ISBN: 978-628-95207-4-3. ISSN: 2414-6390. Digital Object Identifier: 10.18687/LACCEI2023.1.1.1576

Soft skills development in bioengineering students through problem-based learning: An analysis of educational impact

Mariana Martínez-Ávila, PhD[1], Rebeca María García-García, PhD [1], Sara Guajardo-Flores, PhD [1], and Daniel Guajardo-Flores, PhD [1]
[1]Tecnologico de Monterrey, School of Engineering and Sciences, Ave. Eugenio Garza Sada 2501, Monterrey 64849, NL, Mexico, mm.avila@tec.mx, danielgdo@tec.mx

Abstract*– This study aimed to evaluate the perception and self-assessment of soft skills development among bioengineering students using problem-based learning (PBL) methodology. A survey was conducted to assess the relevance perception and self-assessment of seven soft skills with different attributes, before and after the PBL course. The study found that bioengineering students recognized the importance of developing soft skills alongside technical expertise. Communication, critical thinking and problem-solving, entrepreneurship, ethics and professional moral, leadership, continuous learning and information handling, and teamwork skills were consistently improved with the PBL course. The PBL methodology had a positive impact on the development of soft skills attributes, as students either improved or maintained their skill levels. However, significant differences were observed in five of the seven soft skills attributes. The use of technology for making presentations and the impact of understanding the external factors were the least developed attributes among students. The study suggests that PBL may not have included enough opportunities for students to develop these skills, and specific activities may need to be incorporated in the future. Overall, the results underscore the importance of integrating soft skills development into bioengineering education and training programs, as these skills are crucial for success in the field.

Keywords- Soft skills, bioengineering students, Problem-based learning, innovative education.

I. Introduction

Soft skills are becoming increasingly important for engineering students as they prepare for their future careers. These skills include communication, critical thinking and problem solving, entrepreneurship, ethics and professional moral, leadership, and teamwork[1–3]. Hence, to succeed in today's fast-paced and globalized workplace, engineers must be able to collaborate effectively with colleagues from diverse backgrounds and cultures, communicate technical information to non-technical audiences, and adapt to changing circumstances and technologies[3,4].

In addition, industry expectations for soft skills among engineering graduates are high. Employers are looking for engineers who are not only technically proficient, but who can also work well in teams, communicate effectively, and demonstrate leadership potential[1,5]. According to a survey by the National Association of Colleges and Employers (NACE), 80% of employers said that communication skills were essential for their new hires, while 74% cited teamwork skills, and 70% cited problem-solving skills[6].

Evidently, soft skills are increasingly important in today's workplace, and universities play a crucial role in preparing students for these skills. Universities can provide opportunities for students to gain the associated abilities through coursework, experiential learning, and other activities, such as leadership skills through student organizations, volunteer work, and leadership development programs.

There are different teaching and learning approaches that can be used to develop soft skills. By providing hands-on learning experiences, opportunities for collaboration and feedback, and mentorship and support, students can develop the skills they need to excel in any field. Among them, Problem-Based Learning (PBL) has emerged as a popular pedagogical approach in recent years[7–9]. PBL is a student-centered approach that emphasizes the development of critical thinking, problem-solving, and collaboration skills. It involves presenting students with real-world problems and challenging them to work together in multidisciplinary teams to find solutions[8]. PBL has been shown to be particularly effective in promoting the development of soft skills, such as communication, teamwork, and leadership, which are essential in today's rapidly changing and interconnected world.

In this article, we examine the impact of PBL on the development of soft skills in bioengineering students. Bioengineering is a rapidly growing field that combines engineering principles with biological and medical sciences. As such, bioengineering students need to be equipped with a range of soft skills in addition to their technical knowledge. We review the literature on PBL and soft skill development and present the results of a study conducted on a cohort of bioengineering students who participated in a PBL program.

The aim of this article is to provide evidence-based insights into the effectiveness of PBL in promoting the development of soft skills in bioengineering students. We hope that this article will be of interest to educators and researchers in the field of bioengineering and beyond, who are looking for innovative pedagogical approaches to prepare students for the challenges of the 21st century.

Digital Object Identifier: (only for full papers, inserted by LACCEI).
ISSN, ISBN: (to be inserted by LACCEI).
DO NOT REMOVE

II. Background

A. Soft skills for Engineering students

In the current highly competitive job market, students cannot rely solely on their knowledge and technical skills to be competitive. It is crucial for graduates and students to enhance their value by developing a wider range of skills and adapting to the changing performance expectations. They need to capitalize on their traditional technical skills while also acquiring broader skills to remain competitive[7,10,11].

In the field of bioengineering, it is essential for students to develop a range of soft skills that complement their technical knowledge and abilities (hard skills)[3,4,12,13]. Soft skills are a set of personal attributes that enable individuals to interact effectively and harmoniously with others. These skills are highly valued by employers and are essential for success in the workplace, as they facilitate effective communication, teamwork, problem-solving, and leadership. Table I includes the seven soft skills previously identified by Ngoo et al.[1] which have the greatest impact.

Graduates and bioengineering students must adapt to changing performance expectations by developing a broader range of skills that complement their traditional technical skills[1]. While graduates are aware of the need for soft skills, such as communication, analytical, professional, and teamwork skills, employers now expect graduates to have "business awareness" and sensitivity towards current issues. However, both students and employers have reported that many university accounting programs fail to deliver both professional and non-technical skills[5]. Universities play an important role in bridging the gap between graduates and employers[2,14,15].

TABLE I
SOFT SKILLS EVALUATED THROUGH STUDENT'S PERCEPTIONS

Soft skill	**Attribute evaluated (Ability to)**
Communication	▪ Confident communication (written and oral). ▪ Active listening. ▪ Effective presentations. ▪ Technology use in presentations. ▪ Negotiation and consensus-building. ▪ Effective cross-cultural communication. ▪ Expand one's own communicative skill. ▪ Use non-oral skills.
Critical thinking and problem-solving	▪ Problem identification and analysis. ▪ Critical thinking and evaluation ▪ Think out of the box. ▪ Evidence-based decision making. ▪ Focus and attention to tasks. ▪ Adaptability to new environments and cultures.
Entrepreneurship	▪ Identify business opportunities. ▪ Business planning and estimation. ▪ Effective opportunity creation and exploration. ▪ Self-employed (entrepreneurship).
Ethics and professional moral	▪ Understanding impact of external factors. ▪ Ethics analysis and decision making. ▪ Ethical behaviour and social responsibility.
Leadership	▪ Project leadership. ▪ Leadership and follower role adaptation. ▪ Contribute to teambuilding and work. ▪ Supervise team members.
Continuous learning & information handling	▪ Information research and management. ▪ Self-learning and idea reception. ▪ Curiosity and desire for knowledge acquisition.
Teamwork	▪ Team collaboration towards common objectives. ▪ Flexibility to alternate between leadership and follower roles. ▪ Cultural awareness and respect for others. ▪ Effective planning and coordination abilities.

Effective communication is one of the most important soft skills for bioengineering students to develop. Bioengineers must communicate effectively with their colleagues, clients, and stakeholders to convey complex technical information in a clear and concise manner. They must be able to listen actively, understand the perspectives of others, and communicate their own ideas effectively. Developing strong communication skills will enable bioengineering students to work collaboratively with others and to build effective relationships with clients and colleagues.

Teamwork is another essential soft skill for bioengineering students. Bioengineering projects often involve collaboration between interdisciplinary teams, including engineers, scientists, clinicians, and other professionals. Effective teamwork requires good communication, trust, mutual respect, and a willingness to collaborate and compromise. By developing their teamwork skills, bioengineering students can contribute to successful project outcomes and build strong professional relationships.

Problem-solving is another key soft skill that bioengineering students must develop. Bioengineering projects often involve complex technical challenges that require innovative solutions. Students must be able to analyze problems, identify potential solutions, and evaluate the pros and cons of each option. By developing their problem-solving skills, bioengineering students can contribute to innovative and effective solutions that improve health outcomes and advance the field of bioengineering.

Leadership is another important soft skill for bioengineering students. Bioengineering projects often involve managing teams, budgets, and timelines. Students must be able to motivate and inspire others, delegate tasks effectively, and provide constructive feedback. Developing strong leadership skills will enable bioengineering students to take on leadership roles in their careers and to contribute to the advancement of the field.

B. Problem-based learning (PBL)

PBL has its roots in the medical field and was developed in the 1960s at McMaster University in Canada. The original intent of PBL was to help medical students better prepare for the complexities of clinical practice by engaging them in authentic problem-solving activities that resembled the real-life scenarios they would encounter as practicing physicians[8,16].

Over time, PBL has been adopted by other disciplines and is now widely used in various educational contexts, from primary to higher education, to help students develop critical thinking, problem-solving, collaboration, and communication skills[8,9,17]. PBL differs from traditional lecture-based learning in several ways. In a lecture-based learning

environment, the teacher assumes a dominant role, and the students are passive receivers of information. The focus is on the transfer of knowledge from the teacher to the student, and the emphasis is on memorization and recall[10,12].

In contrast, in a PBL environment, the students take responsibility for their own learning. The teacher or facilitator acts as a guide, and the students work in groups to solve complex, real-world problems. The emphasis is on developing problem-solving, critical thinking, and communication skills, rather than just acquiring knowledge[17].

PBL is an effective and engaging teaching and learning approach that has several benefits. Firstly, it promotes active engagement by providing students with real-world problems to solve, which encourages deeper understanding and retention of knowledge. Secondly, it emphasizes collaboration and teamwork, as students work in groups to solve complex problems, helping them to develop interpersonal and communication skills. Thirdly, it encourages self-directed learning, as students take responsibility for their own learning by identifying their own learning needs and developing strategies to address them. Fourthly, it promotes the development of transferable skills, such as problem-solving, critical thinking, and communication, which can be applied in real-world situations. Lastly, PBL is a student-centered approach that emphasizes the development of practical skills rather than just the acquisition of knowledge, making learning more relevant and meaningful to students[8,10,16]. Overall, PBL is a powerful teaching and learning approach that can help students develop the skills they need to succeed in the 21st century.

Several studies have investigated the impact of PBL on the development of soft skills in engineering students. For example, Schmidt and Moust[18] found that PBL had a positive impact on the development of teamwork skills in engineering students. Similarly, Hsieh and Knight [17] found that PBL was effective in developing communication skills in engineering students. However, few studies have investigated the impact of PBL on the development of soft skills in students of bioengineering. Given the multidisciplinary nature of bioengineering, it is important to investigate the potential of PBL to develop soft skills in this field.

Overall, the theoretical framework of this study is based on the principles of PBL and its potential to develop soft skills in students of bioengineering. The study aims to investigate the impact of the assessment activities implemented in a problem-based learning class for bioengineering students in the ranking and level of achievement of soft skills. This with the purpose of improving engineering education in Latin America and the Caribbean.

III. Methodology

A. Participants and data collection

The study consisted of 24 students who were currently enrolled in the 6th semester in the School of Engineering and Sciences at "Tecnológico de Monterrey". The students belong to the fields of Bioprocess Engineering, Food Engineering, or Chemical Engineering.

B. Problem-based learning classes and activities

Following a problem-based learning approach, the class dynamics consisted of organizing the 24 undergraduate students into multidisciplinary teams. Within each team, at least one student from each major is present in every team. Four teams of five students and two teams of four students were formed. Based on real industry problems, each team was assigned a different problem directly linked to a local small and medium-sized enterprise (SME). In general, all the problems were based on reformulating or formulating a product according to the needs of the SME, considering the impact it will have on its quality from a nutritional, sensory, microbiological, among other perspectives. Its technological feasibility must be maintained, and sustainability principles should be considered in decision-making. Innovation in this product may involve changes in formulation or adjustments to the process that lead to achieving, for example, a label with certain claims, or with a specific shelf life.

The students work in small groups to identify the key issues, generate questions, and develop a plan for addressing the problem. They then conduct research to gather information and develop a hypothesis that explains the problem. The students test their hypothesis through experimentation, data analysis, and critical thinking. As part of the class dynamics, students were responsible for scheduling, leading, and organizing meetings directly with a representative of SMEs. Thus, students were in control of defining, devising, and negotiating the scope and deliverables to be provided to the entrepreneurs at the end of the class.

Throughout the process, a group of 4 teachers developed the role of guiding the students and facilitators, providing guidance and feedback as needed while covering enough content so that they have the knowledge bases to solve the problems. During the 10 weeks that the class lasted, different evaluation activities were implemented to evaluate their performance in a continuously observed and feedback environment (Table II).

TABLE II
ASSESSMENT ACTIVITIES IMPLEMENTED IN A PROBLEM-BASED LEARNING CLASS FOR BIOENGINEERING STUDENTS FOR 10 WEEKS.

Type of activity	**Working mode**	**Details of the developed activities**
Learning	Collaborative	▪ Content review. ▪ Laboratory practices (guided according to the topics seen in class). ▪ Class activities (research of specific topics and present the results to the whole class).
Procedural	Collaborative	▪ Development of the prototype for the solution of the problem, considering

		a design of experiments (laboratory)
Integration of conceptual and procedural knowledge	Collaborative	▪ Progress presentations of the problem solution proposal (following the design thinking methodology) ▪ Written technical report explaining the proposed solution to the problem, results obtained, conclusions and future recommendations.
	Individual	▪ Written argumentative exam. ▪ Oral argumentative exam.

The class activities culminate in a presentation and report that summarizes the findings and solutions. Overall, the PBL methodology encourages active learning, collaboration, and critical thinking, and helps students to develop a range of skills that are valuable in both academic and professional settings.

C. Data collection and Indicators

A self-evaluation soft-skills test was conducted to allow participants to assess and reflect on their own performance, skills, abilities, and progress. The seven soft-skills and their respective assessed attributes are presented in Table 1. Specifically, participants were asked to rank the set of attributes corresponding to each skill in order of perceived importance. After the ranking, students were asked to rate the level they consider to have in each attribute (level of dominance) according to a rating scale (Table III).

During self-evaluation, participants were set specific criteria against which they assess themselves. They consider their accomplishments, challenges faced, feedback received from others, and personal observations. This type of evaluation was chosen since it considers self-reflection, introspection, and a honest appraisal of one's own abilities and actions. Additionally, it involves critically analyzing one's strengths, weaknesses, areas for improvement, and overall growth. It was based in a questionnaire developed by Ngoo to measure the attitude of participants towards soft skills [12].

TABLE III
SOFT SKILLS RATING SCALE FOR SELF-ASSESSMENT TESTS.

Level	**Description**
Outstanding	Extremely good performance which could serve as a model example for others.
Above average	Higher or better than what is considered the norm or average.
Average	Satisfactory performance but could improve.
Below average	Lower or worse than what is considered the norm or average.
Lacking	Absence of attribute, requires fully development.

The surveys were implemented at the beginning of the class and at the end (after the 10 weeks it lasted). This with the intention of evaluating the impact of the assessment activities implemented in a problem-based learning class for bioengineering students in the ranking and level of achievement of soft skills.

IV. RESULTS AND DISCUSSION

A. Relevance perception of soft skills

The perception of the bioengineering students about the relevance of soft skills remained constant with respect to the beginning or end of the class (data not shown). As revealed by the survey questionnaires, a problem-based learning class has no effect on the students' perception of the top two most important soft skills attributes (Table IV).

TABLE IV
PERCEPTION OF BIOENGINEERING STUDENTS ABOUT THE RELEVANCE OF SOFT SKILLS. TWO MOST RELEVANT ATTRIBUTES.

Soft skill	**Most relevant attributes**	
Communication	1. Confident communication (written and oral).	71 %
	2. Active listening.	50 %
Critical thinking and problem-solving	1. Problem identification.	75 %
	2. Evidence-based decision making.	38 %
Entrepreneurship	1. Effective opportunity creation and exploration.	88 %
	2. Identify business opportunities.	63 %
Ethics and professional moral	1. Ethical behaviour and social responsibility.	88 %
	2. Understanding impact of external factors.	88 %
Leadership	1. Leadership and follower role adaptation.	88 %
	2. Contribute to teambuilding and work.	79 %
Continuous learning and information handling	1. Curiosity and desire for knowledge acquisition.	79 %
	2. Self-learning and idea reception.	71 %
Teamwork	1. Team collaboration towards common objectives.	75 %
	2. Flexibility to alternate between leadership and follower roles.	50 %

Overall, these results suggest that bioengineering students recognize the value of a broad range of soft skills in their field and understand the importance of developing these skills alongside technical expertise. Communication is a crucial skill in any field, and the emphasis on confident communication and active listening reflects the need for bioengineering professionals to be able to articulate their ideas effectively and understand the needs of others.

Problem identification and analysis, as well as thinking out of the box, demonstrate the importance of critical thinking and innovation in the bioengineering field. Bioengineers must be able to identify problems and come up with creative solutions to address them. Additionally, the emphasis on entrepreneurship and identifying business opportunities suggests that bioengineering students are aware of the growing role of entrepreneurship in the field, as many bioengineering innovations are commercialized through startup companies.

The focus on ethical behavior and social responsibility, as well as understanding the impact of external factors, reflects the need for bioengineers to consider the social and ethical implications of their work and to be mindful of the broader impact of their innovations on society. Furthermore, the emphasis on leadership, follower role adaptation, and team building shows that bioengineering students recognize the importance of collaboration and teamwork in achieving common goals.

Finally, the emphasis on curiosity and desire for knowledge acquisition, as well as self-learning and idea reception, highlights the importance of continuous learning and development in the rapidly evolving field of bioengineering. Overall, the perception of bioengineering students about the relevance of soft skills underscores the importance of the soft skills in bioengineering education and training programs.

B. *Self-assessment of soft skill levels*

In particular, the evolution of soft skills was compared as an effect of the problem-based learning methodology that was applied. For example, as shown in Fig. 1, at the end of the class, more than 80 % of the students had either improved or maintained their level of teamwork skills. In contrast, this result was significantly higher than the students who experienced a negative impact on the development of the attribute (ca. 17 %; $p<0.05$). This trend was observed for all seven soft skills evaluated (data not shown).

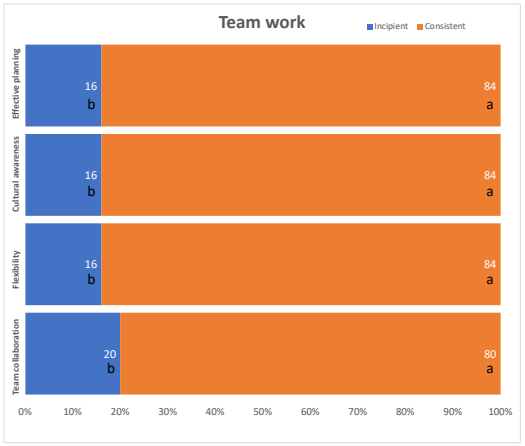

Fig. 1 Impact of the learning method based on problem solving on the attributes of *teamwork skills*. a-b: means with the same letter in each attribute are not significantly different according to t Student test ($p < 0.05$).

When facing real-world problems in the field of bioengineering, students must seek new and creative solutions to address the challenges, analyse and evaluate complex information to find effective solutions and learn to communicate effectively and collaborate with others to achieve a common goal. This helps them develop social and emotional skills, such as empathy, conflict resolution, and teamwork. Overall, an improvement was observed in the level of development of the attributes of each evaluated soft skills.

However, when evaluating between consistent attributes, significant differences were observed in five of the seven soft skills, noticing that critical thinking and teamwork skills were the only ones that did not have a significant difference between their attributes (Fig. 1; $p<0.05$).

C. *Communication skills*

In the communication skills, the learning activities carried out during the class, showed that the attribute least developed among the students was the use of technology for making presentations (Fig. 2). The use of technology for making presentations involves knowledge and management of specific tools, such as presentation software and hardware. While these skills may be useful in the workplace, they are not necessarily required in all situations. Therefore, it is possible that in the context of problem-based learning, these skills may not be significantly developed.

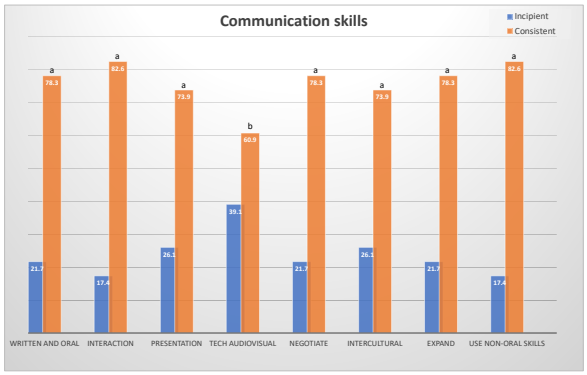

Fig. 2 Impact of the learning method based on problem solving on the attributes of *communications skills*. a-b: means with the same letter between attributes are not significantly different according to t Student test ($p < 0.05$).

Furthermore, the methodology used in problem-based learning may not have included enough opportunities for students to develop their skills in using technology to make presentations. In this case, it may be necessary to consider the inclusion of specific activities, such as workshops or projects focused on the use of technology for making presentations, to develop these skills.

D. *Entrepreneur skills*

A similar behavior was noticed in the development of the entrepreneurship skills, where significantly the attributes that were most developed were the identification of business opportunities and the effective opportunity, creation and exploration of opportunities (Fig. 3).

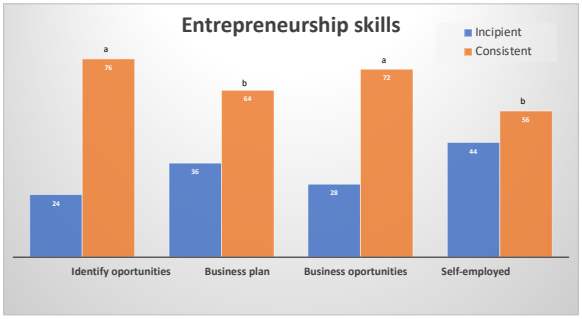

Fig. 3 Impact of the learning method based on problem solving on the attributes of *entrepreneur skills*. a-b: means with the same letter between attributes are not significantly different according to t Student test ($p < 0.05$).

In the context of business, problem-based learning can be particularly useful for developing skills in identifying and exploring business opportunities. By working on real-world problem-solving in the business environment, students can learn to recognize patterns and trends and identify business opportunities that may not have been evident otherwise.

Furthermore, the focus on practical problem-solving in problem-based learning encourages creativity and innovation. When faced with complex business challenges, students can explore new ideas and approaches to address the problem, which can lead to the identification of unique and unconventional business opportunities.

E. Ethics and professional moral skills

In the ethics and professional moral skills, the learning activities carried out during the class, showed that the attribute least developed among the students was the impact of understanding external factors (Fig. 4).

Fig. 4 Impact of the learning method based on problem solving on the attributes of *ethics and professional moral skills*. a-b: means with the same letter between attributes are not significantly different according to t Student test ($p < 0.05$).

Problem-based learning focuses on developing skills to solve specific problems through the application of previous knowledge and skills. Although it may involve discussion and reflection on professional ethics and morality in relation to a particular problem, it does not necessarily focus on understanding external factors that may influence these aspects of the profession.

Therefore, problem-based learning may not be the best methodology for developing a deep understanding of professional ethics and morality in relation to external factors. Other methodologies, such as critical analysis, ethical reflection, and group discussion, may be more effective for this purpose[9,17].

The teaching methodology to strengthen the importance of considering external factors when developing a solution in the field of bioengineering within the framework of the soft skill of professional ethics and morality should combine the identification of external factors, case analysis, discussion, and reflection. External factors, such as cultural beliefs, social norms, political policies, and economic conditions, can significantly influence the ethical decision-making process in bioengineering.

If bioengineers fail to consider external factors when developing solutions, they run the risk of creating unintended consequences that can have negative impacts on society and the environment. For example, the development of new medical technologies and treatments must consider the social and economic context in which they will be implemented, as well as the potential impact on vulnerable populations. Failure to consider these factors can result in the perpetuation of inequalities and the exclusion of certain groups from accessing vital healthcare services.

Within the learning activities that should be included to improve the level of awareness of the ethical and moral impact of the proposed solutions to problems in the bioengineering area, it is suggested case studies activities, where the students can engage in group discussions and reflection sessions to analyse the case studies presented and identify the external factors that may have influenced the ethical decision-making process. This may allow students to consider different perspectives and gain a deeper understanding of the importance of considering external factors.

F. Leadership skills

The development of leadership skills among bioengineering students through a problem-based learning approach, showed no significant differences between their adaptation in the role that they play in a group, the contribution to teambuilding and work to achieve a common goal nor the supervision of team members (Fig. 5; $p<0.05$). In contrast, that the attribute least developed among the students was the ability to lead a project.

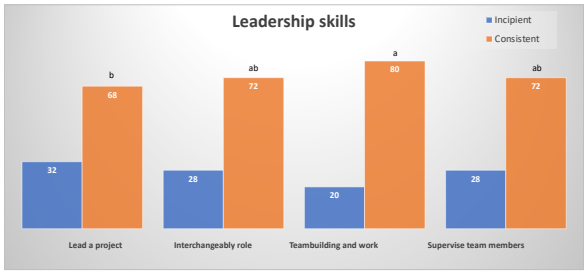

Fig. 5 Impact of the learning method based on problem solving on the attributes of *leadership skills*. a-b: means with the same letter between attributes are not significantly different according to t Student test ($p < 0.05$).

Problem-based learning focuses on developing skills to solve specific problems through the application of previous knowledge and skills. Although this methodology may require students to work in teams and collaborate in problem solving, it does not necessarily focus on developing leadership skills to lead projects.

The ability to lead projects requires a combination of technical and soft skills, such as the ability to communicate effectively, set clear goals, motivate team members, and manage resources efficiently. Although problem solving may require some of these soft skills, it does not necessarily focus on their development in the context of project leadership.

Therefore, other teaching methodologies may be more effective in developing leadership skills in the context of projects. These methodologies may include project leadership simulations, practical activities in which students can lead real or fictional projects and receive feedback on their performance, and opportunities to work in teams and develop collaboration and effective communication skills.

G. *Lifelong learning and information management skills*

Finally, attributes of the continuous learning and information handling skill also showed significant differences (Fig. 6). Surprisingly, the attribute that showed less impact due to the learning method used was the management of relevant information ($p<0.05$).

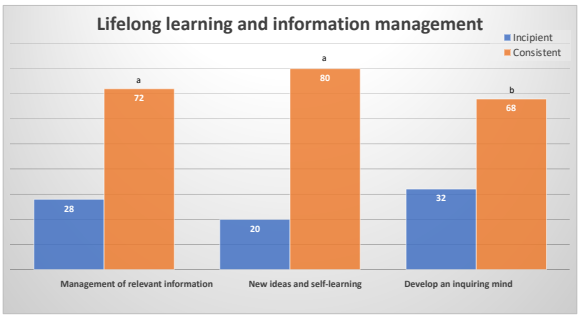

Fig. 6 Impact of the learning method based on problem solving on the attributes of *lifelong learning and information management skills*. a-b: means with the same letter between attributes are not significantly different according to t Student test ($p < 0.05$).

Problem-based learning is a teaching methodology that focuses on the problem-solving process as a means of developing students' learning. This methodology involves the identification and resolution of problems, which requires students to search for and analyze relevant information to find a solution. However, it is possible that an exclusive focus on problem-solving may not allow for significant development of search and management skills for relevant information. This is because the methodology is focused on solving a specific problem, rather than developing broader search and information management skills.

To effectively develop search and information management skills, it is necessary to integrate them into the problem-solving process and teach them explicitly. This means that students must learn to identify reliable sources of information, evaluate the quality of information, and use search and analysis tools to find relevant information. In addition, since the field of bioengineering presents a range of complex ethical and moral issues that require careful consideration. To improve the level of awareness among students regarding the ethical impact of proposed solutions to problems in bioengineering, it is recommended to include case studies activities in the learning activities.

V. Conclusions

In conclusion, this study highlights the importance of soft skills in the education and training programs for bioengineering students. The results showed that bioengineering students recognize the value of a broad range of soft skills in their field and understand the importance of developing these skills alongside technical expertise. Communication, critical thinking and problem-solving, entrepreneurship, ethics and professional moral, leadership, continuous learning and information handling, and teamwork were identified as the most relevant soft skills for bioengineering students.

Therefore, the implementation of problem-based learning methodology proves to be a strategy that positive impacts on the development of soft skills in bioengineering students, with significant improvements observed in five out of seven attributes evaluated. However, specific skills such as using technology for making presentations may require additional attention in future curricula. Overall, this study emphasizes the importance of focusing on the impact that teaching methodologies have on the development of soft skills in the School of Engineering and Sciences students. Feedback is a valuable component in evaluation, since it promotes student learning by emphasizing the goal to be achieved, provides them with information on how their performance has been, and guides them in the improvement actions that students must carry out to achieve the sub-competences levels assigned to this class.

To our knowledge, this is the first time that the development of soft skills in bioengineering students has been evaluated considering the impact of a problem-solving methodology.

Acknowledgment

*The authors would like to **acknowledge the financial and the technical** support of Writing Lab, TecLabs, Tecnologico de Monterrey, Mexico, in the production of this work.*

References

[1] Y.T. Ngoo, K.M. Tiong, W.F. Pok, Bridging the Gap of Perceived Skills between Employers and Accounting Graduates in Malaysia, American Journal of Economics. (2015).

[2] B. Schulz, The importance of soft skills: Education beyond academic knowledge, (2008).

[3] M. Caeiro-Rodriguez, M. Manso-Vazquez, F.A. Mikic-Fonte, M. Llamas-Nistal, M.J. Fernandez-Iglesias, H. Tsalapatas, O. Heidmann, C.V. De Carvalho, T. Jesmin, J. Terasmaa, L.T. Sorensen, Teaching Soft Skills in Engineering Education: An European Perspective, IEEE Access. 9 (2021) 29222–29242. https://doi.org/10.1109/ACCESS.2021.3059516.
[4] S.H. Pulko, S. Parikh, Teaching 'Soft' Skills to Engineers, The International Journal of Electrical Engineering & Education. 40 (2003) 243–254. https://doi.org/10.7227/IJEEE.40.4.2.
[5] M.H. Kavanagh, L. Drennan, What skills and attributes does an accounting graduate need? Evidence from student perceptions and employer expectations, Accounting & Finance. 48 (2008) 279–300. https://doi.org/10.1111/j.1467-629X.2007.00245.x.
[6] J.M. Fernandes, L.M. Cunha, E.P. Azevedo, E.M.G. Lourenço, M.F. Fernandes-Pedrosa, S.M. Zucolotto, Kalanchoe laciniata and Bryophyllum pinnatum: an updated review about ethnopharmacology, phytochemistry, pharmacology and toxicology, Revista Brasileira de Farmacognosia. 29 (2019) 529–558. https://doi.org/10.1016/j.bjp.2019.01.012.
[7] V. Uskov, J.P. Bakken, L. Aluri, R. Rachakonda, N. Rayala, M. Uskova, Smart Pedagogy: Innovative Teaching and Learning Strategies in Engineering Education, in: 2018 IEEE World Engineering Education Conference (EDUNINE), IEEE, Buenos Aires, 2018: pp. 1–6. https://doi.org/10.1109/EDUNINE.2018.8450962.
[8] M. Lehmann, P. Christensen, X. Du, M. Thrane, Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education, European Journal of Engineering Education. 33 (2008) 283–295. https://doi.org/10.1080/03043790802088566.
[9] R. González, A review of Problem-Based Learning applied to Engineering, (2016).
[10] W.B. Gaskins, J. Johnson, C. Maltbie, A. Kukreti, Changing the Learning Environment in the College of Engineering and Applied Science Using Challenge Based Learning, Int. J. Eng. Ped. 5 (2015) 33. https://doi.org/10.3991/ijep.v5i1.4138.
[11] M. Hernández-de-Menéndez, A. Vallejo Guevara, J.C. Tudón Martínez, D. Hernández Alcántara, R. Morales-Menendez, Active learning in engineering education. A review of fundamentals, best practices and experiences, Int J Interact Des Manuf. 13 (2019) 909–922. https://doi.org/10.1007/s12008-019-00557-8.
[12] J. Membrillo-Hernández, M. de Jesús Ramírez-Cadena, A. Ramírez-Medrano, R.M.G. García-Castelán, R. García-García, Implementation of the challenge-based learning approach in Academic Engineering Programs, Int J Interact Des Manuf. 15 (2021) 287–298. https://doi.org/10.1007/s12008-021-00755-3.
[13] J. Membrillo-Hernández, M. de J. Ramírez-Cadena, C. Caballero-Valdés, R. Ganem-Corvera, R. Bustamante-Bello, J.A. Benjamín-Ordoñez, H. Elizalde-Siller, Challenge Based Learning: The Case of Sustainable Development Engineering at the Tecnologico de Monterrey, Mexico City Campus, in: M.E. Auer, D. Guralnick, I. Simonics (Eds.), Teaching and Learning in a Digital World, Springer International Publishing, Cham, 2018: pp. 908–914. https://doi.org/10.1007/978-3-319-73210-7_103.
[14] D. Kelley-Patterson, C. George, Securing graduate commitment: an exploration of the comparative expectations of placement students, graduate recruits and human resource managers within the hospitality, leisure and tourism industries, International Journal of Hospitality Management. 20 (2001) 311–323. https://doi.org/10.1016/S0278-4319(01)00019-6.
[15] M. Cinque, "Lost in translation". Soft skills development in European countries, TJHE. 3 (2016) 389–427. https://doi.org/10.18543/tjhe-3(2)-2016pp389-427.
[16] D.N. Scott, A.R. Hadgraft, D. Vojislav, Engineering education—Is problem-based or project-based learning the answer., 3 (2003) 2–16.
[17] C. Hsieh, L. Knight, Problem-Based Learning for Engineering Students: An Evidence-Based Comparative Study, The Journal of Academic Librarianship. 34 (2008) 25–30. https://doi.org/10.1016/j.acalib.2007.11.007.
[18] Y. Aguilera, L. Mojica, M. Rebollo-Hernanz, M. Berhow, E.G. de Mejía, M.A. Martín-Cabrejas, Black bean coats: New source of anthocyanins stabilized by β-cyclodextrin copigmentation in a sport beverage, Food Chemistry. 212 (2016) 561–570. https://doi.org/10.1016/j.foodchem.2016.06.022.