Engagement in Practice: The Development of Skills and Competencies through Community Outreach Activities

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In this Complete Evidence-based Practice, with the aim of expanding students' worldview and developing skills and competencies for the job market, this complete paper presents the implementation of an annual mentoring program at Maua Institute of Technology for first-year students (Engineering, Business Administration, Design, Information Systems, and Computer Science) consisting of approximately 400 students. In this program, students worked in teams, under the guidance of a mentor professor, for 10 months. They utilized project management methodologies, Design Thinking, empathy mapping, persona development, and other tools to define, propose, develop, and present solutions to community-related problems. All proposed projects were required to align with the United Nations Sustainable Development Goals (SDGs), be low-cost and replicable, and have an external entity or community association as a partner. Throughout the months, students had the opportunity to develop their proposals, implement them, and at the end of the academic year, present the results in an open presentation to the entire academic community. Aside from detailing the mentoring program's development, this paper presents both the qualitative and quantitative feedback from students regarding the program and their self-development through a Likert-type questionnaire administered at the end of the semester. It also presents the qualitative feedback from faculty members regarding the technical and behavioral aspects acquired by the students. The obtained data demonstrate that the development of applied projects that combine learning with real community problems fosters greater engagement and expands the incoming student's worldview, allowing them to perceive themselves as capable of being transformative agents in their communities.

Introduction

This complete paper presents the implementation of an annual mentoring program [1-4] at Maua Institute of Technology for first-year students (Engineering, Business Administration, Design, Information Systems, and Computer Science), comprising approximately 400 students. In this program, students are expected to play an active role in the activities that will be developed, rather than simply participating in some external activity. Therefore, the interventions must directly involve communities external to higher education institutions and be linked to the students' education [5-8].

Mentoring Program

The mentoring program was designed with the following objectives:

- To promote a community-focused extension project following the UN Sustainable Development Goals [9-11].
- To develop skills related to work and project management in a team setting.
- To develop oral and written communication skills.
- To broaden the students' vision beyond the institution by exposing them to real-life situations.

The mentoring program consisted of weekly 100-minute meetings throughout the academic year. Students were divided into teams of up to 5 members and, under faculty supervision, received guidance on their extension projects. The program was divided into

two stages: Mentoring (40 hours) – 1st semestre and Extension, Innovation, and Entrepreneurship (40 hours) – 2nd semester.

The Mentoring stage in the first semester aimed to facilitate the newcomers' adaptation and integration into the university environment, raise awareness of social responsibility, select a community partner institution, and obtain an initial understanding of that community's needs. The weekly in-person meetings were mediated by a mentoring professor and a senior student, referred to as a godfather or godmother for each group of 30 newcomers.

As part of the preparation for the extension, the students developed an intervention proposal using a methodology based on Design Thinking [12-20], a user-centered approach for creative problem-solving and innovation, and utilized the Business Model Canvas [21] to propose solutions aligned with the UN Sustainable Development Goals [9-11]. Thus, the students went through the following stages of Design Thinking as per Table 1.

Table 1. Design Thinking Stages

Month	Design Thinking Stage	Description	Activity	Tool
1	Immersion	Presentation of Mentoring and Design Thinking Methodology	Define the problem to be solved.	Mind Map [22]
2 -3	Analysis and Synthesis	Creating the persona	Create the persona for your project and present it to the class.	Empathy Map / User Journey [20]
		Completing the persona: Empathy Map	Completing the empathy map by putting oneself in the user's place for your extension project.	
4	Ideation	Brainstorm	Complete the project brainstorm and select generated ideas.	Brainstorm [19]
5 – 9	Prototyping and Implementation	Project development and monitoring	Partial development reports of the models, assembly, and prototype testing	Assessment by competencies using rubrics [23-25]
10		Oral Presentation	Develop a presentation for the community	

In the brainstorm creation stage, the use of the Lucid Spark and Jamboard [26-27] free tools for electronic and shared brainstorming was suggested. The use of these tools by students allows sharing of ideas and working with visual project management tools in teams.

By the end, all proposed projects were expected to align with the United Nations Sustainable Development Goals (SDGs), be low-cost and replicable, and have an external entity or community association as a partner. Proposals must bring together what is desirable from a human perspective (desirability) with what is technologically feasible (feasibility) and economically viable (viability).

The Extension, Innovation, and Entrepreneurship activity stage, developed in the second academic semester, sought to engage students in proposing solutions for community demands identified through partner institutions in organized civil society, always based on a project methodology. It could eventually identify opportunities for social entrepreneurship, always involving actions that impact society's improvement by creating/proposing a new reality.

As possible solutions emerged in the Ideation stage, the student group should identify the most viable one based on viability and usability criteria; this stage is described in a short technical report with the delimitation of the problem and the study of the solution's viability.

Since the students are newcomers, a report model is provided along with the rubric (Table 2) containing the evaluation criteria. The assessment here is purely formative, with no "grade" given, serving only to guide students in conducting and describing their work.

It is also proposed that students be able to realize and demonstrate their ideas, so in the Prototyping stage, students used the institution's facilities (laboratories, FabLab, project spaces) to model, assemble, and test prototypes.

The results of this phase of the work were presented in the form of panels or orally at the end of the year at the University Extension Symposium, with the presence and evaluation of partner entities.

Table 2. Rubric Used

Description/ Objective	1 - Poor	2 - Did not meet the minimum requirements	3 - Achieved objectives	4 - Exceeded expectations
General Formatting. Adherence to standards and norms. Formatting based on the provided template.	Did not adhere to formatting	Some minor errors or inaccuracies in formatting (incorrect margins, font size, or position of figures and tables)	All formatting elements were correctly placed.	Not applicable
Overall Organization. Spelling, clarity, fluency, and coherence of the text.	Two or more items are missing or presented in the wrong order. Some items contain incomplete information.	All items are present, in the correct order, but some lack information. Unclear and/or erroneous spelling.	All items are present, in the correct order. Most information is correct and clear. Clear writing.	The content of the work was presented logically and clearly. Methods, calculations, results, and conclusion are well developed. Contains appropriate technical language. Clear writing with technical language.
Figures and Images	Did not include images.	Used images unrelated to the text. Or used illegible images.	The images are legible and illustrate the text to facilitate understanding of the work.	The images are clear, well-placed, and helpful in understanding and drawing attention to the work.
Methodology. Design Thinking (Persona, Empathy Map).	Did not present the required items.	Did not present one of the required items.	Presented all requested items with minor errors.	All items presented clearly and correctly.
Results	Did not present results.	The presented results are insufficient or of no interest to the partner institution.	The results were presented correctly.	The results are relevant and important to the partner institution.
Conclusion. Analysis of the obtained results.	Did not present conclusions.	The conclusion does not connect the methods and results with the achievement of the objectives.	Well developed, demonstrating the objectives and connecting them with the methods and results.	The conclusion is well developed, complete and grounded, supporting the achievement of the objectives.

Major Partner Entities and Projects

As the proposal aimed to foster interaction between student groups and the community in pursuit of solutions, initial partners were sought near our institution's location, engaging in activities with social purposes:

i. Vergueiro Incinerator. Former garbage incinerator in Ipiranga-SP, deactivated and abandoned for over 20 years. The proposal, originating from neighborhood associations and collectives in the region, aims to install a cultural facility (Eco-Cultural Plant), with leisure spaces, a skate park, an ecological museum, and a library. The site also houses rooms that can accommodate courses and other community needs. The movement has already promoted various actions with local artists, such as theatrical performances, music shows, and craft fairs. Some proposed projects related to the Eco-Cultural Plant proposal include: a. Mobile geodesic structures to provide event coverings in the facility's courtyard; b. Mobile applications to guide museum visitors; c. Pre-college and computer courses.

ii. Ambiental Mission. An environmental non-governmental organization NGO operating in the Ipiranga-SP area. The site encompasses activities from planting orchids and native food-producing plants to Brazilian stingless bees. They also compost organic waste. Main proposals for this partner include: a. Composting workshops; b. Remote monitoring of composting using low-cost equipment (temperature sensors, humidity sensors, gas detectors); c. Mobile applications to guide visitors, providing information about plants, food, and bees.

iii. Passatempo Educativo. An non-governmental organization NGO in the educational field working with public schools, seeking to compensate for the lack of laboratories and experimental demonstration classes related to Physics, Chemistry, Biology, and Mathematics. Key projects include: a. Low-cost Physics and Chemistry labs; b. Preparation of experimental classes; c. "Science Soccer" project, combining concepts of Physics, Chemistry, Biology, and Mathematics with sports.

iv. APAE São Caetano. School focused on caring for children with special needs. Project demands include: a. Panel with psychomotor and sensory toys; b. Automation of the fiscal coupon registration process; c. Platforms for promoting entity activities (Website, Instagram, Facebook).

v. AMAS São Caetano (Methodist Association of Social Action of São Caetano). Institution dedicated to educating and caring for children, adolescents, and adults with special needs, supported by the Methodist Church and the City Hall. a. Development of educational and musical toys; b. Production of musical instruments; c. Counter for exchanging diapers and adapted clothing for youth and adults.

vi. "Hands-on" Non-governmental organization. The work consists of helping to build and improve housing for people with mental and/or physical disabilities in the needy communities in São Paulo. A group of specialized bricklayers and architects teach students how to build houses.

Example of Project Developed Experiments to stimulate elementary school children's knowledge. The problem addressed with the support of the Passatempo Educativo partner was the lack of interest in the school environment. New methods were envisioned to motivate children to learn, achieve academic performance, develop as individuals and citizens, and address school dropout. In the immersion phase, the Persona framework was used, representing an 11-years-old girl from a low-income family, struggling with studies but hopeful for a better future, along with the Empathy Map (Figure 1) to understand user needs. In the ideation phase, the Brainstorm method, using the 6-3-5 method, was applied to generate ideas. Subsequently, a prioritization matrix was developed to select the most promising ideas as a basis for solving the problem.

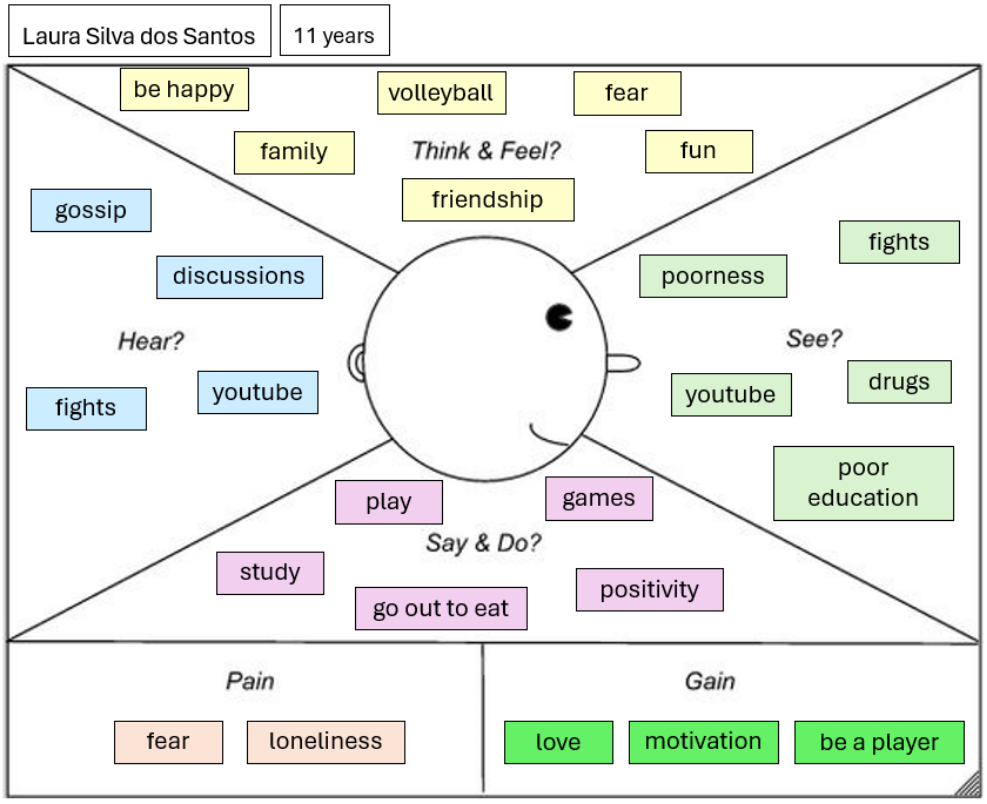

Figure 1. Empathy Map (example for Importance of Incentive and Resources for Educational Institution Project)

As a result, experimental kits for Chemistry and Physics laboratories were created, and two are presented to exemplify theoretical concepts for the students.

"Underwater Volcano". For this experiment, a small transparent glass tube, a large transparent glass tube, a string, hot water, and dye were used. Initially, the string was tied to the mouth of the small glass tube so that it could lift the container. Next, dye and hot water were added to the small container. Afterward, the large glass tube was filled with cold water, and the smaller tube was inserted into it with the help of the string. It was then observed that the hot water inside the small container began to rise, but after a short period, it descended again and returned to its initial state (Figure 2).

"Liquid Layer". In this experiment, the solubility and density properties were observed in materials such as honey, vegetable oil, water, and colored alcohol, using a cylindrical tube and objects such as a marble, a piece of candle, and a ping-pong ball. The procedure

involved adding honey to the tube, followed by the sequential addition of water, oil, and alcohol. The materials floated according to their characteristics, demonstrating the mentioned properties. Density, defined by the ratio of mass to volume, varied depending on the type of material, explaining why the ping-pong ball floated while the marble sank (Figure 3).

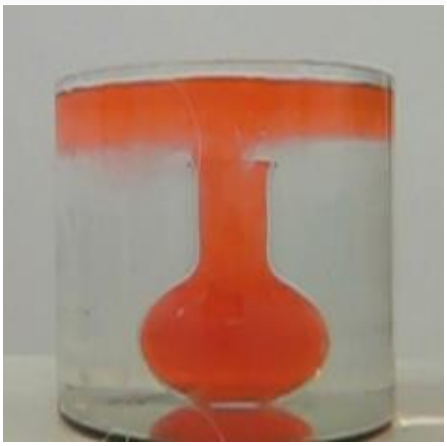

Figure 2. Underwater Volcano

Figure 3. Liquid Layer

Figures 4 and 5 show the students' presentation to the representatives of the NGO.

Figures 4 and 5. Final presentation of the work.

Other projects developed with community partners are summarized below (Figure 6):

Figure 6. Projects based on motivational and inclusive education, creation of eco-cultural spaces and resources, and construction of houses for the needy population (hands-on).

Results and Discussion

To qualitatively and quantitatively evaluate whether the proposed objectives for the mentoring program were achieved, the perception of the students and faculty was analyzed by applying a mixed questionnaire (quali/quantitative) to the students, with Likert scale questions ranging from 0 (none) to 5 (completely) on issues related to their self-awareness and their perception of project development and their own competencies. It also included open-ended questions allowing students to express themselves more fully and enabling a more qualitative analysis of their development. The questionnaire applied to the students received responses from 60 students teams (almost 240 students), representing almost 60% of the total.

As for the faculty, interviews were conducted to gather their main perceptions.

According to the collected data, students reported encountering some challenges during the project development process. The major challenges and their respective quantities are presented in Table 3 as follows:

Table 3. Challenges during the project development process

Challenges	% of responses
Project definition	31 (55.4%)
Team's understanding of the objectives to be achieved	30 (53.6%)
Time management for team members	30 (53.6%)
Activity deadlines	20 (35.7%)
Other	12 (21.4%)

It can be observed that the greatest challenge was related to project definition (55.4%), understanding of the objectives (53.6%), and team management 53.6%), highlighting the need to define the correct understanding of the project's expectations and its management for all team members. These are fundamental practices when considering good workplace practices, such as project management.

Overall, the students indicated the following actions to overcome these challenges:

"Practicing methodologies such as Design Thinking and Brainstorm."

"We scheduled meeting times to develop the project and write the report."

"With time organization and task division."

"We had to take time to think about everything we planned to do, what was actually within our reach to carry out the project."

"We faced the problems and challenges together, scheduled meetings, and made prototypes and projects for better understanding and the ideal and physical construction of the site."

"Discussing with the group to find ideal solutions."

"Gathering in conversation circles until finding the necessary solutions."

"The team overcame the challenges by organizing and planning what everyone would do, dividing into small tasks for which each member would be responsible."

There is a significant appearance of various words related to team and project management, demonstrating a greater development of this new culture of organization and the development of activities in a more orderly manner.

The students expressed their perception regarding their own development as observed in the responses to the question: "What skills do you consider to have improved during the project development?" This feedback is consolidated in Table 4. High levels of self-perception regarding the development of skills for teamwork (76.7%), seeking new challenges (63.3%), and improved communication (58.3%) and the use of tools such as Design Thinking (53.3%) indicate that the proposed mentoring objectives were internalized.

Furthermore, there is a significant contribution from the implementation of pedagogical approaches such as Project-Based Learning, where an emotional connection is promoted within the cognitive process. From a psychological perspective, when students are actively engaged in their own development, it tends to strengthen their overall cognitive abilities, thus improving their learning and self-growth [32-33].

Table 4. Skills developed throughout the project

Skills	% of responses
Teamwork development	46 (76.7%)
Seeking challenges and finding solutions	38 (63.3%)
Communication	35 (58.3%)
Problem-solving through Design Thinking	32 (53.3%)
Recognizing ethical and legal aspects in project development	27 (45.0%)
Other	5 (8.3%)

Here are the qualitative perceptions shared by the students in response to the question, "How did the project contribute to the personal and professional development of the participants?":

"Through the project, we were able to exercise empathy, attempting to fully grasp the pain, frustrations, and suffering that these people go through and have gone through to get to the situation they are in today."

"Humility and empathy."

"It contributed to learning by working on a real project in which we are directly involved."

"The project allowed us to become more immersed in the problems of society as a whole and not be constrained by our own bubble and social class."

"Learning new technologies and communication with clients."

"It allowed us to have greater contact with the job market, providing us with a client in need of a project to be done."

"The project gave us a foundation for working with real clients, as in college we usually do work but do not have real clients. In this project, it was possible to experience firsthand what it is like to work within the job market."

Once again, it is indicative that the proposal developed with the students helped promote an emotional connection within the cognitive process.

The main perceptions shared in interviews with the faculty were as follows:

"There was much student learning, such as the social awareness acquired throughout the work, the action in attempting to resolve a problem faced by the community, knowledge of a project methodology, writing the article and the poster, the use of tools such as SolidWorks, the 6-3-5 Brainstorm method, prioritization matrix, video editing, oral communication (presentation), and finally the feedback from partner institutions."

It is evident that both the students and the faculty noticed the development of these young individuals in terms of empathy, problem-solving, motivation from real-world issues, and satisfaction in delivering feedback to partners. It is worth noting that some teams stood out for delivering higher-quality prototypes.

Final Considerations

The use of project methodology, Design Thinking, combining project development by students with a higher purpose (solving real problems involving the community), is extremely important for the construction of a humanized and systematic view of projects among students. By focusing on the user, empathy, and continuous user participation throughout the process, students' perceptions regarding the impact of their projects and their future professional roles are broadened.

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References

[1] A. Galbraith, H. A. Schluterman, L. B. Massey, and G. Scroggin, *"Full Paper: Incorporating Academic Coaching in First-Year Engineering Program to Support Student Success and Persistence,"* presented at *14th Annual First-Year Engineering Experience (FYEE) Conference*, Univ. of Tennessee, Knoxville, TN, USA, Jul. 2023. [Online]. Available: https://peer.asee.org/44828

[2] Struck Jannini, A. V. (2023, June), “Reflections on Mentorship – Being the Change You Want to See in Engineering Education” Paper presented at *2023 ASEE Annual Conference & Exposition*, Baltimore , Maryland. https://peer.asee.org/44154

[3] Khalil, M. K., & Elkhider, I. A. (2016). Applying learning theories and instructional design models for effective instruction. *Advances in physiology education*, 40(2), 147–156. https://doi.org/10.1152/advan.00138.2015

[4] Johri, A. (2023). *International Handbook of Engineering Education Research* (1st ed.). Taylor & Francis. Retrieved from https://www.perlego.com/book/4140786/international-handbook-of-engineering-education-research-pdf (Original work published 2023)

[5] Cutri, R.; Gil, H. A. C. and Freitas, P. A. de M. "A curricularização da extensão e sua aplicação nas escolas de engenharia," in *Proceedings of the XLVIII Brasilian Congress of Engineering Education*, 2020, doi: 10.37702/COBENGE.2020.3031.

[6] Gil, H. A. C.; Cutri, R.; Marques, A. E. B.; Matta, C. M. B. da, and Facca, C.A. "Extensão universitária no primeiro ano de engenharia: Oportunidade para o contato do estudante com demandas da comunidade e com uma metodologia de projeto". In *LI Congresso Brasileiro de Educação em Engenharia (COBENGE), 2023* (pp. 4207-4216). Available in: DOI: 10.37702/2175-957X.COBENGE.2023.4207

[7] Belfadel, D., & Macwan, I., & Drazan, J. F. Full paper: "Engaging First-Year Engineering Students Through Team-Based Design and Peer Review: A Service-Learning Approach" Paper presented at *14th Annual First-Year Engineering Experience (FYEE) Conference*, University of Tennessee in Knoxville, Tennessee. 2023. Avaliable in: https://strategy.asee.org/44822

[8] Won, D., & Ragusa, G., & Menezes, G. B., & Sharif, A., & Shahverdi, M., & Li, N., & Pacheco-Vega, A. BEST ZONE IV PAPER and BEST OVERALL ZONE WINNER – "BOOSTing Preparedness Through Engineering Project-based Service Learning" Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. 10.18260/1-2—36549

[9] Kelly, W. E., & Mohsen, J. P., & Haselbach, L. (2016, June), Engineering the UN Post-2015 "Sustainable Development Goals" Paper presented at *2016 ASEE Annual Conference & Exposition*, New Orleans, Louisiana. 10.18260/p.26672

[10] Zelinka, D., & Amadei, B., "A Methodology to Model the Integrated Nature of the Sustainable Development Goals: Importance for Engineering Education" Paper presented at *2017 ASEE Annual Conference & Exposition*, Columbus, Ohio. 10.18260/1-2—27479

[11] Laugelli, B. J., "Designing for a Sustainable World: Integrating the United Nations Sustainable Development Goals into a First-year Engineering Course in Science, Technology, and Society" Paper presented at *2020 ASEE Virtual Annual Conference* Content Access, Virtual On line . 10.18260/1-2—34407

[12] Brown,T. Design Thinking. São Paulo: Elsevier, 2010.

[13] Facca, C.A.; Freitas, P.A.de M.; Gil, H.A.C.; Guzzo, F.; Barbosa, A.M.T.B.. "Design Thinking como metodologia de projeto aplicada ao ensino de engenharia: O projeto "OPENFAB" na disciplina de introdução à engenharia." *Brazilian Journal of Developmen*t nov.5, n.9, p.16085-16098. ISSN2525-8761, 2019.

[14] Dodson, K. H., & Patterson, K. E., & Tipton, J. B., Work-in-Progress – "Emphasizing Human-Centered Design in the Freshman Year through an Interactive Engineering Design Process Experience" Paper presented at *2017 FYEE Conference*, Daytona Beach, Florida. https://peer.asee.org/29448

[15] Fila, N. D., & McKIlligan, S., & Guerin, K., "Design Thinking in Engineering Course Design" Paper presented at *2018 ASEE Annual Conference & Exposition* , Salt Lake City, Utah. 10.18260/1-2—30271

[16] Faber, C. J., & Kit, K., & Pionke, C. D., “Understanding the Processes and Challenges Students’ Experience Solving an Open-Ended Problem” Paper presented at *2017 FYEE Conference*, Daytona Beach, Florida. https://peer.asee.org/29440

[17] Phelan, M. A., & Guha, A., & Harrison, B. K., & Moukarzel, G., & Tetteh, A. A., & Har-El, Y., & Ochia, R., “Design-thinking Concepts in Undergraduate Engineering Capstone Projects” Paper presented at *2020 ASEE Virtual Annual Conference* Content Access, Virtual On line . 10.18260/1-2—34399

[18] Sadeghipour, K., & Brookstein, D., & Fagan, S., & Budischak, C., Work in Progress: “Introducing Design Thinking in First-Year Engineering Education” Paper presented at *2020 ASEE Virtual Annual Conference* Content Access, Virtual On line . 10.18260/1-2—35658

[19] Müller-Roterberg, C. (2021). *Design Thinking para Leigos*. Editora Alta Books. https://integrada.minhabiblioteca.com.br/books/9786555204445

[20] VIANNA, M. et al. *Design Thinking: Inovação em negócios*. Rio de Janeiro: MJV Press, 2011. 164 p.

[21] Osterwalder, A.; Pigneur, Y. *Business Model Generation: Inovação em modelos de negócios*. Rio de Janeiro: Alta Books, 2011. 300 p. Tradução: Raphael Bonelli

[22] Buzan, T.; *The Mind Map Book: Unlock your creativity, boost your memory,change your life.* 5. ed. Hampshire, UK: BBC Active, Pearson Education, 2010. 217 p.

[23] Arribas, E. et al “Development of a laboratory practice for physics introductory courses using a rubric for evaluation by competences”, 2019 *J. Phys.: Conf.* Ser. 1287 012025 DOI 10.1088/1742-6596/1287/1/012025

[24] Chan, Cky. "Rubrics for Engineering Education", *Engineering Education Enhancement and Research Asia* (E3R Asia), 2015. – Available in: https://hke3r.cetl.hku.hk/pdf/Rubrics-for-Engineering-Education.pdf

[25] Cutri, R.; Gil, H. A. C. ; Freitas, P.A.de M. ‘Avaliação por competências ? Uma proposta de aplicação em disciplinas de engenharia”. In: *XLVII Congresso Brasileiro de Educação em Engenharia* (COBENGE), 2020.

[26] Lousas virtuais on-line. Avaliable in: https://lucidspark.com/pt/solucoes/educacao [Accessed March. 12, 2024].

[27] Digital whiteboard. Avaliable in: https://jamboard.google.com/ [Accessed March. 12, 2024].