# (09-026) - Evaluating the Integration and Perception of Threshold Concepts in Engineering and Project Management Education

Lo-Iacono-Ferreira, Vanesag. [1]; García-Bernabeu, Ana María [2]; Micó-Vicent, Barbara [2]; Jordán-Núñez, Jordi [2]; TORREGROSA-LÓPEZ, JUAN IGNACIO [2]

[1] Universitat Politécnica de València, [2] Universitat Politecnica de València

The present study explores the possible discrepancy between students' mastery of threshold concepts across different disciplines in universities and the desired level of comprehension. These foundational concepts are crucial for students to advance in their academic journey. The study employs a meticulously designed survey specifically targeting university students to gather insights into students' grasp of these concepts. The survey investigates various aspects, including the contextual application of knowledge, quality of academic work, efficiency in information sourcing, and the coherence of written reports. Furthermore, it delves into students' proficiency in transversal skills such as social commitment, innovation, teamwork, effective communication, and decision-making.

The study hypothesizes that a probable gap in threshold concept may hinder learning, diverting attention away from discipline-specific technical learning to remediate less specific skills such as developing well-structured documents. The outcomes of this research could potentially have significant implications for curriculum design and academic success, particularly in addressing the balance between technical and transversal skill development in higher education

Keywords: threshold; concepts; skills; gaps; higher; education

## Evaluación de la Integración y Percepción de Conceptos Umbral en la Educación de Ingeniería y Gestión de Proyectos

Este estudio explora la posible discrepancia entre el dominio de conceptos clave por parte de los estudiantes en diferentes disciplinas universitarias y el nivel de comprensión deseado. Estos conceptos fundamentales son cruciales para que los estudiantes avancen en su trayectoria académica. A través de una encuesta a los profesores universitarios se investiga la aplicación contextual del conocimiento, la calidad del trabajo académico, la eficiencia en la obtención de información y la coherencia de los informes escritos. Además, profundiza en la competencia de los estudiantes en habilidades transversales como el compromiso social, la innovación, el trabajo en equipo, la comunicación efectiva y la toma de decisiones.

El estudio plantea la hipótesis de que una posible brecha en un concepto clave podría obstaculizar el aprendizaje, desviando la atención de la formación técnica específica de la disciplina hacia la mejora de habilidades menos específicas como el desarrollo de documentos bien estructurados. Los resultados de esta investigación pueden tener implicaciones significativas tanto para el diseño del plan de estudios así como en el éxito académico, especialmente en lo que respecta al equilibrio entre el desarrollo de habilidades técnicas y transversales en la educación superior.

Palabras clave: umbral; conceptos; habilidades; brechas; educación; superior

Correspondencia: Juan Ignacio Torregrosa-López jitorreg@iqn.upv.es

Agradecimientos: The authors would like to acknowledge the contribution, assistance, and financial support of Universitat Politècnica de València (UPV): Learning and Teaching Program. Innovation and Educational Improvement Projects (PIME/22-23/353).

## 1. Introduction

Threshold concepts are pivotal in understanding how students transition from novice to expert within their disciplines. These concepts are not just content-specific; they are transformative and integrally linked to the identity formation of the learner within the discipline (Flanagan, 2017). The evolution of threshold concept theory has expanded from identifying specific troublesome knowledge to exploring the pedagogical frameworks that support learners in navigating these critical junctures (Timmermans & Meyer, 2019).

Integrating threshold concepts into curriculum design has gained substantial attention for its potential to enhance learner engagement and conceptual understanding (Carstensen & Bernhard, 2018). Emphasizing threshold concepts facilitates a deeper, more connected understanding of the subject matter, promoting a learner-centered approach that acknowledges the complexities of learning (Barradell, 2018). This pedagogical shift encourages educators to focus on transmitting knowledge and the learner's journey through liminality and toward mastery (Klaassen, 2018).

Mastering threshold concepts involves navigating liminal spaces, where learners oscillate between old understandings and new, transformative insights (Land et al., 2016). This liminality can be fraught with uncertainty and discomfort, challenging both learners and educators to engage with the inherent messiness of deep learning (Ross et al., 2017). Recent research has emphasized the importance of resilience and perseverance through these liminal phases, advocating for pedagogies that support students' affective and cognitive needs during this transformative process (Kift, Nelson, & Clarke, 2010).

The interconnection between threshold concepts and the development of transversal skills such as critical thinking, collaboration, and problem-solving has been increasingly recognized as vital for preparing students for the complexities of the modern world (Davies & Mangan, 2017). These skills, which transcend disciplinary boundaries, are essential for students to apply their understanding in diverse contexts, enhancing their adaptability, creativity, and employability in a rapidly changing world (Sin & Reid, 2018).

While the body of literature on threshold concepts has grown, there remains a need for empirical studies that explore the implementation and impact of threshold concept-based pedagogies across diverse disciplines and cultural contexts (Quinlan et al., 2019). Additionally, the dynamic relationship between the mastery of threshold concepts and the development of transversal skills in enhancing student learning outcomes warrants further investigation.

Lo-Iacono-Ferreira et. Al (2023) has previously identified ten critical threshold concepts crucial for students' success in academic and professional projects, structured across three dimensions: context and planning, development and execution, and report writing and oral presentation. These dimensions were established through comprehensive analysis and iterative discussions among faculty members from various disciplines, primarily within engineering and business administration. This framework has guided the development of targeted interventions to enhance students' understanding and application of these essential concepts, further demonstrating the effectiveness of Project Based Learning (PBL) in addressing these educational gaps. Table 1 gathers the threshold concepts identified and its dimensions.

**Table 1: Threshold concepts defined and its dimensions**

| Dimension | Threshold concept |
|---|---|
| Context and Planning | Academic framework |
| | Work planning |
| Development and Execution | Search and analysis of the bibliography |
| | Search for information and data |
| | Processing of information and data |
| | Application of the methodology for problem resolution and analysis |
| | Discussion of the results |
| Report Writing and Oral Presentation | Writing reports |
| | Preparing presentations |
| | oral defense |

Exploring threshold concepts in higher education offers valuable insights into the nature of learning and curriculum design. By focusing on these transformative concepts, educators can facilitate deeper, more meaningful project-based learning experiences that prepare students for the complexities of their future professional and personal lives.

PBL has emerged as a powerful pedagogical strategy that complements the integration of threshold concepts within educational frameworks. PBL is characterized by its focus on real-world problems and challenges, fostering an environment where students actively engage in their learning processes through investigation, collaboration, and reflection (University of Queensland, 2024). This methodology effectively addresses threshold concepts, which are transformative and often troublesome for learners, by providing a practical context in which these concepts can be explored and understood deeply.

The essence of PBL lies in its ability to create meaningful learning experiences beyond traditional lecture-based instruction. By engaging students in projects that require the application of critical thinking, problem-solving, and collaborative skills, PBL supports the development of a deeper understanding of the subject matter. This approach aligns well with the characteristics of threshold concepts, which necessitate a shift in perspective and an integrative understanding of complex ideas (Hasni et al., 2016). The hands-on nature of PBL allows students to encounter and navigate these liminal spaces in a supportive and structured manner, enhancing their ability to master challenging content.

Moreover, PBL promotes the development of transversal skills essential for students' future professional and personal success. These skills, which include communication, teamwork, and adaptability, are cultivated through the collaborative and often interdisciplinary nature of project-based tasks (Monteiro et al., 2016). By integrating these projects into the curriculum, educators can create a learning environment that mirrors the complexities of real-world scenarios, thereby preparing students to apply their knowledge in diverse contexts.

Research within engineering and project management education has shown that PBL effectively enhances students' skills and knowledge application. For example, using PBL in precision agriculture projects at Tecnológico de Monterrey has significantly improved students' learning outcomes and engagement by integrating design thinking and data science (Saavedra et al., 2022). Additionally, innovative protocols for developing teamwork competencies in virtual

environments have successfully addressed the challenges posed by remote learning scenarios, further highlighting the versatility and effectiveness of PBL (Tejedor et al., 2022).

In summary, PBL is a robust methodology for addressing threshold concepts by creating immersive and integrative learning experiences. By fostering an environment that encourages active engagement and collaboration, PBL helps students navigate the transformative process of mastering complex ideas, ultimately leading to a more profound and enduring understanding of their disciplines.

This study aims to have a first overview of the perception of undergraduate students of their knowledge of threshold concepts and the degree of integration in and proposes a method to ensure students correctly identify and use threshold concepts in their' Project Based Learning assignments. A first overview of undergraduate students' perceptions of threshold concepts and the level of integration in the program for each degree involved. Moreover, a clear definition and graphical elements are proposed as complementary procedure to help students identify threshold concepts in their PBL assignments' development.

## 2. Methodology

The study used a quantitative research method, gathering data via an online survey on students' perceptions and mastery of threshold concepts across various higher education disciplines. The survey targeted undergraduate and postgraduate students from diverse fields, including Engineering, Computer Science, and Business Administration, recruited through multiple channels. It included closed-ended questions with Likert-scale and multiple-choice formats to quantify perceptions and abilities. Descriptive statistics summarized the data, while correlation and comparative analyses explored relationships and differences in perceptions across demographics. The findings comprehensively assessed students' experiences with threshold concepts, informing the study's discussion and recommendations.

The definition of the graphical elements for each threshold concept has been carried out in three steps based on the definition of the threshold concepts under study (Lo-Iacono-Ferreira et al., 2023):

1. Consolidate the definition.
2. Choose key elements that can be identified with the overall definition of the threshold concepts.
3. Integrate the elements.

The design of the graphical elements has been carried under the premises of overall coherence, balance, clarity, and visual effectiveness.

## 3. Results

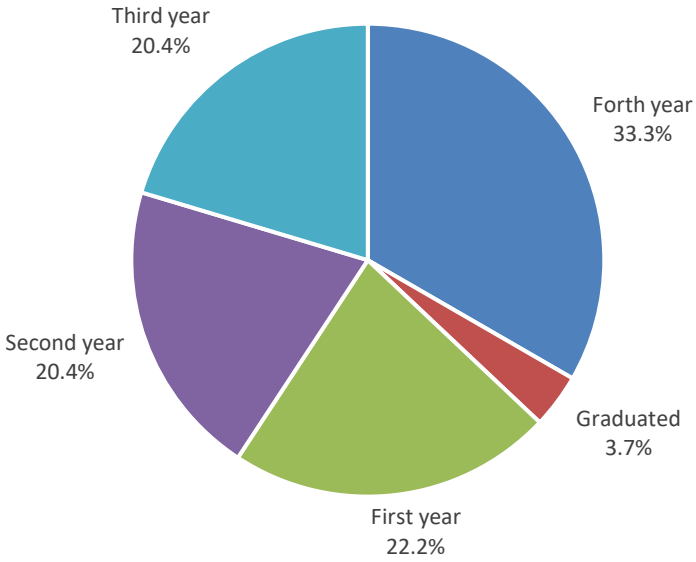
By using an online survey, the authors gather data on students' perceptions and mastery of threshold concepts across different disciplines in higher education. The survey was designed to assess various aspects of students' academic experiences, including the relevance of course content to their field of study, their ability to identify and relate relevant theories and approaches, their self-assessment of transversal skills, and specific challenges faced in academic skills such as managing citations and references.

The survey was distributed to students enrolled in undergraduate and postgraduate programs at a comprehensive university, encompassing a range of disciplines such as Engineering (Electrical, Mechanical, Chemical), Computer Science, Business Administration, and more. Participants were recruited through university email lists, social media platforms, and academic department announcements, aiming for a diverse respondent pool that reflects the breadth of academic programs the institution offers.

The survey instrument consisted of closed-ended questions using both Likert-scale and multiple-choice formats, allowing for the quantification of students' perceptions and abilities. Questions were developed based on a review of the literature on threshold concepts and academic skills essential for higher education success. Participants were asked to rate their agreement with statements regarding the relevance of their course content, their confidence in identifying and relating theories, their proficiency in transversal skills, and their approach to managing citations and references.

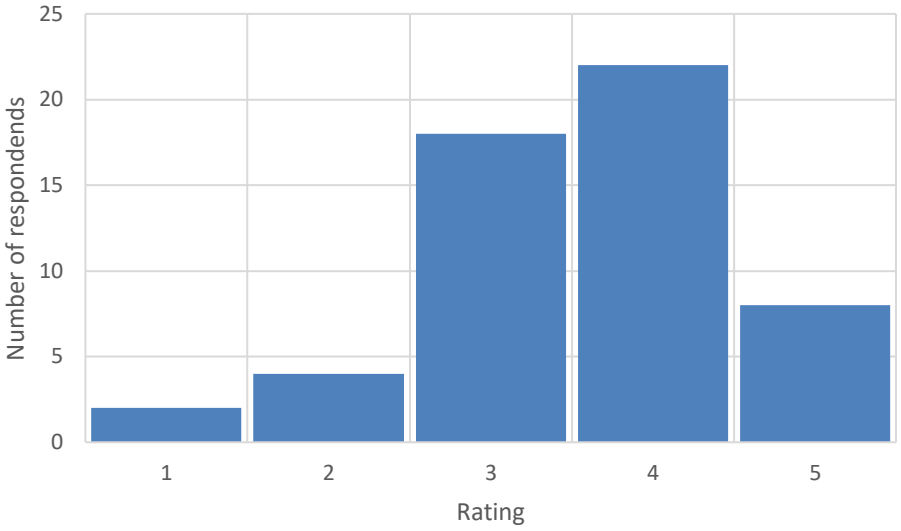
The survey garnered responses from a diverse group of students across various disciplines, predominantly from Electrical Engineering, Mechanical Engineering, and Industrial Design and Product Development Engineering, with a notable representation from other fields such as Business Administration and Computer Science. The respondents were spread across different years of study, from first-year undergraduates to graduate students, providing a broad perspective on the mastery of threshold concepts across different stages of academic progression. Figure 1 shows the survey participants by their current academic year. It aims to provide an overview of respondent diversity, highlighting the survey data's range of academic progression stages.

**Figure 1: Students' perceptions of course content relevance**



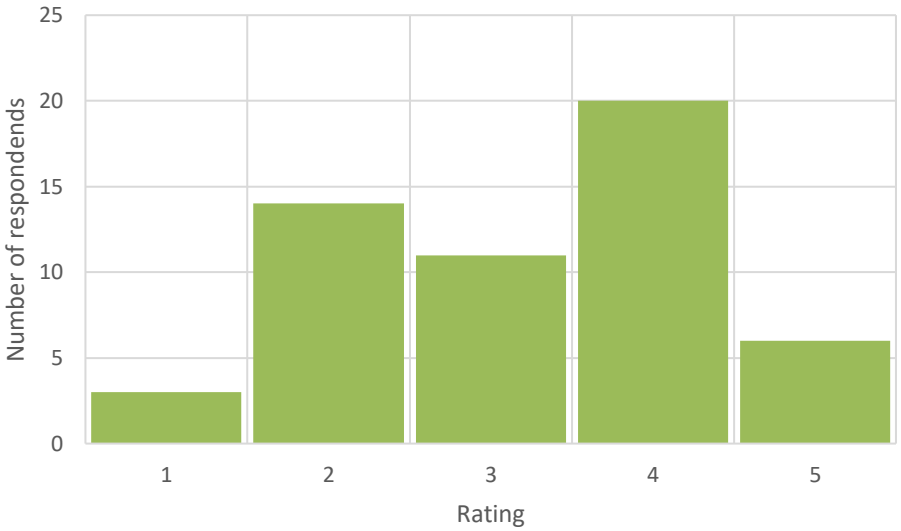

The average rating for the relevance of course content to degree development was approximately 3.56 out of 5. This suggests that, on average, students perceive the course content as moderately relevant to their degree development. However, the distribution of responses indicates a significant variance in perceptions, with a substantial number of students rating this aspect a 4, showing a positive view towards content relevance. At the same time, ratings of 3 or lower suggest room for improvement. Figure 2 shows the distribution of the responses.

**Figure 2: Perception of content relevance**



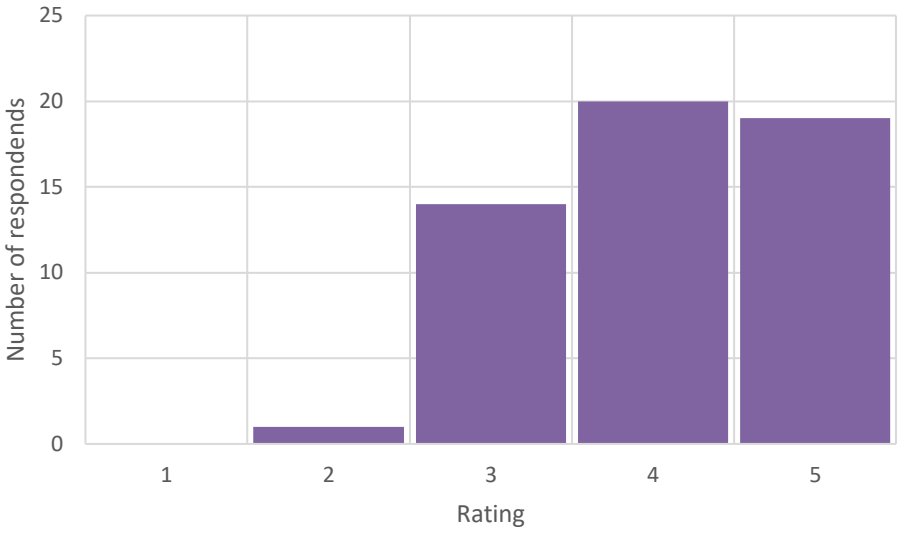

Students reported an average confidence level of 3.22 out of 5 in identifying and relating theories and approaches relevant to their field. This moderate average points towards an ambivalence in confidence levels among students, with a notable portion expressing higher confidence (ratings of 4 and above) and a similarly significant portion indicating lower confidence (ratings of 3 and below). This highlights a potential gap in curriculum effectiveness regarding theoretical application. Figure 3 shows the distribution of the responses.

**Figure 3: Students' confidence in identifying and relating theories**



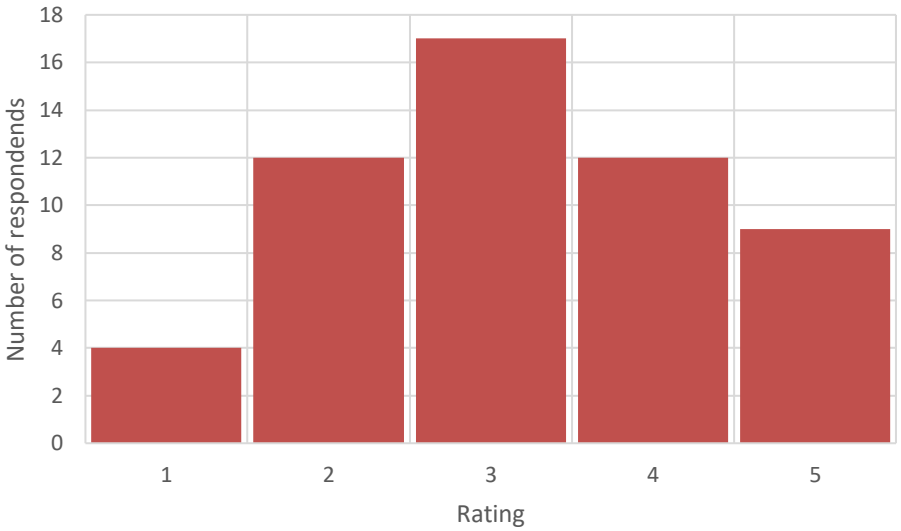

The effectiveness of academic planning in achieving educational objectives received an average rating of 4.06 out of 5, reflecting a generally positive perception among students. Most respondents rated the effectiveness as 4 or 5, indicating satisfaction with how academic planning facilitates the achievement of academic goals. Nonetheless, a non-negligible number of students rated 3, pointing to areas where planning could be enhanced. Figure 4 shows the distribution of responses regarding the effectiveness of academic planning perception.

**Figure 4: Students' perceptions of the effectiveness of academic planning in achieving educational objectives**




Responses were mixed when asked about incorporating citations and references, with "sometimes" being the most common reply, as shown in Figure 5. The average rating for challenges managing citations and references was approximately 3.17 out of 5, denoting moderate difficulty. This moderate average, along with many students facing significant challenges (ratings of 5), suggests that citation management is a notable difficulty for a portion of the student body.

**Figure 5: Challenges with citation and references**




The survey data provides valuable insights into students' perceptions and experiences across several key dimensions of their academic journey. The moderate average rating (3.56) for the relevance of course content suggests a dichotomy in student perspectives. While many find the content appropriately aligned with their degree objectives, indicating effective curriculum design, a considerable fraction perceives a misalignment, hinting at potential areas for curriculum enhancement. This variance in perceptions may stem from diverse expectations

and career objectives among students, underscoring the importance of offering flexible and varied learning pathways that cater to a broad spectrum of student ambitions and interests.

The students' confidence in identifying and relating theories (average rating of 3.22) sheds light on a critical aspect of higher education – the ability to comprehend theoretical concepts and apply them in practical contexts. Students' relatively moderate confidence level signals an opportunity for academic programs to incorporate more experiential learning elements. Such elements could include practical projects, internships, and simulation exercises that bridge theoretical knowledge with real-world applications, enhancing students' ability to synthesize and apply complex concepts.

The effectiveness of academic planning, receiving a more favorable average rating of 4.06, reflects a general satisfaction with academic programs' structural and organizational aspects. This positive feedback indicates well-structured academic pathways and support systems that guide students toward their educational goals. However, lower ratings suggest that for a subset of students, the planning and execution of academic programs may not fully meet their needs or expectations. Enhancing personalized academic advising, offering flexible course selection options, and facilitating cross-disciplinary learning opportunities could address these concerns, ensuring academic planning resonates more closely with students' goals and preferences.

Challenges with citations and references, with an average difficulty rating of 3.17, highlight a common hurdle in academic writing and research. The management of citations and adherence to stylistic conventions can be daunting, particularly for students in the early stages of their academic careers or those less familiar with research methodologies. This challenge underscores academic institutions' need to provide robust support mechanisms, such as workshops on academic writing, access to citation management tools, and personalized guidance from instructors or writing centers. Empowering students with the skills and resources to manage citations effectively enhances the quality of academic work. It instills a deeper appreciation for academic integrity and the importance of scholarly discourse.

The findings from these analytical methods provided a comprehensive picture of students' experiences with threshold concepts in their academic journey, informing the discussion and recommendations presented in the subsequent sections of the paper.

The analysis of student's perception regarding their capabilities over threshold concepts evidences the need for clearer identification of these concepts. For example, even when students can accomplish correct work planning, they don't develop it. It is not always evident that they need to plan. The same happens with all the threshold concepts (see Table 1).

The definition of graphical icons is based on overall coherence, balance, clarity, and visual effectiveness. The elements for each threshold concept are presented in Table 2. Notice that each dimension has a based color (red, yellow, and blue).

Combining a compass and an open book is a powerful visual metaphor representing the academic framework. The compass suggests orientation and direction, while the open book represents the knowledge and academic regulations that guide the student's work. Both elements define the icon of the *academic framework concept*.

Merging the clock and timeline diagram defines the icon of the *work planning* concept, providing a clear visual representation of the essential elements of the planning process. The clock symbolizes time management, while the deadline diagram represents the assignment of tasks on a specific calendar.

Files and folders represent an organized and hierarchical structure essential in searching and processing a bibliography, as in the *search and analysis of the bibliography*. Students need to organize and categorize bibliographic resources effectively to easily access and manage them appropriately in their academic projects.

**Table 2: Elements definition for each threshold concept**

| Icon | Threshold concept | Graphical elements assigned |
|---|---|---|
|  | Academic framework | **Compass**: orientation and guidance for the student.<br>**Open book**: knowledge of regulations, guidelines and regulations. |
|  | Work planning | **Clock**: Time Management<br>**Deadline Diagram**: Assigning Tasks on a Specific Calendar |
|  | Search and analysis of the bibliography | **Folders in order**: familiarity with the concept of archiving bibliographic data. Academic environment for data collection. |
|  | Search for information and data | **Magnifying glass**: universal icon to represent a search.<br>**Checking point**: communicates the idea of finding and confirming relevant information. |
|  | Processing of information and data | **Computer**: medium that processes and manipulates information.<br>**Arrows**: suggest entry and exit of information. |
|  | Application of the methodology for problem resolution and analysis | **Pencil**: symbol for problem-solving action.<br>**Problem equation**: mathematical icons represent the problem in a simple and clear way. |
|  | Discussion of the results | **Round table**: Equality of participation and collaboration.<br>**People and speech bubble**: Exchange of opinions and ideas. |
|  | Writing reports | **Pen**: Universal symbol for final writing<br>**Written sheet**: represents the written Report. |
|  | Preparing presentations | **Projector**: represents the tool used to share information visually.<br>**Projected light beams**: Projection of ideas and content. |
|  | Oral defense | **Person with speech bubbles:** Represents the speaker, the presenter.<br>**Audience**: represents the audience. |

The combination of the magnifying glass and the green checking allows students to quickly identify the search activity and ensure the quality of the information obtained, thus facilitating their academic research process. These are the elements defined for the *search for information and data* concept.

The computer icon with incoming and outgoing arrows is versatile and adaptable, making it suitable for use in various educational and technological contexts. It can be easily incorporated into digital platforms, printed materials, and presentations to effectively *process information and data*.

The image of the pencil in action, solving an equation, highlights the importance of activity and active engagement in the problem-solving process. This highlights the practical application of the methodology to address specific challenges. These elements define the icon of the concept of *application of the methodology for problem resolution and analysis*.

Using a round table and people discussing as an icon allows students to quickly identify with the activity represented, facilitating their understanding of the concept of analysis and *discussion of results* in the academic context.

The image of the pen writing in a book evokes the idea of structure and organization, highlighting the importance of following established guidelines in writing the report. It suggests a careful and systematic approach to presenting information when *writing reports*.

The projector with light beams is easily recognizable in the academic environment, where presentations are integral to the educational process. It facilitates students' identification of the concept of presentation development when *preparing presentations*.

The importance of effective communication during the oral defense, both in terms of verbal and non-verbal expression, is presented by a person and his audience. The icon highlights the need to convey ideas clearly and persuasively and maintain appropriate posture and body expression to connect with the audience when developing *oral defenses*.

In light of these findings, future research could explore the factors contributing to the variability in student perceptions and experiences, such as differences in instructional strategies, student backgrounds, or program structures. Moreover, longitudinal studies could assess the impact of targeted interventions, like enhanced experiential learning opportunities or academic writing support, on student outcomes and satisfaction over time.

## 4. Discussion

In exploring the intersection of student experiences with threshold concepts and curriculum design in engineering and project management disciplines, our study uncovers several key insights. The moderate perceptions of course content relevance and varied confidence in applying theoretical knowledge offer a nuanced view into the pedagogical frameworks supporting learning transitions.

The finding that students perceive course content as moderately relevant suggests a nuanced alignment between academic curricula and professional aspirations. This alignment, as Flanagan (2017) highlighted, underscores the transformative potential of learning. The pedagogical challenge lies in effectively guiding learners through the liminal spaces of understanding threshold concepts, as Carstensen & Bernhard (2018) described. Our study's results suggest that while many curricula are successful, there remains room for pedagogical innovation to ensure all students recognize and appreciate the relevance of their studies.

Our results, which indicate a variance in student confidence in applying theoretical knowledge, resonate with learning limitations characterized by uncertainty and transformation (Land et al., 2016). This variance suggests a potential disconnect between pedagogical intentions and student experiences, underscoring the need for curricula to effectively bridge theoretical understanding with practical application. Timmermans & Meyer (2019) advocate for embedding threshold concepts within pedagogies sensitive to learning transitions' cognitive and affective dimensions. Our findings support this view, indicating that a more nuanced and supportive approach may be required to navigate these learning thresholds.

The moderate challenges in citation and reference management reported by students reflect the complexity of academic writing and integrity. While seemingly distinct from the conceptual understanding of discipline-specific content, this aspect of learning is integral to academic

development. The difficulties students face suggest a broader need for support in academic literacy, resonating with Ross et al. (2017) observations on the messiness of deep learning.

Moreover, the uneven development of transversal skills such as critical thinking and problem-solving identified in our study connects with Davies & Mangan (2017) assertions on the importance of these skills for navigating the professional world. Our findings suggest an opportunity for curricula to more deeply integrate threshold concepts to foster these essential skills, thereby preparing students for the complexities of modern professional challenges, as discussed by Sin & Reid (2018).

When a case study is presented intended to be worked on by PBL, especially in the first years of the degree, identifying those threshold concepts to which special attention should be paid can facilitate the integration of concepts in the project's development.

However, students are expected to internalize the concepts as they progress. Before failing to mention the threshold concepts associated with a project to be developed, it is proposed that the identification exercise be incorporated, proposing that students identify the threshold concepts associated with a job before starting to work. The next step will be to avoid mentioning threshold concepts, which will already be internalized.

The following timing is proposed:

- First course: Teachers will identify threshold dimensions and concepts for each project.
- Second course: Identify threshold concepts by the student before executing the proposed project, with the help of contextualizing the dimensions.
- Third course: Ask explicitly about threshold concepts, encouraging students to identify those involved before executing the proposed project.
- Fourth course: Avoid asking about threshold concepts.

It is advisable to incorporate threshold concepts into the elements to be evaluated. When evaluations are complex, simplifying the elements by grouping them by dimensions could be a useful resource.

## 5. Conclusions

This study explored students' perceptions of various aspects of their academic experience, including the relevance of course content, confidence in applying theoretical knowledge, the effectiveness of academic planning, and challenges associated with citations and references. The findings reveal that while there is a generally positive perception of course relevance and academic planning, variations in confidence in applying theoretical knowledge and managing academic references point towards areas for further pedagogical development.

The moderately positive perception of course content relevance, reflected in an average rating of 3.56 out of 5, highlights a dichotomy in student perspectives. This dichotomy underscores the importance of continuous curriculum evaluation and adaptation. It suggests that while many curricula are effectively aligned with academic and professional aspirations, there remains a segment of the student population that perceives a misalignment. Addressing this misalignment requires a multifaceted approach that encompasses not only the content but also the pedagogical strategies employed to deliver that content.

Students' moderate confidence in applying theoretical knowledge underscores a critical area for pedagogical innovation. Integrating more experiential learning opportunities, such as project-based learning, internships, and simulation exercises, could enhance students' ability to bridge theory with practice. Such integration could also serve to reinforce the relevance of course content by providing tangible examples of its application in professional contexts.

The general satisfaction with academic planning reflects positively on academic programs' structural and organizational aspects. However, the presence of students who express less satisfaction points to the need for more personalized academic advising and greater flexibility in academic pathways. Tailoring academic experiences to individual student needs and learning styles can enhance the educational journey and promote greater engagement with threshold concepts.

Challenges in managing citations and references highlight a broader issue of academic literacy. Addressing this challenge through targeted support, including workshops on academic writing and access to citation management tools, can foster a deeper understanding of academic integrity and the importance of scholarly communication.

In conclusion, our study contributes valuable insights into the student academic experience, offering a basis for both future research and practical interventions. As higher education continues to evolve, understanding students' perspectives and challenges is crucial in crafting supportive, dynamic, and relevant educational environments. Future research should delve into the factors influencing student perceptions and explore the impact of specific interventions to enhance the academic experience. By fostering a more engaging, inclusive, and adaptive learning landscape, institutions can better prepare students for success within and beyond the academic realm.

This comprehensive exploration highlights the complexity of integrating threshold concepts into curricula and the importance of a balanced and nuanced approach to educational reform. Continuous dialogue between educators, students, and academic researchers is essential in navigating these complexities and in fostering environments where all students can thrive.

This study is just a preliminary approach. Further research includes a deep analysis of the perception of students by degree. Enlarging the study to master's degrees is also planned. The perception of professors will also be studied and compared. Also, the implementation of curricula that focus on threshold concepts in project management and engineering disciplines will be considered. This approach will enable students to acquire critical thinking skills, problem-solving abilities, and adaptive expertise, all of which are essential for navigating the complexities of modern engineering challenges. Furthermore, students will be equipped to contribute innovatively to global project management initiatives.

## 6. References

Barradell, S. (2018). The identification and implications of differences between practitioner and educator perceptions of threshold concepts in health and social care. Teaching in Higher Education, 23(6), 674-691. https://doi.org/ 10.4276/030802211X13153015305592

Carstensen, A.-K., & Bernhard, J. (2018). Understanding the transition from engineering student to professional engineer: A cultural-historical activity theory perspective. Studies in Higher Education, 43(3), 457-472. https://doi.org/1 10.1080/03043797.2019.1681631

Davies, P., & Mangan, J. (2017). Threshold concepts and the integration of understanding in economics. Studies in Higher Education, 42(8), 1483-1500. https://doi.org/ 10.1080/03075070701685148

Flanagan, M. T. (2017). Threshold concepts: Undergraduate teaching, postgraduate training, professional development and school education. A short introduction and a bibliography. Retrieved from https://www.ee.ucl.ac.uk/~mflanaga/thresholds.html on April 1sst, 2024.

Hasni, A., et al. (2016). The key characteristics of project-based learning. Disciplinary and Interdisciplinary Science Education Research. https://doi.org/10.1186/s43031-021-00042-x

Kift, S., Nelson, K. J., & Clarke, J. A. (2010). Transition pedagogy: A third generation approach to FYE - A case study of policy and practice for the higher education sector. The International Journal of the First Year in Higher Education, 1(1), 1-20. https://doi.org/ 10.5204/intjfyhe.v1i1.13

Klaassen, R. G. (2018). Curriculum design for transformative learning: A framework proposal from threshold concept theory. Educational Studies, 44(5), 567-585. https://doi.org/ 10.1163/9789460912078_001

Land, R., Rattray, J., & Vivian, P. (2016). Learning in the liminal space: A semiotic approach to threshold concepts. Higher Education, 71(5), 585-598. https://doi.org/ 10.1007/s10734-013-9705-x

Lo Iacono Ferreira, V. G., Hilario Caballero, A., Micó Vicent, B., Jordán Núñez, V., Lerma Arce, P., Ferrer Gisbert, J. E.,Solanas Galbis, I. Miró Orozco, J Capó Vicedo, J. Lora-García, M. Pérez Sánchez, J.A. Maestro Cano, R. Vercher, C. Quijada, L. Santos Juanes-Jordá, J.I. Torregrosa-López & García Bernabeu, A. M. (2023). Enhancing fundamental concepts in academic and professional projects. 18th International Technology, Education and Development Conference https://doi.org/10.21125/inted.2024.0988

Monteiro, S., et al. (2016). Developing and validating a scale of STEM project-based learning. Frontiers. http://doi.org/10.1007/s11165-020-09965-3

Quinlan, K. M., Male, S., Baillie, C., Stamboulis, A., Fill, J., & Jaffer, Z. (2019). Methodological challenges in researching threshold concepts: A comparative analysis of three projects. Higher Education, 77(5), 783-798. https://doi.org/ 10.1007/s10734-013-9623-y

Ross, M., Perkins, H., & Bodey, K. (2017). Academic motivation and information literacy self-efficacy: The importance of a simple desire to know. Library & Information Science Research, 39(1), 2-9. https://doi.org/ 10.1016/j.lisr.2016.01.002

Saavedra, V., et al. (2022). Design of experiments, design thinking and data science for learning precision agriculture. 26th International Congress on Project Management and Engineering. http://dspace.aeipro.com/xmlui/handle/123456789/3320

Sin, C., & Reid, A. (2018). Developing civic-mindedness in undergraduate business students through critical praxis. Journal of Business Ethics, 150(4), 945-958. https://doi.org/ 10.1007/s13520-015-0044-0

Tejedor, B., et al. (2022). An innovative protocol for the development and evaluation of the teamwork competency in virtual environments. 26th International Congress on Project Management and Engineering. http://dspace.aeipro.com/xmlui/bitstream/handle/123456789/3301/AT09-006_22

Timmermans, J. A., & Meyer, J. H. F. (2019). A framework for working with university teachers to create and embed 'Integrated Threshold Concept Knowledge' (ITCK) in their practice. International Journal for Academic Development, 24(4), 354-368. https://doi.org/10.1080/1360144X.2017.1388241

University of Queensland. (2024). Project-based learning. Institute for Teaching and Learning Innovation.

**Declaration of Generative AI and AI-assisted technologies in the writing process.**

While preparing this work, the authors used ChatGPT to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

**Communication aligned with the Sustainable Development Goals**