33 (Brasil, 2017e)
Computer Engineering (CE)	Inep Ordinance No. 245, of June 2, 2014. Published in the Federal Official Gazette on June 4, 2014 (Brasil, 2014)

As mentioned earlier, the pedagogical project for the Mobility Engineering (ME 2) program was analyzed. The project cites the following competencies: mastery of technical knowledge, problem-solving skills, evaluation skills, ease of interaction and communication, competence to participate in and manage projects, attitude of responsibility, and self-improvement. In addition, the pedagogical project states that mobility engineers must be able to work independently and as part of a team, possess reflective, critical, and creative thinking skills, have extensive knowledge and familiarity with basic calculation and computer tools and with the physical phenomena involved in their field of activity, and have a clinical eye (PPC, 2022). With this joint analysis, the competencies were identified according to the number of occurrences, as shown in Table 5.

Table 5: TCs mentioned in the graduate profile of engineering programs

TCs Identified	CE	PE	EE 2	EE 1	ME 1	CE	ME 2	Incidents
Constant updating on new technologies	2	2	2	2	3	3	1	15
Clear oral and written communication	1		1				1	3
Collaboration	1	1	1	1	1		1	6
Creativity	1	1	1	2	1	2	1	9
Critical thinking to solve problems	1	1	1	1	1	1	1	7
Entrepreneurship		1	1		1	1		4
Ethics and humanism	1	1	1	1	1	1		6
Innovation	1	1	1	1	2	2		8
Multidisciplinarity	1	1		1	1			4
Organization	1			1	1		1	4
Proactivity	1	1	1	1	1		1	6
Resilience	1				1			2

Below are the 12 TCs identified by these authors, as well as their semantic descriptions.

- 1) **Critical thinking to solve problems:** variant questions, processes, and information in the search for the fundamental causes of problems and opportunities for improvement.
- 2) **Creativity:** thinks and implements different forms of action to improve results and generate value.
- 3) **Entrepreneurship:** acts boldly and enthusiastically, focusing on results and generating value for customers.
- 4) **Innovation:** generates new forms of productive combinations (new products, new processes, new raw materials, new companies, etc.) that generate considerable value.
- 5) **Proactivity:** acts before being asked and before being forced by circumstances.
- 6) **Multidisciplinarity:** respects other areas of knowledge and articulates knowledge from other areas to make decisions.
- 7) **Collaboration:** acts in a respectful, supportive, and productive manner in collective activities.
- 8) **Ethics and humanism:** acts correctly from an ethical, moral, and human standpoint.
- 9) **Constant updating on new technologies:** seeks information for constant updating through studies, reading, and interactions.
- 10) **Organization:** keeps all resources (time, money, physical items, and people) under its management in an orderly and properly allocated manner.
- 11) **Resilience:** able to deal with adverse situations, overcome pressures, obstacles, and problems, and respond positively to them.
- 12) **Clear oral and written communication:** In all oral and written communications, performance, content, and design are presented effectively.

3. METHODOLOGY

The methodology used in the project is bibliographic research, using literature review as a theoretical basis, through the PRISMA 2020 Protocol (Page et al., 2024) and a case study (Yin, 2001).

The approach is quantitative-qualitative research, combining statistical analysis of numerical data and discourse analysis of textual data (Orlandi, 2001; Creswell and Creswell, 2021). Mixed research methods should be used when quantitative and qualitative approaches together provide a better understanding of the problem, when one of the approaches used alone cannot answer the research question, and when, based on a quantitative study, it is complemented by a qualitative study to improve understanding of the research problem (Creswell and Creswell, 2021). The choice of quantitative-qualitative analysis of the collected data is justified by the need to provide a more comprehensive and in-depth understanding of the phenomenon under investigation. The quantitative approach allows for the identification of patterns, frequencies, and correlations between variables, offering an objective and measurable view of the data. On the other hand, qualitative analysis allows for the exploration of the meanings, perceptions, and experiences of the participants, deepening the interpretation of the numerical results. By integrating these two approaches, the research benefits from methodological complementarity, allowing for the validation of quantitative data with qualitative narratives and vice versa.

In terms of objectives, the research is exploratory and descriptive, deepening understanding of the “Development of Transversal Competencies in Engineering” project and the impacts perceived by students of the undergraduate program in Mobility Engineering. Considering the particularities and generalities of the Mobility Engineering program at Unifei, it was found that the program seeks to meet the demands related to urban mobility and transportation from the point of view of society and the industrial sector with a systemic, integrated, and connected vision. The focus is on training professionals with broader skills that combine technical, innovative, and entrepreneurial training through the dissemination and creation of knowledge and social responsibility in the areas that make up the program. The program aims to train higher education professionals to work in the job market and/or the academic sector, carrying out actions and research focused on developing solutions that improve the use and integration of transportation systems for both passenger and cargo transportation.

The sample of 23 students is representative of the population when considering it to be equal to the expected number of students in the subjects mentioned. Each subject has 50 students enrolled, meaning that the population considered was the number of students who should have taken the subjects considered in the case study presented, i.e., 150 students. In this case, the sample corresponds to approximately 15% of the population.

The authors understand that there is no selection bias in the data collection in the class of the aforementioned subject in the second semester of 2021, a period under the effects of the pandemic, since methodological adaptations such as hybrid teaching were applied uniformly.

The first step of the project “Development of Transversal Competencies in Engineering” was to present the project’s objectives, emphasizing the 12 TCs proposed in the study. Deming’s Plan-Do-Check-Act (PDCA) continuous improvement cycle (Werkema, 1995) was presented, inviting students to apply it to the development of their TCs. At each stage of the project, information was collected using electronic forms. The stages of the project and the implementation period are described below.

Stage 1 (August 2021): Students completed a self-assessment on the practice of the 12 TCs. Each competency was presented as a first-person statement, and students indicated how often they acted following each one on a 5-point scale: 1-Never, 2-Rarely, 3-Sometimes, 4-Most of the time, 5-Always. The form also included an open field for comments.

Stage 2 (September 2021): the overall results of the self-assessment were presented, and the least frequent TCs were identified by tabulating the answers using descriptive statistics. This presentation of the data was made during class, which led to a discussion about the most difficult TCs to perform.

Stage 3 (September 2021): After the self-assessment, the students drew up an improvement plan for three prioritized TCs. A form was used to record the prioritized TCs, the analysis of the causes of the limited execution of the TCs, the sources of reference and best practices, and an action plan.

Stage 4 (September 2021): the teachers analyzed the plans submitted by the students and gave feedback to them, assessing the quality of the analysis and proposing additional actions.

Stage 5 (September to November 2021): implementation of the plan by the students.

Stage 6 (November 2021): questionnaire to find out the status of the implementation of the plan outlined in stage 3, the students' perception of the improvement of the TCs so far, and the need for new actions for the plan.

Figure 3 shows a parallel between the stages of Deming's Plan-Do-Check-Act (PDCA) method (Werkema, 1995) and the stages of the project.

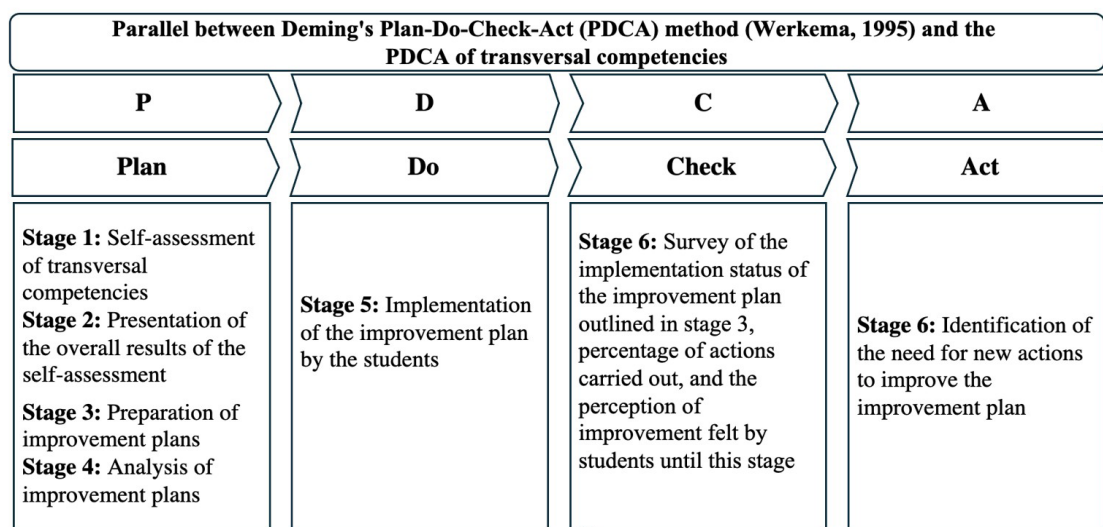


Figure 3. Parallel between Deming's Plan-Do-Check-Act (PDCA) method (Werkema, 1995) and the PDCA of transversal competencies.

In the next section, the results (numerical and textual data) of each of the stages are presented with the respective discussions on the implications for understanding the experience of developing TCs reported in this work.

4. RESULTS AND DISCUSSION

The results of the literature review enabled 54 valid articles to be included according to the inclusion and exclusion criteria. Other articles were included in this paper due to their relevance to completing the proposed discussions.

To analyze the results of the case study, numerical data is presented to help understand the process of developing TCs in the context of the students involved in the research: frequency of TCs execution (steps 1 and 2), TCs prioritized by the students (step 3), analysis of the quality of the action plans (step 4), status of execution of the action plans and perception of improvement of the TCs at the end of the project (step 6).

To complement the quantitative analysis, reflections will be presented based on the analysis of the students' discourse in the completed forms. The material analyzed included: comments on expectations (stage 1), analyses of phenomena, processes and improvement plans (stage 3), and reports on the implementation of the plans. According to Orlandi (2001), the reports were treated as discursive representations, considering the students as subjects conditioned by their social position and ideology. The effects of meaning produced in the discourses were analyzed, taking into account who is speaking, who is being spoken to and the student context.

Figure 4 shows the percentage of students who had a high frequency of execution in the TCs, i.e. students who answered 4-Most of the time and 5-Always for the analyzed TCs.

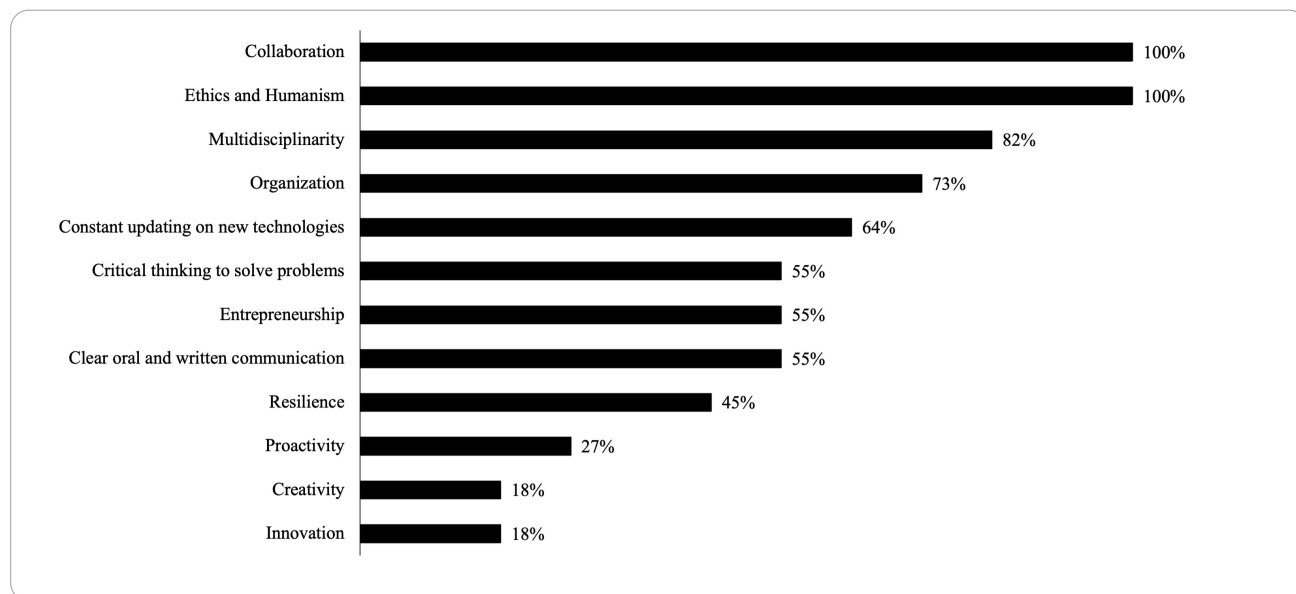


Figure 4. Percentage of students with high execution frequency in the analyzed TCs.

Looking at Figure 4, it can be seen that ethics and humanism, collaboration, multidisciplinarity, organization and technological updating are the TCs with the highest frequency of execution (over 64%). In an intermediate situation, communication, entrepreneurship, criticality and resilience were around 50%. Creativity, innovation and proactivity, on the other hand, were less frequent (below 27%). These results are similar to other applications in the project, which also point to difficulties in innovation and creativity (Campos and Pinto, 2023; Pinto, Campos and Lima Jr., 2024).

Also in stage 1, the form had an open field in which students were invited to comment freely. In general, the speeches indicated that the students were subjects under construction, marked by the expectation of personal and professional development. Terms such as "I hope", "I seek" and "I intend" indicated an identity that was still in formation and open to change. An example of a discursive body is represented in one student's account: "I'm really looking forward to learning about the qualities expected of an engineer and how I can improve the desired competencies." This excerpt can be considered an example of a discourse that reveals the internalization of a logic of continuous self-development.

In stage 2, the data in Figure 4 was presented to the students, which led to a discussion about the least frequent TCs in the context of the participants, indicating an incentive to prioritize these TCs for development.

In stage 3, based on their reflections on the self-assessment in stage 1, the students were asked to draw up an improvement plan for the three prioritized TCs. Figure 5 shows the percentage of students who chose each of the proposed TCs.

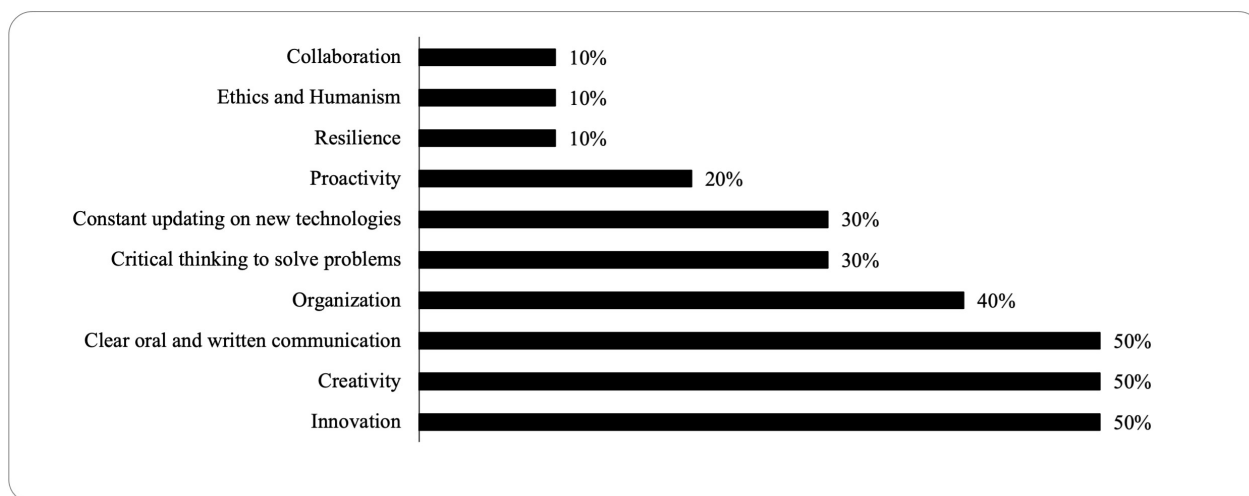


Figure 5. Percentage of students per priority transversal competence (TC).

The TCs most prioritized by the students were innovation, creativity and clarity in oral and written communication. **It is important to note that these three TCs are among those that students perform least often** (Figure 4). The TCs chosen least often were collaboration, ethics and humanism and resilience.

Also at this stage, for each TC prioritized, the students had to carry out the planning steps according to the PDCA method (Werkema, 1995) and reflect on the development of their TCs in the following phases:

1. Problem identification: choice of the three TCs prioritized for development.
2. Analyzing the phenomenon: identifying the causes of limited performance.
3. Process analysis: researching and recording best performance practices for the prioritized TCs.
4. Drawing up the action plan: defining concrete and specific actions based on what was learned in the process analysis.

Figure 6 shows examples of a student's reflections on each phase mentioned above.

Concerning the students' discourse in the phenomenon analysis phase (identification of causes), it was observed that the difficulties in performing the TCs were attributed to discursive memories linked to upbringing, family environment and lack of encouragement, revealed in expressions such as "I grew up in an environment with old beliefs" and "I was always given everything ready-made". These discourses show that limitations are seen as social effects and not just individual failings.

With regard to process analysis, the students' reports show a strong influence of the ideology of individual responsibility for personal development. Students highlighted self-centered practices, such as reading and consuming digital content, suggesting that improvement depends on individual effort. The students' speeches also show a tension between the desire for change and the difficulty of breaking away from automated routines.

About drawing up the action plan, the analysis of the students' plans pointed to a view that personal improvement is seen as the result of effective time management and access to external resources (videos, books, events). At this stage, the students mentioned alternative learning spaces

such as YouTube, social networks, institutional events and modes of action such as organizational charts, schedules, reading habits and participation in extracurricular activities which reinforce the idea that the student recognizes that they need to be proactive, innovative and a strategist in their own training. Collective practices, such as junior companies or extension projects, were also indicated as strategies for individual improvement.

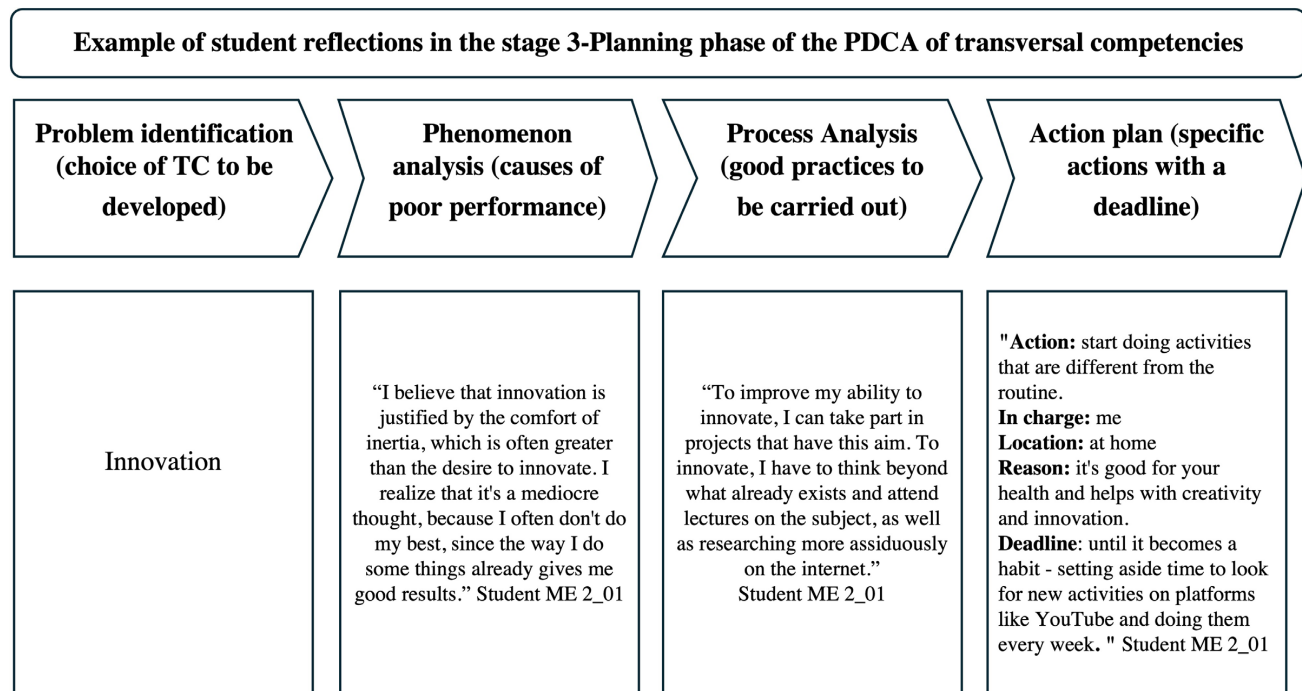


Figure 6. Example of student reflections - stage 3.

In stage 4, the students' action plans were analyzed in terms of the quality of the analysis and the actions defined. The feedback was adapted to the size of the classes: in smaller classes, it was verbal and dialogued in a virtual meeting; in larger classes, it was written. To ensure individualized feedback, written feedback was sent via the institutional platform around 30 days after the plan was delivered, with comments on quality and suggestions for improvement.

In stage 5, the students carried out the execution phase of the PDCA method. In stage 6, the last two stages of the PDCA method were carried out (checking and corrective action, if necessary) when it was possible to find out the percentage of actions carried out and the students' perception of improvement. At this stage of the project, the students reported that 21% of the plan had been carried out, 71% was in progress and 6% had not been carried out. When asked about their perception of improvement in the TCs, 84% reported that they saw improvement, while 16% of the students reported "no". In other rounds of application of the "Development of Transversal Competencies in Engineering" project, Campos and Pinto (2023) found similar results, indicating that, through this approach, students report the perceived development of their TCs.

To conclude the "transversal competencies PDCA" practice, the students were instructed to continue reflecting on how to improve their professional profile by incorporating the techniques they had learned into their daily lives. This guidance has become relevant as it encourages students to incorporate practices of self-knowledge, self-awareness and self-leadership with a view to achieving their professional goals.

5. CONCLUSIONS

The results presented in this study describe a structured approach to the development of TCs in mobility engineering students through the development of IDPs. The application of the “PDCA of Transversal Competencies” method proved to be a strategy that encourages self-reflection and continuous improvement of these competencies, which are essential for training professionals who are prepared for the challenges of today’s job market. The innovative contribution of this work is the application of a tool used to manage the continuous improvement of processes and products by means of the four-stage iterative cycle associated with the development of transversal competencies in undergraduate engineering students. The association of the tool with the development of TCs contributes to improving the education of engineering students and ensures that technical education is connected to a more human education. The student can use the results achieved to improve their performance in their professional career and act in a systemic way in their chosen profession.

Although the results indicate a positive perception of improvement in the TCs and an appreciation of self-management by the students, some limitations were identified in practice. To increase the effectiveness of the IDP, more personalized follow-up is needed, especially in large classes, where written feedback, although feasible, could still be improved. The implementation of periodic verbal feedback sessions or individual mentoring, as suggested by Chang et al. (2021), Hardy et al. (2022) and Mahdzir et al. (2021), can strengthen active learning and offer more targeted support to students. In addition, the development of a digital platform could facilitate interaction with the IDP, optimize data management and allow the process to be automated in the future using artificial intelligence.

The study’s limitations include the number of students and the fact that the data is based on a single experience, which prevents the results from being generalized. For future research, we suggest replicating the approach in other courses and engineering programs, as well as carrying out longitudinal analyses to monitor the impact of TCs on students’ academic and professional trajectories. It would also be relevant to investigate the effectiveness of the PDCA in different student profiles and to explore the relationship between the development of TCs and performance in the job market. Comparative studies between programs and institutions could broaden our understanding of the method’s applicability in different educational contexts.

The results of this study reinforce the need to integrate the development of TCs in a structured way into mobility engineering curricula. Implementing strategies such as the “PDCA of Transversal Competencies” can contribute to training engineers who are better prepared to deal with the complexity and dynamism of the market, making them professionals who are able to face multidisciplinary challenges with autonomy and responsibility.

AUTHORS’ CONTRIBUTIONS

LBPC: Project administration, Formal analysis, Funding acquisition, Conceptualization, Data curation, Writing original draft, Writing Review and editing, Investigation, Methodology, Resources, Supervision, Validation, and Visualization; JAP: Formal analysis, Funding acquisition, Conceptualization, Data curation, Writing original draft, Writing review and editing, Investigation, Resources, Validation and Visualization; SSS: Data curation, Writing review and editing and Visualization; OFLJ: Conceptualization, Writing review and editing, Validation and Visualization.

CONFLICTS OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

USE OF ARTIFICIAL INTELLIGENCE-ASSISTED TECHNOLOGY STATEMENT

The authors declare that generative artificial intelligence tools, specifically ChatGPT (OpenAI), were used as a support resource during the preparation of this article. The use of AI was limited to checking technical terminology in English, translating selected terms and excerpts, assisting in content and discourse analysis based on data previously organized by the authors, and suggesting improvements to align the writing with academic standards. All analytical decisions, interpretations, and final formulations presented in this article are the sole responsibility of the authors, who critically reviewed and supervised all contributions generated by the AI tool.

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