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INTEGRATIVE MODEL OF THEORY AND PRACTICE FOR ENGINEERING AND MANAGEMENT EDUCATION IN LATIN AMERICA

MODELO INTEGRATIVO DE TEORIA E PRÁTICA PARA EDUCAÇÃO EM ENGENHARIA E GESTÃO NA AMÉRICA LATINA

Edwin Gerardo Acuña Acuña
ORCID 0000-0001-7897-4137

Universidad Latinoamericana de Ciencia y Tecnología,
ULACIT
San José, Costa Rica
edwacuac@gmail.com

Abstract. This project targets the alignment of academic theory with practical industry application in Latin American engineering and management education. It introduces a model that integrates research with teaching, encouraging students to actively participate in and shape their own learning experiences. Utilizing a 'Push and Pull' strategy, the project intertwines structured academic goals with demand-driven learning, aligning education with industrial needs. The outcome is a student-centered approach where learners engage as active participants, bridging the gap between theory and practice.
The effectiveness of this method is discussed in terms of its potential to transform passive learning into a dynamic, collaborative process. It suggests that early engagement in research can enhance students' educational outcomes. The project underlines the importance of industry-relevant education and positions it as a catalyst for student innovation and practical problem-solving. It implies that active student involvement in research is necessary for the modernization of educational practices.
In conclusion, the project advocates for an industry-focused educational approach as essential for improving engineering and management training in Latin America. This model promotes a deep integration of theoretical knowledge and practical skills, proposing a new standard for educational institutions aiming to prepare students for professional success.

Keywords: innovation, data mining, engineering, productivity, investigation.

Resumo. Este projeto visa alinhar a teoria acadêmica com a aplicação prática da indústria na educação de engenharia e gestão na América Latina. Introduz um modelo que integra pesquisa e ensino, incentivando os alunos a participarem ativamente e a moldarem suas próprias experiências de aprendizagem. Utilizando uma estratégia de 'Empurrar e Puxar', o projeto entrelaça objetivos acadêmicos estruturados com aprendizado orientado pela demanda, alinhando a educação com as necessidades industriais. O resultado é uma abordagem centrada no aluno, onde os aprendizes atuam como participantes ativos, diminuindo a distância entre teoria e prática. A eficácia deste método é discutida em termos de seu potencial para transformar o aprendizado passivo em um processo dinâmico e colaborativo. Sugere-se que o envolvimento precoce em pesquisas pode melhorar os resultados educacionais dos alunos. O projeto sublinha a importância de uma educação relevante para a indústria e a posiciona como um catalisador para a inovação estudantil e a resolução prática de problemas. Implica que o envolvimento ativo dos alunos em pesquisas é necessário para a modernização das práticas educacionais. Em conclusão, o projeto defende uma abordagem educacional focada na indústria como essencial para melhorar o treinamento em engenharia e gestão na América Latina. Este modelo promove uma integração profunda do conhecimento teórico e habilidades práticas, propondo um novo padrão para instituições educacionais que visam preparar os alunos para o sucesso profissional.

Palavras-chave: inovação, mineração de dados, engenharia, produtividade, investigação.

1. INTRODUCTION

In Latin America, management and industrial engineering are pivotal for fostering essential skills and broadening knowledge, directly contributing to the growth of the corporate sector across the region. Leading institutions like the Latin American University of Science and

Technology in Costa Rica, the Costa Rica Institute of Technology, the Catholic University of Santa María in Peru, and the University of America in Colombia are spearheading extensive research in these fields. According to Philippi et al. (2023), such institutions have proposed incorporating research components from the beginning of university curricula, embedding a robust research ethos early in tertiary education and preparing professionals to tackle complex challenges across various domains (Philippi, D., Maccari, E., Da Costa, P., & Dos Santos, J., 2023).

The process of integrating research into university programs faces notable challenges despite the creation of numerous initiatives designed to engage students and introduce them to the fundamentals of scientific inquiry. As Acuña (2024) notes, the lack of a research-oriented culture within faculties dedicated to management and industrial engineering necessitates a significant shift in student attitudes to foster research interest from the initial semesters (Acuña, 2024).

University research frameworks may adopt a 'push' or 'pull' modality to address these issues effectively. In the 'push' system, research outputs are completed by set deadlines, whereas the 'pull' system conducts research based on immediate needs, thus avoiding inefficiencies. Yao (2024) highlights the efficiency of the 'pull' system in adapting research to the precise and timely needs of the industry, thereby enhancing the relevance and application of academic work in real-world scenarios (Yao, K., 2024).

Furthermore, involving students from the inception of projects is crucial to leverage their capacities fully. However, academic structures often inhibit this involvement, which Jaber and Csonka (2023) identify as a significant barrier to fostering an engaging and motivating research environment (Jaber, A., & Csonka, B., 2023).

This comprehensive approach not only supports the commercial sector but also showcases the critical role of government oversight in enhancing the connections between academia and industry, as discussed by Vidal-Alaball et al. (2024). Their research emphasizes the transformative potential of integrating advanced technology, like artificial intelligence, into academic research, which can lead to significant advancements in both educational and professional practices (Vidal-Alaball, J., Panadés Zafra, R., Escalé-Besa, A., & Martinez-Millana, A., 2024).

In summary, the resolute pursuit of advanced research methodologies within Latin American universities is critical for addressing the multifaceted challenges faced by businesses and industries, fostering a culture of innovation and competitiveness across the region.

Table 1. Desired Situation

Component	Description	Interaction
Students	Starting point of the educational process.	Mutual strengthening with the Research Group. Integrated into the Academic Cycle.
Research Group	Entities that strengthen and are strengthened by interactions with students and corporate research.	Strengthens and is strengthened by Students and Corporate Research.
Corporate Research	Research activities conducted in business contexts that strengthen the Research Group.	Strengthens and is strengthened by the Research Group.
Academic Cycle	Formal educational process in which students participate.	Integrates Students and prepares them to become Graduate Engineers.
Graduate Engineer	The final product of the educational process, ready to contribute to society and businesses.	Contributes to the continuous improvement of Companies and Society.
Companies and Society	Beneficiaries of the skills and knowledge of graduate engineers.	Receive contributions from Graduate Engineers for continuous improvement.

Source: Own elaboration Acuña

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The diagram you provided visually represents how students, research groups, corporate research, and the academic cycle interact to strengthen the training of graduate engineers and their impact on businesses and society. Here, I present an analysis of each component of the diagram, including specific and relevant examples based on the citations provided:

Students

Students are the starting point of the engineering and management education system. Their training is not only dictated by the academic cycle but is also enriched by participating in research groups and corporate research projects. Example: According to Acuña (2023), student involvement in projects that apply data mining and IoT to develop biomedical products is an example of how students can apply theory in practical contexts and advance their learning while contributing to technological innovation.

Research Group

These groups act as a bridge between theoretical knowledge and its practical application, allowing students and corporate research to mutually strengthen each other. Example: Orozco-Hernández et al. (2021) discuss how research groups in Latin America are implementing circular economy strategies, reflecting the integration of sustainable approaches in academic research and their relevance to business and social needs.

Corporate Research

Research conducted within a business context provides opportunities for research groups to apply and test their theories and models in real environments. Example: Maldonado-Guzmán and Aguilar-Barajas (2018) illustrate how corporate social responsibility is used by companies in Latin America as a tool for sustainable development, offering academic researchers real cases to study and improve their approaches.

Academic Cycle

The academic cycle provides the basic educational structure that prepares students to become graduate engineers. This cycle integrates both formal teaching and practical research opportunities. Example: Programs that incorporate data mining algorithms for user preference analysis, as studied by Dong (2024), can be included in curricula to teach students how data science techniques are applied in brand building.

Graduate Engineer

Engineers who complete this educational and research cycle are well-equipped to tackle complex challenges in the business world and contribute to societal development. Example: Graduates who have worked on projects involving circular economy or corporate social responsibility are prepared to lead sustainable initiatives in their respective industries.

Companies and Society

The final interaction in the diagram shows how graduate engineers influence businesses and society, promoting continuous improvement through innovation and the application of new technologies and sustainable strategies. Example: Companies that adopt innovations developed by engineers trained in these academic environments move towards greater sustainability and competitiveness in the global market.

The arrows in the diagram underscore a dynamic interchange among all elements of the model, highlighting the critical integration of education, research, and practical application within business contexts. This interconnected approach signifies that engineering education

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should not be siloed but rather deeply intertwined with industry and societal needs, ensuring that education and research are both relevant and beneficial.

In advancing a systematic approach to embedding customer-oriented methodologies within curricula, students from fields like management, industrial engineering, biomedical sciences, and systems at Latin American universities are recognized as active co-contributors in their educational and research endeavors. This paradigm views students as pivotal stakeholders within research incubators, promoting their growth through a structured seven-phase methodological process.

Acuña (2022) elaborates on this approach by highlighting two crucial phases that are vital for fostering research acumen among industrial engineering scholars. The first phase involves a thorough examination of existing policies, the current research landscape, teaching dynamics, and the operations of research groups, as detailed in foundational works by Kitchenham et al. (2009). Building on this groundwork, the second phase employs process management principles to develop a sustainable and results-oriented framework aimed at cultivating researchers equipped with long-term, strategic methodologies.

At the heart of this model is the "Pull" strategy, which places students at the forefront of project initiation. This student-centric approach ensures that projects are not only designed to meet the educational and developmental needs of students but also focused on generating significant "value" through research efforts. The collaborative nature of the research teams fosters mutual learning and amplifies the intrinsic capabilities and human potential of each participant, as illustrated through the innovative research documented by Lee et al. (2023) in the field of graphene environmental technologies.

This refined description integrates the citations more seamlessly into the narrative, linking the theoretical framework and practical outcomes to enhance the overall clarity and impact of the analysis.

2. CONCEPTUAL FRAMEWORK

Research Seedbeds in Higher Education

For universities engaging in this framework, research activity transcends supplementary academic exercises, becoming a crucial conduit for growth and academic development. These opportunities are realized through student participation in research seedbeds across various engineering fields. Research seedbeds are instrumental in nurturing a robust research culture among students by offering immersive research training, formative experiences, and ample networking opportunities. Villalba Cuéllar (2017) articulates the necessary conditions to foster such a culture, including mastery of research methodologies, participation in academic dissemination events, sharing progress in investigative meetings, and conducting evaluations to identify new research avenues. These practices cultivate skills in autonomous thinking, critical analysis, and rigorous debate, steering away from conventional educational paradigms towards more dynamic and interactive teaching methodologies.

Cantú Munguía *et al.* (2019) points out that while research seedbeds offer a distinct training paradigm from traditional programs, they integrate seamlessly with institutional policies and academic standards. This integration facilitates the adoption of curriculum strategies that encompass theoretical foundations, hypotheses formulation, and practical steps derived from the seedbeds' conceptual methodologies. Engaging with thematic groups and research networks further expands the scope and depth of seedbed projects within the institutional research framework, with project evaluations conducted through scholarly publications, presentations, and participation in external forums, thus enhancing students' professional skills and innovative potential.

Restrepo (2009) underscores the critical role of research seedbeds in developing key research skills through formative research, creating learning communities, reevaluating and

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refining methods, exploring contextual problems, and engaging in expansive networks to develop comprehensive solutions.

Research Process Approach

This approach emphasizes systematic, disciplined, and controlled processes essential to any research activity. Pérez (2007) describes research as encompassing tasks beyond the immediate knowledge domain, including management activities crucial for the successful completion of all research stages. This perspective views the research subject as a system of interrelated processes aimed at achieving a comprehensive objective, which involves stages of identification, planning, execution, verification, and proactive engagement.

Push and Pull Systems in Research

Push System: This traditional approach involves fully developing research concepts and methodologies before presenting them to potential business stakeholders. Typically, a research group or faculty member originates the idea, develops the project, secures funding from interested entities, and subsequently recruits students, convincing them of the project's merits and relevance to their academic and professional growth.

Pull System: In contrast to the push system, the pull strategy begins with marketing the research idea to potential stakeholders, including companies and students, before the research commences. Aligning the project theme with students' professional aspirations is vital to ensure their sustained interest and active participation from inception to completion. This approach not only fosters greater student engagement but also ensures that research outputs are directly applicable to current industry challenges.

These methodologies represent a synthesis of traditional and contemporary educational strategies in research, highlighting the importance of aligning practical, industry-relevant projects with academic research frameworks to foster a dynamic and robust research environment.

Table 2. Systematic "Pull" Structure related to strengthening research in the seedbed

Stage	Description
Student Participation in Project Idea Formulation	Students engage in generating and shaping project ideas, initiating the research cycle.
Construction of Learning from Student Needs	Learning is constructed based on the specific needs and interests of the students.
Use of Pull Systems	Research and projects are driven by the demand and needs of the students and the industry.
Project or Work Completion	The research cycle culminates in the completion of projects or assignments.
Desertion of Work	Potential dropout or discontinuation points in the project if not aligned with student expectations.
Growth of University Research Teams	Research groups expand and enhance their capacity as a result of continuous student engagement.

Source: own elaboration based on Acuña

The cyclic model depicted in the provided diagram emphasizes a dynamic and iterative approach to educational research, designed to align closely with both student expectations and industry needs. Each stage of the cycle not only contributes to the development of research projects but also to student engagement and the overall efficacy of educational outcomes. Here's an enhanced analysis using the specified citations:

Student Participation in Project Idea Formulation

In this crucial first stage, students actively participate in defining the research questions and project directions. This involvement is essential as it ensures that research is highly relevant to students' interests and goals, thereby increasing engagement and ownership. Ouadah et al.

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(2021) illustrate how combining theoretical research with practical data mining techniques can provide valuable insights into complex scientific problems like hydrogen storage, demonstrating the importance of grounding academic research in real-world applications that resonate with student interests.

Construction of Learning from Student Needs

This stage focuses on adapting the educational process to meet the specific needs of students. The personalized approach described by Hellali et al. (2024) in their study on detecting corticosteroid sensitivity in sepsis patients using data mining techniques highlights the potential of tailored educational methodologies to significantly enhance learning outcomes by addressing individual student characteristics and learning styles.

Use of Pull Systems

The use of pull systems, where research directions are driven by the demands of students and industry, ensures that projects remain relevant and applicable. This approach not only increases the marketability of research outcomes but also enhances student retention and satisfaction by keeping research aligned with current industry challenges and technological advancements. Gu et al. (2024) provide an example of how research into the properties of biological materials can lead to practical applications in agriculture, underscoring the benefits of aligning academic research with real-world problems.

Project or Work Completion

The completion of projects marks the tangible culmination of the research process, allowing students to see the practical impact of their work. This stage is critical as it provides a direct assessment of how theoretical knowledge has been transformed into practical solutions, reinforcing the link between academic study and practical application.

Desertion of Work

This potentially challenging stage involves the risk of student disengagement or project abandonment, which can occur if the project does not meet expectations or if students encounter insurmountable challenges. Addressing this requires ongoing support and flexibility in project management, ensuring that students remain motivated and that projects can be adapted to meet evolving needs.

Growth of University Research Teams

Successful navigation through the previous stages can lead to the expansion of university research teams, as successful projects and high student engagement often attract more resources and interest. This growth fosters a sustainable cycle of innovation and learning, enhancing the institution's research capabilities and its impact on the academic and industrial sectors.

This refined analysis underscores the importance of a dynamic, responsive approach to research in higher education, emphasizing how effectively integrating practical, industry-aligned projects with academic frameworks can enhance learning experiences and ensure the relevance and utility of research outputs.

Scientific Production

As noted by Serrano (2011), scientific production is far more than just an accumulation of documents housed within an informational institution; it represents the tangible output of knowledge generated through rigorous research. Each university involved in engineering research is expected to produce results and format them according to specific institutional guidelines. These results are then systematized and organized within a comprehensive

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database, ensuring that all findings are accessible and can be utilized for further scientific and academic endeavors.

Research Project Protocol

According to Morales y Lopez (2020), a research protocol or project serves as a crucial document that not only guides the execution of research but also provides a roadmap for subsequent stages. This protocol includes the essential guidelines that each participating university implements for the development of research proposals. These proposals must be registered at the corresponding university and submitted by interested parties to the coordinators of the university seedbeds.

- The protocol should include, but not be limited to, the following sections:
- Introduction: Outlining the purpose and significance of the research.
- Methodology: Detailed methods and procedures for conducting the research.
- Expected Outcomes: Anticipated results and their potential impact.
- Timeline: Key milestones and deadlines.
- Budget: Estimated costs and funding sources.
- Ethical Considerations: Addressing any ethical concerns related to the study.

These sections ensure that each research project is thoroughly planned and executed according to high academic and scientific standards.

To illustrate the practical application of these protocols, consider the work of Calvo-Lorenzo and Uriarte-Llano (2024), who utilized synthetic data generation techniques in medical research to create massive datasets of synthetic clinical histories for hip fractures. This approach not only exemplifies the advanced use of technology in research but also underscores the importance of structured and well-documented research protocols that guide such innovative projects.

Furthermore, the sustainable prototype for remote monitoring of honey bee apiaries in the Maya regions of Campeche, Mexico, as developed by Salgado et al. (2024), demonstrates the real-world application of IoT technology in environmental research. This project was likely guided by a detailed research protocol that outlined the integration of technology in traditional beekeeping, highlighting the protocol's role in facilitating innovative and sustainable research solutions in diverse fields.

This enhanced section underscores the necessity of detailed research protocols and the tangible outcomes they yield, reinforcing the importance of methodical preparation and execution in scientific endeavors.

Table 3. Research Project proyocol

Physics	Logistics
• General aspects: • Topic: • Proponent: • Major: • Year: • Period of research development: • Schedule • Expected products • List of References • Annexes.	• General aspects: • Topic: • Proponent: • Major: • Year: • Period of research development: • Schedule • Expected products • List of References • Annexes.

Source: Own elaboration from Acuña

Research project report

As highlighted by Quintero-Corzo *et al.* (2008), the Final Report is an essential document that consolidates all the key components and details of the research undertaken, marking it as the definitive culmination of the study. This report is not merely a collection of findings but a comprehensive summary that reflects the full scope and depth of the research process, aligning closely with the project's initial protocol and objectives.

The task of preparing the Final Report involves presenting a detailed account of the research results derived from the university seedbed's efforts. It is imperative that this report adheres to the guidelines set forth in the project protocol to ensure coherence and continuity between the research conducted and the outcomes reported. The content of the Final Report should mirror the research methodology employed and must include, at a minimum, the following elements as specified in Table 4:

- Abstract: A concise summary of the research objectives, methodology, results, and conclusions.
- Introduction: Background information and the statement of the research problem.
- Literature Review: A review of existing research and how this project contributes to the existing knowledge base.
- Methodology: Detailed description of the research design, data collection methods, and analytical techniques used.
- Results: Comprehensive presentation of the data findings, supported by tables, graphs, and statistical analysis.
- Discussion: Interpretation of the results, discussing how they align with or challenge existing theories.
- Conclusions: Summary of the research findings and their implications for further research and practical applications.
- References: Complete list of sources cited throughout the research.

This structure ensures that the Final Report serves as a valid and valuable academic document, capable of informing future research and contributing to the broader academic community. The report should be crafted carefully to reflect the rigorous academic standards expected of such critical academic outputs, thereby underscoring the integrity and reliability of the research conducted.

Table 4. Research Project Report

Physics	Logics
• General aspects: • Topic: • Researcher(s): • Major/Program: • Year: • Period of research development: • Conclusions and recommendations • List of references • Appendices	• Justification • Background • Objectives • General • Specific • Goals and indicators • Benefited population • Theoretical resources supporting the proposal • Description of methodological aspects • Type of study • Population and sample or participants • Definition of concepts and variables • Research techniques and instruments used • Methods and strategies for data analysis • Data analysis or interpretive framework

Source: Own elaboration from Acuña.

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This document proposes the minimum elements to be considered in the report, and the researcher may include additional elements to provide better support and backing to the report.

Research Training and Education

As part of the educational journey in applied universities, the integration of teaching and research is pivotal, particularly through focused student research initiatives developed using strategic educational methodologies. According to Garza *et al.* (2023), effective strategies for research education encompass courses that impart scientific and investigative skills, equip students with scientific methodologies, and lay the foundations of statistical analysis and experimental design.

The collaborative efforts of teacher-researchers in selecting and approving research topics are crucial. Such joint participation ensures that research activities within Engineering Schools align with pre-established academic guidelines, fostering a cohesive educational environment.

Strategies for Research Education

As stated by Rojas Arenas *et al.* (2020), cultivating a research culture within higher education institutions is essential and can be effectively achieved through integrating research-oriented content into the curriculum, as well as involving students and faculty in research groups or projects. This approach not only enhances the learning experience but also ensures that research outcomes are directly reflected in curricular development. By presenting research projects in academic forums and involving both teachers and students in these initiatives, universities can establish a research policy that actively supports the transfer of knowledge from research to curriculum.

Applied Research

Applied research serves as a bridge between theoretical knowledge and practical application, generating new insights and technologies through strategic research efforts. As described by Bueno *et al.* (2006), this type of research is instrumental in extending the boundaries of specific fields and can include the development of new technologies. Such initiatives are fundamental in addressing real-world issues and enhancing the technological landscape.

Justification of the Research Process

The significance of the research process is well-articulated by Henríquez Fierro y Zepeda González (2003), who emphasizes that the relevance of research is measured by its capacity to address societal challenges or contribute to theoretical advancements. Essential questions to evaluate the impact of research include its practical applications, benefits to stakeholders, contributions to existing knowledge, and technological advancements. In undergraduate and graduate programs, research should not only align with academic disciplines and student interests but also aim to make a transformative impact on society and the environment.

In this context, the use of data mining techniques as explored in studies by Ouadah et al. (2021), Guo et al. (2024), and Lu et al. (2023) illustrates how advanced analytical methods can enhance the effectiveness of research by providing deeper insights and innovative solutions in fields ranging from hydrogen storage to architectural design and software engineering. Moreover, the integration of robotic technologies in surgical procedures, as investigated by Iborra, Herranz-Pinilla, and López-Costea (2024), showcases the application of research findings in developing cutting-edge medical technologies.

By reinforcing the connection between educational practices and research outputs, universities can create robust frameworks that not only enhance academic knowledge but also contribute significantly to societal and technological advancements.

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3. METHODOLOGY

Understanding Methodology

As outlined by Otálvaro *et al.* (2018), a well-designed research methodology is fundamental for achieving accurate and reliable results. It plays a critical role in maximizing the validity and reliability of the information gathered, thereby reducing potential errors. Validity ensures that the research measures exactly what it is intended to measure, which is crucial for obtaining dependable data.

Implementation of the 'Push' Approach

Acknowledging the need to bolster university research, a process management model utilizing the "Push" approach was introduced. A dedicated team of teacher-researchers was assembled to spearhead the project, with adequate resources allocated to support their efforts. The initial model was developed and subsequently validated by the Curriculum Committee and process management experts. This model was then rolled out within a research seedbed, ensuring thorough design and implementation of mission process controls, adhering to the prescribed methodological stages.

Mission of the Seedbed among Universities, Companies, and Students

The research seedbed is dedicated to nurturing future scientists in fields such as quality, production, and business management. Its mission is to equip students with the necessary skills and competencies for research, thereby fostering the creation of business and educational alliances. This initiative aims to improve societal quality of life through the practical application of research and innovation.

Vision of the University Seedbed Processes

The vision is to achieve recognition at various academic levels—locally, nationally, and internationally—and to actively participate in events that stimulate research within the Latin American industry and beyond. This vision supports the broader goal of enhancing the research stature of the institutions involved.

Seedbed Processes

Proposed Research Model

A research model encompassing seven distinct processes is proposed to prepare young professionals who are conscious of their social roles and the relevance of their contributions in Latin America. These processes include job offers, program selection, motivation, apprentice training, interest selection, and the deepening of both conceptual and procedural understanding of each project. This model promotes a collective approach to problem-solving and is designed to address practical issues prevalent in the region.

Selection of Apprentices

As Pepper *et al.* (2018) emphasizes, the interaction and collaboration among students, teachers, and tutors are crucial for the effective learning and critical evaluation of knowledge. The mission here is to identify and engage motivated students from participating universities, providing them with essential conceptual, attitudinal, and procedural skills necessary for successful participation in seedbed processes.

Training of Apprentices Towards Research Seedbeds

Rojas Arenas *et al.* (2020) points out that engineering education should focus on fostering creativity, appreciation, analysis, and reasoned selection through a pedagogical methodology rather than mere experimental exercises. This approach ensures that teaching and research commitments are met, and students are well-prepared to engage as co-producers in the initial selection and formulation of research interests.

Research Implementation

According to Gómez (2003) insights, establishing research programs and projects aligned with university lines and societal needs is crucial. These programs should address central problems of academic programs or broader societal issues, thereby enhancing the relevance and impact of the research conducted.

This comprehensive methodology framework not only outlines the operational aspects of conducting research but also emphasizes the strategic integration of educational practices with research objectives, ensuring that the outcomes are both academically rigorous and socially relevant.

Enhancing Data Collection and Analysis Transparency

To ensure greater transparency in the research process, the methodology emphasized detailed procedures for data collection and analysis. Data were gathered through an online survey targeting professors, companies, researchers, and research departments from participating high-level academic universities. The survey aimed to assess perceptions of techno-scientific cooperation between academia and industry. Additionally, feedback was collected from 67 students who participated in research seminars during 2021 and 2022. These surveys sought to evaluate the development of communicative skills and their effectiveness as a formative strategy for comprehensive training. The data collected underwent systematic analysis, incorporating both quantitative and qualitative methods to identify trends and key insights. This robust approach ensured that findings were well-supported and accurately reflected the research objectives.

Objective

To create a space in the Institute of Engineering and Management Research, with the support of universities and companies, to promote autonomous learning through academic research. The objective is to train and prepare future researchers in Latin America, developing critical, analytical and interdisciplinary skills, and fostering collaboration between students, professors and companies to generate knowledge relevant to industry and society.

4. RESULTS AND DISCUSSION

An online survey was conducted among professors, companies, researchers and research departments of participating universities of high academic level to understand their perception on the techno-scientific cooperation between academia and companies. A total of 67 projects were evaluated during 2021 and 2022 in different universities.

Then, the 67 students from the research seminars were surveyed to understand their opinion on the communicative skills developed in the seminars as a formative strategy for the comprehensive training of future graduates. The results are presented below:

Motivation to join the research seminars

Students join the research seminars with the primary objective of concluding the research, with 71.64%. In addition, another important motive is to improve their academic processes at the university, with 85.07%, which demonstrates that research allows them to develop a more critical and constructive mindset.

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Figure 1. Motivations to join the research seminars for participating students.
Source: Own elaboration Acuña

67 projects from various universities were surveyed to evaluate the perception of professors, companies, researchers, and research departments in university research seedbeds. The results identified variables that affect academic production and activity development. While professors value teamwork and leadership, they observed that the work tends to be individualistic and that seedbed leaders only have academic functions, which does not promote teamwork or leadership among them.

Description of the Graph Elements

- X-axis: The categories represent different perceived benefits or outcomes related to participating in research.
- Y-axis: The percentages, indicating how many participants felt they achieved these outcomes.

Analysis of Each Category

1. Vencer el miedo a la investigación (Overcoming the fear of research) - 40.30%. This category, with the smallest percentage, suggests that a significant number of students were able to overcome their apprehension towards engaging in research. However, it also implies that more than half of the students still retain some fear of research, indicating potential areas for educational improvement.
2. Mejorar sus procesos académicos (Improve their academic processes) - 85.07%. This category shows the highest individual response rate, indicating that the majority of students found that engaging in research significantly enhanced their academic skills and processes. This might include better understanding of scientific methods, critical thinking, and academic writing skills.
3. Obtener los beneficios de los semilleros (Reap the benefits of research seedbeds) - 17.91%. A lower percentage here suggests that while some students recognize and appreciate the direct benefits of participating in research seedbeds or groups, this recognition is not as widespread. This might reflect a lack of awareness or visibility of these benefits.

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4. Poder llevar la investigación al final (Being able to complete the research) - 71.64%. This indicates that a substantial majority were able to see their research through to completion. This high percentage could reflect well-structured research programs and good mentorship.

5. Otros (Others) - 17.91%. This could include any other unspecified benefits that respondents felt were worth mentioning, though the equal percentage to the benefits of research seedbeds may suggest a data entry or visualization error unless precisely clarified.

6. Total - 100.00%. It's unusual to see a category labeled "Total" in this context, as it typically would sum multiple components. However, in this graph, it stands alone at 100%, perhaps indicating that all respondents acknowledged some form of benefit from their engagement with research.

Overall Insights

The graph illustrates strong positive outcomes in specific areas, particularly in improving academic processes and completing research. However, there are areas with less impact, such as understanding the benefits of research seedbeds and overcoming the fear of research, which could be targeted for further developmental strategies.

Relevant Fields of Study and Participant Levels in Research Seedbeds

These initial results from data collection and evaluation processes in the field shed light on some of the individual factors that explain the possibility of academics engaging in each work process. For example, their previous experience in research interaction, their academic status during university, as well as their fields of research and the scope of academic collaboration.

Figure 2. Fields of study and areas of knowledge of students in research seedbeds.
Source: Own elaboration Acuña

The distribution of participants by areas of knowledge according to the sin (Figure 11) indicates that areas i (industrial engineering students) and 2 (biomedical engineering) had the highest percentage of participation, with 34% and 25%, respectively. The area with the lowest participation (11%) was area iii (electronic engineering).

Most Frequent Forms of Dissemination of Seedbed Research

University research seedbeds disseminate technoscientific knowledge through congresses, seminars, colloquiums, and work networks. These forms represented 56.71% and 17.91% respectively in the two-year study period (see Figure 3). Research contracts, training personnel, recently hired graduates, and publications are also important, with remaining scores of 25.38%.

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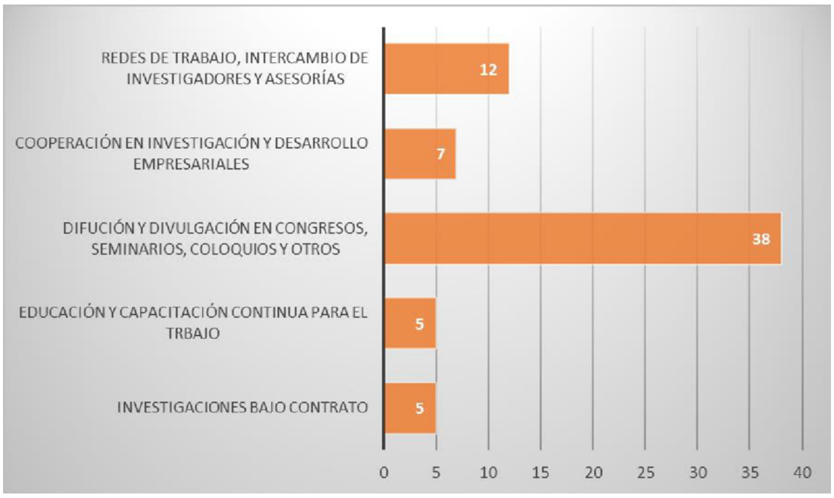

Figure 3. Dissemination and dissemination of research by universities in the results of seedbeds.
Source: Own elaboration Acuña

An approach that is well indicated (Garza *et. al*, 2021) establishes that these studies are characterized by the following: Teachers highlighted the relationship between the praxeological pedagogical model and the research seedbed, and the most commonly used words in their responses are related to student practice, the application of theories, and problem-solving in the community. A management model for university research seedbeds is proposed, which seeks to promote academic growth of students from an engineering and management perspective. The model includes various phases of knowledge management, including human capital, technological capacity, physical infrastructure, information technologies, innovation, and student communication. The comprehensive approach seeks to promote the generation of new knowledge and the creation of strategic partnerships with companies and other relevant actors to improve the competitiveness of universities and contribute to the economic and social development of the region.

The reasons stated by (Morales y Lopes, 2020) to discourage redundant publication are as follows: "[…] Any university that seeks to promote and support links with productive sectors must have an institutional link unit that directly depends on the rectory or general direction."

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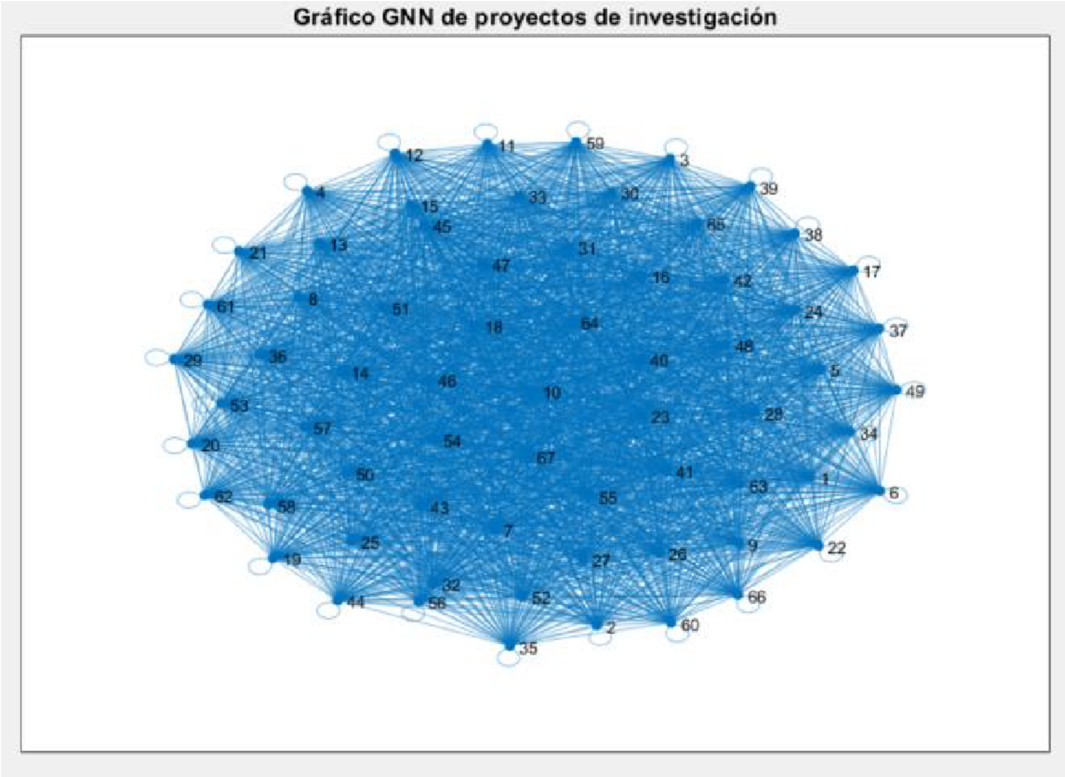

Figure 4. Interrelationships among Careers in Research Projects: Collaboration Percentages
Source: Own elaboration Acuña

Each research project has different associated outcomes, reflecting the impact and achievements obtained through the research. These outcomes may include metrics such as publications, patents, academic recognitions, industry collaborations, conference presentations, among others.

By visualizing the GNN graph, you can identify how projects are related in terms of their outcomes. Projects that are more interconnected may indicate successful collaborations and synergies among the student research groups. On the other hand, projects with fewer connections may represent less explored research areas or more independent projects.

The image you provided depicts a Graph Neural Network (GNN) visualization of research projects. This graph is a complex network consisting of nodes and edges, where each node represents a research project and the edges between them indicate relationships or connections between these projects. Here's a detailed analysis:

Structure and Layout

Nodes: The graph features numbered nodes from 1 to 67, each likely representing individual research projects. The nodes are distributed evenly around a circular layout, which helps in visualizing densely interconnected networks without overlapping too much.

Edges: The connections between the nodes are numerous and densely packed, suggesting a high degree of interrelation among the projects. The blue lines could represent various types of relationships like collaboration, thematic similarities, shared resources, or cumulative knowledge.

Density: The network is highly dense, indicating that most projects are interconnected. This suggests either a multidisciplinary field of study or a closely knit research area where projects build on or relate to one another significantly.

Implications and Uses

Collaboration Detection: This type of visualization can be crucial for identifying clusters of highly interconnected projects, which may indicate collaborative groups or research consortia.

Research Impact and Reach: The network allows for the identification of highly central projects (those with many connections), which might be pivotal or foundational within this research network. Such projects could be key influencers or critical knowledge nodes within the field.

Resource Allocation: Understanding the connectivity of projects can aid in resource allocation by highlighting the projects that bridge different research areas or those that might benefit most from additional resources due to their central role.

Technical Aspects

Graph Analysis: Techniques like centrality measures, community detection, and path analysis could be applied to this network to uncover deeper insights such as the most influential projects, potential communities within the graph, or the shortest paths for information flow.

Dynamic Analysis: If this graph represents a snapshot in time, tracking its evolution could reveal trends in research focus, the emergence of new topics, or shifts in collaboration patterns over time.

This graph provides a compelling overview of the interconnections within a set of research projects, serving as a powerful tool for analyzing the structure and dynamics of scientific collaborations or thematic interrelations in a visual and intuitive manner.

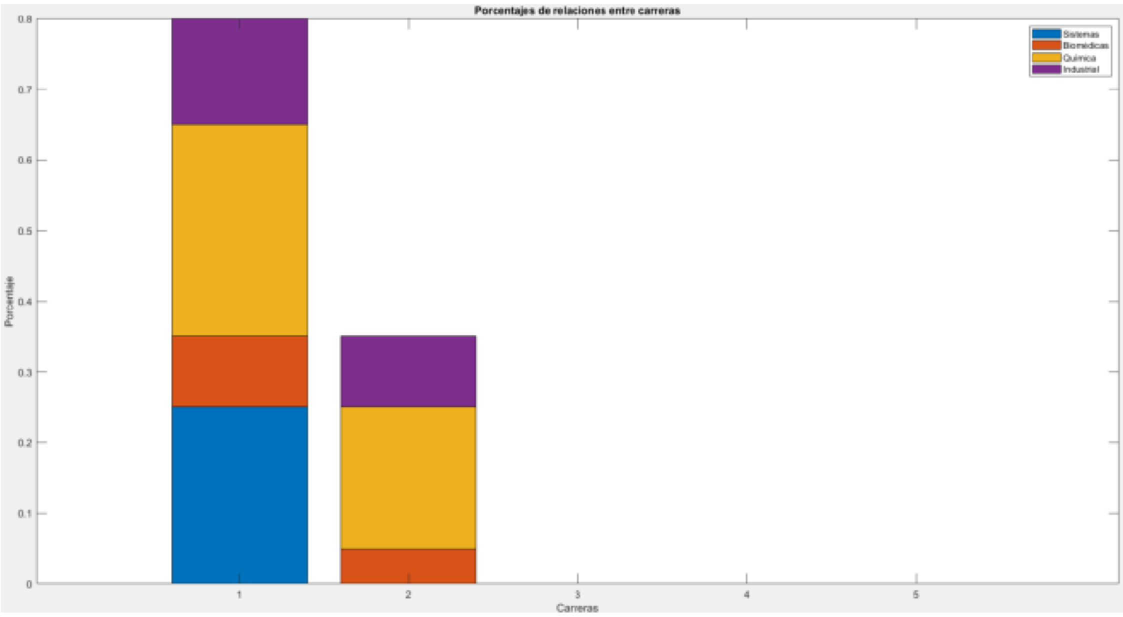

Figure 5. Percentages of relationships among careers in research projects
Source: Own elaboration Acuña

In the bar graph, each career represents a field of study: Systems, Biomedical, Chemistry, Industrial, and Electronics. The segments of each bar represent the percentages of relationships between these careers in the context of research.

For example, let's consider the bar corresponding to the Systems career and analyze the colored segments. Each segment indicates the percentage of research projects related to other careers.

Suppose the segments are as follows:

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Blue segment: Represents 25% of research projects in Systems related to the Biomedical career. This are focused on collaborations, knowledge exchange, or applications in the field of Biomedical Engineering.

Green segment: Represents 10% of research projects in Systems related to the Chemistry career. This suggests that a smaller portion of research projects in Systems are connected to Chemistry, possibly in areas such as material synthesis or chemical process design.

The image you uploaded is a bar graph displaying the percentages of relationships among different academic programs, labeled as "Carreras" (which translates to "Careers" or "Majors") on the x-axis, and the percentages on the y-axis. Each bar is segmented into different colors representing specific disciplines, with the legend indicating the disciplines as "Sistemas" (Systems), "Química" (Chemistry), "Biomédica" (Biomedical), and "Industrial" (Industrial).

Analysis of the Graph:

Bar Composition and Distribution:

- Career 1 exhibits a fairly even distribution among the four disciplines. This suggests a multidisciplinary approach where elements from Systems, Chemistry, Biomedical, and Industrial are almost equally represented.
- Career 2 shows a dominance of Systems and Chemistry, with a smaller representation from Biomedical, and no presence of Industrial. This could indicate a specialized focus on Systems and Chemistry-related topics within this career.
- Career 3 consists only of Systems and Chemistry, with Systems taking a slightly larger share. This suggests a concentrated focus on these two areas, possibly indicating a career path that integrates both fields significantly.
- Career 4 and Career 5 are not represented in the graph, which could imply that the data for these careers was not available or they do not engage significantly with the disciplines considered in this analysis.

Interpretation of Interdisciplinary Relationships:

- The graph provides insight into how interdisciplinary each career is, based on the contribution of each discipline. Careers with more balanced distributions (like Career 1) may offer a more holistic education that integrates diverse fields, preparing students for versatile roles.
- Careers that lean heavily towards one or two disciplines may be more specialized, offering depth in specific areas of study. For example, Career 2 seems to focus more on Systems and Chemistry, which could be tailored towards sectors like chemical engineering systems or systems biology.

Potential Educational Implications:

- For educational institutions, this graph can help in understanding the interdisciplinary engagement across different careers. This could inform curriculum development, resource allocation, and even marketing strategies to attract students interested in specific interdisciplinary mixes.
- For students, such information can aid in selecting a career path that aligns with their interest in certain disciplines and their desire for either a broad or specialized knowledge base.

Summary:

The bar graph serves as a useful tool for visualizing the integration of various disciplines within different academic programs. It highlights the diversity and specialization of academic offerings, providing stakeholders with valuable insights into the educational structure and focus areas of the institution.

Yellow segment: Represents 30% of research projects in Systems related to the Industrial career. This indicates that a significant portion of research projects in Systems are related to industrial aspects, such as process optimization, supply chain management, or productivity improvement in manufacturing environments.

Orange segment: Represents 15% of research projects in Systems related to the Electronics career. This suggests that a proportion of research projects in Systems are focused on electronic applications, such as circuit design, automation, or robotics.

5. CONCLUSION

Effective knowledge management is critical in engineering and management education, fostering environments where students can thrive and contribute actively to their learning. This involves integrating complex models that promote academic growth and encourage a deep engagement with knowledge. Within these frameworks, student participation in research is crucial, as it enhances learning and fosters innovation.

Several key elements influence the efficacy of knowledge management, including:

- **Human Capital:** The skills, knowledge, and abilities of the academic and student body.
- **Technological Resources:** Access to modern tools and platforms that facilitate research and learning.
- **Infrastructure:** Adequate facilities that support experimental and theoretical research.
- **Information Technology:** Robust IT systems that allow for efficient data management and communication.

Strategic alliances among universities, industries, and students play a vital role in enriching academic outcomes and driving innovation in engineering and management. These partnerships provide a holistic education and help devise practical solutions to modern industrial challenges, reflecting the interconnected nature of today's global issues. Key insights from the research highlight the importance of:

- **Management Tool-Based Frameworks:** Creating structured approaches that systematically educate engineering students, encouraging them to actively contribute to their educational paths.
- **Research Training Regimes:** Developing comprehensive training programs across various engineering specialties to enhance research skills.
- **Accreditation and Engagement:** Achieving accreditation renewal benchmarks which also encourage broader student participation in research initiatives.
- **Interdisciplinary Collaborations:** Promoting cross-disciplinary research among faculty to enhance the breadth and depth of academic inquiry.

Pepper-Loza y Terán-Vega (2019) emphasizes the critical role of research seedbeds in developing emerging researchers equipped for advanced studies. These platforms are not only beneficial to the academic community but also contribute significantly to societal advancement. By leveraging the outputs of these seedbeds, institutions can enhance their academic offerings and societal impact. Addressing the four cornerstone areas of research advancement is crucial:

- **Curriculum Design:** Refining course offerings to meet current and future needs.
- **Industrial Research Training:** Integrating real-world applications and training within academic programs.
- **Academic Program Development:** Continuously improving academic offerings to maintain relevance and rigor.
- **Research Seedbed Oversight:** Managing and nurturing these incubators for innovation and knowledge creation.

Limitations and Future Research Directions

Despite the promising insights and frameworks discussed, limitations exist within the proposed models, such as:

- The varying levels of technological resources and infrastructure across institutions, which may hinder the universal applicability of these frameworks.
- Potential resistance to change among faculty or administrative bodies when integrating innovative curricula or interdisciplinary approaches.
- The challenge of sustaining long-term partnerships with industries and ensuring mutual benefits.

Future research should explore the scalability of these models in diverse educational contexts, particularly in under-resourced institutions. Additionally, longitudinal studies are recommended to evaluate the long-term impact of strategic alliances and research seedbeds on academic and societal outcomes. Investigating the integration of emerging technologies such as artificial intelligence and quantum computing in knowledge management frameworks could also offer transformative insights.

By discerning various levels of analysis, educational entities can enhance their knowledge management practices, which underpin the development of effective training strategies for prospective engineers. This involves pioneering curricula and forming research collectives that prioritize issues pertinent to specific countries or relevant industry sectors, thereby advancing academic and industrial collaboration.

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