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Industry-Oriented Model for Integrating Theory and Practice in Engineering and Management Education in Latin America

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Abstract– ***This project aims to bridge the gap between theory and practice in engineering and management in Latin America through an industry-oriented model. By integrating research and pedagogical practice, it enables students to initiate scientific research and co-produce their own education. The combination of "Push" and "Pull" research approaches establishes a productive process involving research, pedagogy, and the industrial sector. The goal is to provide comprehensive training, making students active participants in their learning and strengthening the theory-practice link. The project focuses on Entrepreneurship and Innovation in Education, Strategies, Policies, and Management Practices in R&D, Innovation, and Entrepreneurship, and Technology Transfer and University-Industry Knowledge Exchange. This approach ensures practical experience, alignment with global standards, and relevance to the workforce, effectively bridging the gap between academia and real-world practice.***

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

I. Introduction (Heading 1)

In Latin America, research in management and industrial engineering is vital for developing student skills and fostering business growth. Universities such as 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 have significantly contributed to these fields. However, despite the establishment of research seedbeds, there is a pressing need to strengthen research from the earliest academic levels. Encouraging scientific inquiry from the first semesters and training professionals capable of addressing challenges in business, industry, academia, and society are crucial steps forward [1].

The importance of entrepreneurship and innovation in education cannot be overstated. Integrating these elements into the curriculum helps foster creative problem-solving and entrepreneurial thinking among students [2]. Effective strategies, policies, and management practices in R&D, innovation, and entrepreneurship are essential for aligning educational programs with global standards and best practices. Furthermore, promoting technology transfer and university-industry knowledge exchange ensures that students gain practical experience and industry insights, making their education directly applicable to the workforce [3].

[4] highlights the challenges universities face in implementing research, despite the creation of programs and workshops designed to teach scientific concepts, methods, and techniques. The lack of a research culture in management and industrial engineering faculties necessitates a shift in student mindset. Early exposure to research and effective program implementation can foster a robust university research culture, producing high-quality projects that address real-world issues.

[5] categorizes university research systems into "push" and "pull" models. The push system schedules and produces research by set deadlines, while the pull system conducts studies as needed to avoid waste and additional costs. Unfortunately, in Latin American universities, students are often excluded from project creation, which diminishes their motivation and commitment. Involving students from the outset can unlock their human and professional potential, fostering a more engaged and productive research environment [4].

Under the push approach, it is often assumed that students possess the skills to produce academic texts with rigor, which is frequently not the case. As [6] points out, society benefits from research applications that explain social phenomena, with governments playing a crucial role as regulators and supporters of these relationships.

The research processes illustrated in Figure 2 are of interest not only to the research departments of the involved universities but also to institutions from various geographical, business, and educational sectors. By focusing on entrepreneurship and innovation in education, implementing effective R&D strategies, and fostering university-industry knowledge exchange, this project aims to bridge the gap between theory and practice [7]. This comprehensive approach ensures that students are well-prepared to contribute meaningfully to business, industry, and society.

Figure 1. Desired Situation.

Students
↓
Strengthens
Research Group
↓
Strengthens
Company Research
↓
Feeds into
Academic Cycle
↓
Graduated Engineer
↓
Continuous Improvement
Companies and Society

Source: Created by the author.

How to systematically initiate students in management, industrial engineering, biomedical sciences, and systems from Latin American universities towards customer-oriented approaches, acting as co-producers of their own training in scientific research processes in seedbed lines?

To address this question, seven methodological phases are followed. According to [8], "Two phases are analyzed to train researchers in industrial engineering: the first considers the policy and current situation of research and teaching, and the research groups. The second phase uses process management to design a model for training researchers with enduring and result-oriented activities."[9]

One of the main design criteria is the "Pull" approach. In this approach, the project is conceived and formulated with the student at its center. Through the research team, the production of the "value" project begins, fostering collaborative learning among the participants of the seedbeds and unlocking each participant's human potential by the end of the process [10].

This methodology ensures that students in management, industrial engineering, biomedical sciences, and systems from Latin American universities are systematically initiated into customer-oriented approaches. By acting as co-producers of their own training, students are more engaged in scientific research processes, leading to more meaningful and effective outcomes [11].

II. Conceptual Framework

In Latin America, research in management and industrial engineering is essential for developing student skills and fostering business growth. Universities such as 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 have significantly contributed to these fields. Despite the establishment of research seedbeds, there is a pressing need to strengthen research from the earliest academic levels. Encouraging scientific inquiry from the first semesters and training professionals capable of addressing challenges in business, industry, academia, and society are crucial steps forward [12].

Entrepreneurship and innovation in education are vital components of this process. By integrating these elements into the curriculum, students develop creative problem-solving and entrepreneurial thinking skills. Effective strategies, policies, and management practices in R&D, innovation, and entrepreneurship align educational programs with global standards and best practices. Promoting technology transfer and university-industry knowledge exchange ensures that students gain practical experience and industry insights, making their education directly applicable to the workforce.

Research activity offers an opportunity for growth and academic development through projects and training in various engineering fields, facilitated by student participation in research seedbeds. These seedbeds foster a research culture among students through activities that generate research training, formative research, and networking. [13] asserts that research seedbeds must meet conditions that guarantee the creation of a research culture fostering autonomous thought, critical thinking, and argumentative debate. These conditions include knowledge of research project methodology, attendance at academic dissemination events, socialization of research progress, and evaluation of the process to determine new research lines. This approach moves away from traditional university models, embracing active and constructive teaching methods.

[14] indicates that research seedbeds represent a different training paradigm than formal educational programs but can be articulated with institutional policies and academic requirements. Researchers support using curricular strategies and processes in research seedbeds, which include projects with theoretical references, hypotheses, and actions based on the conceptual methodology of the research seminar. Thematic groups and research networks collaborate with other groups to enrich seedbed projects within the institutional research framework. Evaluation is carried out through publications, presentations, and external events, enhancing students' professional competencies and innovation through creativity.

[15] highlights that research seedbeds are crucial for developing research skills through formative research, forming learning communities, deconstructing and reconstructing methods, studying contextualized problems, and participating in networks to expand solutions [16].

The research process involves systematic, disciplined, and controlled activities. [17] mentions that conducting research requires not only field-specific activities but also management tasks that ensure the effective completion of all research stages. This concept views the phenomenon under study as a system of interrelated processes with a global objective, based on identifying, planning, executing, verifying, and acting.

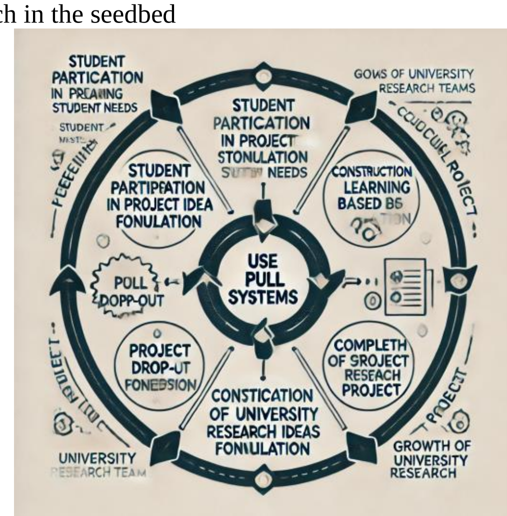
In the "push" research system, projects are first produced with all formalism and then sold to business participants. Interest from companies leads to project formulation, funding efforts, and student involvement. Conversely, the "pull" system focuses on selling the idea to companies or interested parties before starting the research. This approach ensures student motivation and alignment of the project's theme with their professional career, leading to more engaged and successful project outcomes.

[18] highlights the challenges universities face in implementing research despite programs and workshops designed to teach scientific concepts, methods, and techniques. The lack of a research culture in management and industrial engineering faculties necessitates a shift in student mindset. Early exposure to research and effective program implementation can foster a robust university research culture, producing high-quality projects that address real-world issues. [19] categorizes university research systems into "push" and "pull" models, emphasizing the need for inclusive student participation to unlock their human and professional potential.

In Latin American universities, professors or research groups sometimes exclude students from creating projects, which limits their motivation and commitment. Involving students from the beginning can unleash their human and professional potential. [20] notes that society benefits from research applications that explain social phenomena, with governments playing a crucial role as regulators and supporters of these relationships.

The research processes illustrated in Figure 2 are of interest not only to university research departments but also to institutions from various geographical, business, and educational sectors. By focusing on entrepreneurship and innovation in education, implementing effective R&D strategies, and fostering university-industry knowledge exchange, this project aims to bridge the gap between theory and practice. This comprehensive approach ensures that students are well-prepared to contribute meaningfully to business, industry, and society [21].

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



Source: Created by the author.

In aligning with the focus on entrepreneurship and innovation in education, the processes within marketing and industry are driven by demand, much like the immediate replacement of a delivered product.

The linkage between universities, students, and businesses aims to facilitate knowledge transfer, cooperation, and technology exchange, which fuel national and international innovation systems. Understanding the characteristics and standards driving these flows among different actors is crucial. [22] explains that "knowledge and technology differ in terms of their purpose, storage, and observability. Knowledge is tacitly stored in people's minds, while technology is encoded in tangible products." Studies on university-business cooperation and research seedbeds often focus on knowledge flows that yield measurable economic returns, such as industrial patents, licensing, or innovative market-ready companies. Bueno [23] emphasizes the commitment of all actors to support management, entrepreneurship, and innovation initiatives due to their significant regional economic benefits.

Constructivist learning, as described by [24], is grounded in Piaget's theory that learning involves integrating new information with existing knowledge. This process leads to the construction, revision, and differentiation of mental representations. In this model, students actively construct their own knowledge, with teachers facilitating this process by allowing students to set and achieve their learning objectives through observation, analysis, experimentation, and peer interaction.

The cycle time of the process, as highlighted by [25], involves improving production by eliminating unnecessary elements and determining the required time for specific activities. In the context of university research, this represents the time taken for a cohort of students to enter a project, develop its mission, and prepare to move on to subsequent research initiatives.

Scientific production, as [26] points out, is more than a collection of documents; it represents the materialized part of generated knowledge, systematized and organized in a database. Each university's engineering research results are formatted according to institutional standards and contribute to this body of knowledge.

A research project protocol, described by [27], guides the execution of research through successive stages. Each participating university establishes basic guidelines for developing research proposals or projects. These protocols are registered at the respective universities and presented by interested individuals to the coordinating staff of the university seedbeds.

By focusing on entrepreneurship and innovation in education, implementing effective strategies, policies, and management practices in R&D, innovation, and entrepreneurship, and fostering technology transfer and university-industry knowledge exchange, this project aims to bridge the gap between theory and practice. This comprehensive approach ensures that students are well-prepared to contribute meaningfully to business, industry, and society, effectively bridging academia and real-world practice.

In the context of university research, scientific production is the tangible manifestation of generated knowledge. [28] explains that it is much more than a collection of documents stored in an information institution. Each university produces results from their engineering research, which are then systematized and organized into a database, adhering to the format established by each institution.

A research project protocol, as described by [29], is a document that guides the execution of research and serves as a reference throughout the successive stages of the project. It outlines the basic guidelines for developing research proposals, which must be registered at the respective universities and submitted by interested individuals to the coordinators of the university seedbeds. The protocol typically includes essential sections to ensure comprehensive project planning and execution.

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Table1. *Research Project Protocol*

Physics	Logic
• 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: Created by the author.

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[33] defines the final research project report as the document that compiles all details and fundamental parts of the research conducted, marking the culmination of the study. The task is to present a report that shows the results of the research conducted by the university seedbed, which must align with the previously proposed project protocol. The report's content should be consistent with the research approach used and should include, at a minimum, the specified aspects.

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Table2. Research Project Report

Physics	Logic
• 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: Created by the author.

This document proposes the minimum elements to be considered in the research report, while allowing researchers to include additional elements for better support and backing.

Research training and education, integral parts of the educational process, will focus on the relationship between teaching and research and on student research developed through research strategies in learning. [35] highlights that strategies for research education include subjects that teach scientific and investigative criteria, providing students with scientific methodology, statistical foundations, and experimental design. The joint participation of teacher-researchers in the analysis, selection, and approval of research topics will guide research in Engineering Schools in alignment with pre-established guidelines.

Research education is essential to foster a research culture in higher education institutions. As [36] states, it can be implemented through curricular content, research groups, or research projects with the participation of students and teachers. Universities will focus research on the relationship between teaching and research through strategies embedded in each course. Including research results in curricular design, presenting projects in academic activities, and involving teachers and students will contribute to a research policy committed to curricular transfer.

Applied research, as defined by [37], is a process where research groups generate new knowledge by applying acquired knowledge to expand the boundaries of an area. This may also involve creating new technology from strategic research.

The justification of the research process, as Henríquez [38] indicates, is based on its ability to solve social problems or build new theories. To determine its significance, questions such as "What is it for?", "Who benefits?", "Will it help solve practical problems?", "Does it contribute to knowledge?", and

"Does it contribute to technology?" must be asked. Research in undergraduate and graduate programs involves generating knowledge that adapts to the discipline and student interest to provide a transformative contribution. The research experience should include educational aspects to transcend knowledge and transform the environments in which one interacts.

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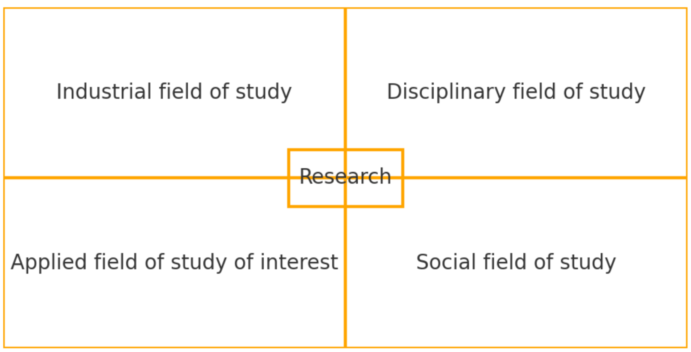
Figure 3. Structure of the research process in the research group.



Source: Created by the author.

To justify the professional training in the specific area, it is crucial to detail the admission and graduation requirements and organize the study plans according to the academic cycles. The proposed research process consists of the following steps, as illustrated in **Figure 4.** Step-by-Step Research Project Methodology

Step 1	Step 2	Step 3	Step 4
Locate documents	Organize documents	Review documents	Systematize information
Categorize information	Analyze information	Prepare final report	Socialize information
Prepare guidelines	Prepare proposals	Implement experiences	Validate experiences

Source: Created by the author.

A key consideration is that the research process is conducted from a qualitative perspective. Researchers engaging in this type of study focus on reviewing diverse materials, which may include audio, visual, written, or printed records. In this context, the norms for engineering courses, required to be documented in writing, will be utilized. The primary evidence for this research will be the submission of the document in a digital format.

III. METHODOLOGY

Before proceeding, it is essential to define the methodology. [40] states that a robust research design is critical for seeking answers and achieving objectives, aiming to maximize the validity and reliability of information while minimizing errors. Validity refers to the accuracy of measuring what is intended, which is crucial for obtaining reliable data.

Recognizing the need to strengthen university research, a process management model was proposed under the "Push" approach in scientific research. A team of educators was assembled to lead the project, with necessary resources allocated. The initial model was designed and validated by the Curriculum Committee and process management experts. This model was then implemented in a research seedbed, and the complete design and deployment of mission process controls were disseminated following the methodological stages [41].

The mission of the seedbed among universities, companies, and students is to train scientists in engineering fields such as quality, production, and business management. The objective is to provide students with opportunities to train as researchers and promote business and educational alliances, equipping them with the skills and competencies necessary for research and contributing to the improvement of societal quality of life.

The vision of the university seedbed processes is to achieve recognition at various academic levels and participate in national and international events, thereby promoting research broadly across the Latin American industry and beyond [42].

A comprehensive research model with seven processes is proposed to train young professionals who are conscious of their social responsibilities and the significance of their work in Latin America. These processes include job offers, program selection, motivation, apprentice training, interest selection, and the conceptual and procedural deepening of each project. The model encourages collective construction within the classroom, addressing practical regional problems. [43] describes a seedbed as an organization that fulfills a global objective through interrelated processes, transforming consumer needs into valuable outcomes via human talent and activities.

Key aspects of these models include the selection of apprentices. [44] underscores the importance of interaction and collaboration among students, educators, and tutors for effective learning and critical knowledge review. The mission is to provide motivated students with the foundational conceptual, attitudinal, and procedural elements required for optimal performance in seedbed processes. This encompasses competencies such as research planning, reading and writing skills, creativity, problem-solving, communication, proactivity, adaptability, and dynamism.

Training apprentices toward research seedbeds involves educating students in the creation, appreciation, analysis, and judicious selection through a pedagogical methodology rather than mere experimental exercises, as noted by [45]. Educators are committed to developing students' fundamental research components, enabling them to co-create their research interests.

The establishment of research programs and projects based on specific thematic lines addresses central programmatic issues or societal challenges, as stated by [46]. By the end of 2022, the initial four processes—job offers, program selection, motivation towards research, and apprentice training—were implemented for the first cohort in the participating universities.

The policies of the participating universities have been harmonized to establish clearer criteria for these processes. [47] emphasizes that the objective of research is to develop scientific-technological, educational, and socio-cultural programs to enhance the quality of life and competitiveness.

[48] observes that seedbeds presented papers at scientific events based on teaching projects approved by the Vice-Rectorate of Research and Postgraduate Studies and evaluated by Colciencias peers. In 2022, the seedbeds expanded their coverage to include students from various semesters and programs in universities in Peru, Mexico, Colombia, and Costa Rica. These seedbeds, established in free zones, have extended into different fields of pedagogical research, involving engineering students, companies, and educators. Participants in these seedbeds engage in teaching projects as research assistants, approved by the research and postgraduate groups of the participating universities.

By focusing on entrepreneurship and innovation in education, implementing effective strategies, policies, and management practices in R&D, innovation, and entrepreneurship, and fostering technology transfer and university-industry knowledge exchange, this project aims to bridge the gap between theory and practice. This comprehensive approach ensures that students are well-prepared to contribute significantly to business, industry, and society, effectively bridging academia and real-world practice.

Figure 5. Example of works proposed by the seedbeds in 2022 at the participating universities.

Research policies and student groups are key in curriculum redesign.
↓
Increased student participation in interdisciplinary research projects.
↓
Improved accreditation through student participation in events with presentations.
↓
Integration of undergraduate and postgraduate programs.
↓
Support for institutional and inter-institutional teaching research.
↓
Thesis and research projects handled with greater maturity.
↓
Interdisciplinary networks and groups.
↓
Reflective evaluations for curricular decisions and interdisciplinary strategies.
↓
Dissemination of work to the academic community.
↓
New learning and pedagogical relationships between teachers and students.

Source: Created by the author.

In defining the commitments of the seedbeds, [49] identifies key reasons to discourage redundant publication. These reasons form the foundation for the academic commitments, which include: 1) institutional belonging, 2) scientific and pedagogical vocation, and 3) collective academic entrepreneurship, wherein students actively participate in intellectual projects.

Considering this framework, the following table outlines the commitments acquired by students and educators in the university seedbed process:

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Figure 6. Commitments of the seedbeds within the project timeline.

Create a code of ethics.
↓
Adopt a study and group work methodology.
↓
Select basic bibliography on topics relevant to pedagogical research.
↓
Define a permanent schedule and place of work.
↓
Consult web pages, platforms, and e-learning sites regularly. Maintain direct contact with other groups, professionals, institutions, and networks.
↓
Participate in at least one scientific congress or event each year.
↓
Structure, attend, and manage the documentation and pedagogical archive of the projects and groups.
↓
Develop printed, interactive, and virtual materials from school imagery and symbols.
↓
Prepare reports, protocols, and minutes of sessions, seminars, and events. Ensure that memory files are added to institutional databases.
↓
Develop a work plan with requirements, responsibilities, and deadlines.

Source: Created by the author.

Research seedbeds offer significant benefits to participants. [50] notes that seedbeds provide an excellent space where students, guided by a research mentor, can form learning communities around a research topic.

By focusing on entrepreneurship and innovation in education, implementing effective strategies, and fostering technology transfer and university-industry knowledge exchange, this project bridges the gap between theory and practice. This ensures students are well-prepared to contribute meaningfully to business, industry, and society, effectively linking academia with real-world practice.

Figure 7. Benefits in participation in proposed university seedbeds.

Begin as researchers.
↓
Priority for applying in calls for monitorships.
↓
Receive certificates and letters of institutional recommendation for future professional résumés, applying for scholarships, national and international calls, internships, and academic-scientific stimuli.
↓
Enjoy an equipped physical space and materials essential for developing research activities.
↓
Familiarize early with different research methods and knowledge production processes.
↓
Continuous support for the construction, validation, conceptual mastery, and methodology of research processes.
↓
Work closely with university research professors.
↓
Greater security leading up to the final stage before receiving the degree and integration into real engineering practice contexts.
↓
Strengthen thesis and graduation projects.
↓
Priority for using technological tools.
↓
Exchange experiences with other areas and institutions.
↓
Receive financial support from the university or external organizations.

Source: Created by the author.

IV. OBJECTIVE

The Institute of Engineering and Management Research, supported by universities and companies, promotes autonomous learning through academic research. It aims to train future researchers in Latin America, developing critical, analytical, and interdisciplinary skills, and fostering collaboration to generate industry-relevant knowledge.

VI. RESULTS AND DISCUSSION

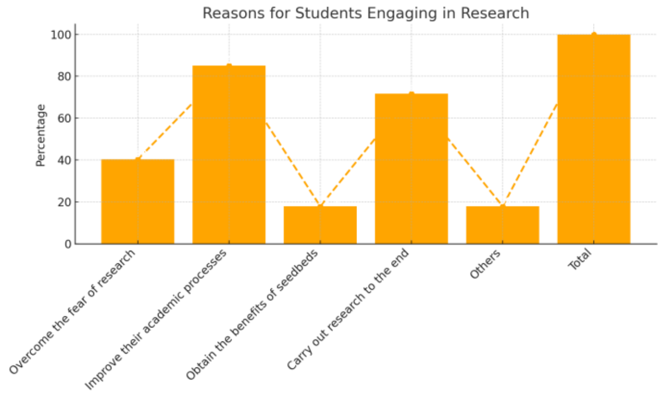
An online survey was conducted among professors, companies, researchers, and research departments at participating high-level universities to gauge perceptions of techno-scientific cooperation between academia and industry. A total of 67 projects were evaluated in 2021 and 2022.

Additionally, 67 students from research seminars were surveyed to understand their views on the communicative skills developed in the seminars as a formative strategy. The results are as follows:

Motivation to Join Research Seminars:

- 71.64% of students joined primarily to complete research.
- 85.07% aimed to improve their academic processes, indicating that research fosters a more critical and constructive mindset.

Figure 8. Motivations to join the research seminars for participating students.

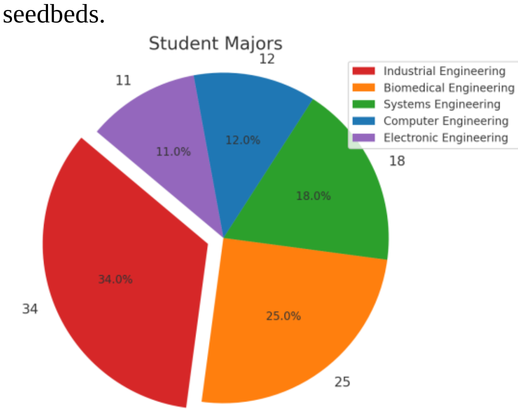


Source: Created by the author.

A survey of 67 projects from various universities evaluated the perceptions of professors, companies, researchers, and research departments in university research seedbeds. The results highlighted factors affecting academic production and activity development. While professors value teamwork and leadership, they noted that work tends to be individualistic and that seedbed leaders focus solely on academic functions, which does not promote teamwork or leadership.

Relevant Fields of Study and Participant Levels in Research Seedbeds: Initial results reveal individual factors influencing academic engagement in work processes, including previous research experience, academic status, fields of research, and the extent of academic collaboration.

Figure 9: Fields of study and areas of knowledge of students in research seedbeds.



Source: Created by the author.

The distribution of participants by areas of knowledge (Figure 11) shows that industrial engineering students (34%) and biomedical engineering students (25%) had the highest participation rates. Electronic engineering had the lowest participation at 11%.

Most Frequent Forms of Dissemination of Seedbed Research: University research seedbeds primarily disseminate technoscientific knowledge through congresses, seminars, colloquiums, and work networks, accounting for 56.71% and 17.91% of activities during the study period (Figure 12). Other significant forms of dissemination include research contracts, training personnel, newly hired graduates, and publications, comprising 25.38%.

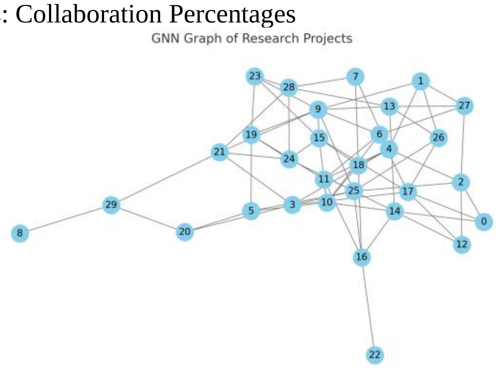
Figure 10: Dissemination and dissemination of research by universities in the results of seedbeds.

Source: Created by the author.

Garza Puentes (2021) highlights the praxeological pedagogical model's relationship with research seedbeds, emphasizing student practice, theory application, and community problem-solving. A proposed management model for university research seedbeds aims to promote students' academic growth in engineering and management. This model includes phases of knowledge management: human capital, technological capacity, physical infrastructure, information technologies, innovation, and student communication. It fosters new knowledge generation and strategic partnerships with companies to enhance university competitiveness and contribute to regional economic and social development.

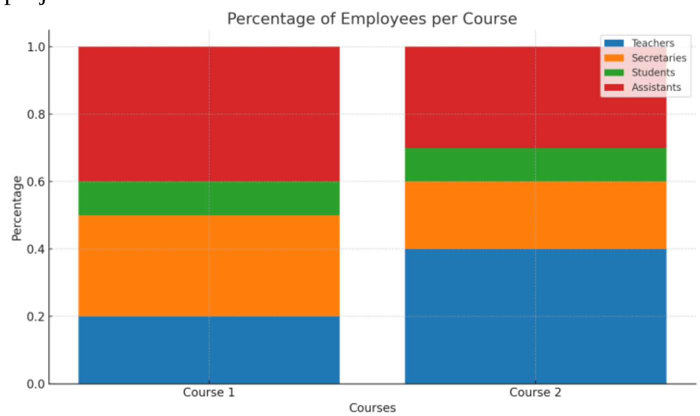
[51] advises against redundant publication, emphasizing the need for an institutional link unit under the rectory or general direction to support university ties with productive sectors.

Figure 11: Interrelationships among Careers in Research Projects: Collaboration Percentages



Source: Created by the author.

Each research project yields different outcomes, such as publications, patents, academic recognitions, industry collaborations, and conference presentations. Visualizing the GNN graph helps identify how projects are related based on these outcomes. Highly interconnected projects may indicate successful collaborations and synergies among student research groups, while fewer connections may suggest less explored research areas or more independent projects. **Figure 12:** Percentages of relationships among careers in research projects



Source: Created by the author.

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

For example, in the Systems career bar:

- **Blue segment (25%)**: Indicates Systems projects related to Biomedical, highlighting collaborations or applications in Biomedical Engineering.
- **Green segment (10%)**: Reflects Systems projects connected to Chemistry, such as material synthesis or chemical processes.
- **Yellow segment (30%)**: Shows Systems projects related to Industrial, focusing on process optimization or supply chain management.
- **Orange segment (15%)**: Represents Systems projects related to Electronics, involving circuit design, automation, or robotics.

VI. CONCLUSIONS

This project successfully bridges the gap between theory and practice in engineering and management education in Latin America through an industry-oriented model. By integrating research and pedagogical practice, students are empowered to initiate scientific research and actively participate in their education. The dual approach of "Push" and "Pull" research methodologies fosters a productive synergy between research, pedagogy, and the industrial sector, providing comprehensive training and enhancing student engagement.

Focusing on entrepreneurship and innovation in education, the project implements effective strategies and policies in R&D and promotes technology transfer and university-industry knowledge exchange. This approach ensures that students gain practical experience, align with global standards, and remain relevant to the workforce. Research seedbeds play a pivotal role in cultivating a robust research culture, enhancing students' critical, analytical, and interdisciplinary skills, and fostering collaboration among students, professors, and companies. This comprehensive strategy effectively bridges the divide between academia and real-world practice, preparing students to make significant contributions to business, industry, and society.

REFERENCES

[1] J. Breitwieser, L. Nobbe, D. Biedermann, and G. Brod, "Boosting self-regulated learning with mobile interventions: Planning and prompting help children maintain a regular study routine," *Computers & Education*, vol. 205, 2023, doi: 10.1016/j.compedu.2023.104879.

[2] R. W. d. S. Bueno and M. L. Niess, "Redesigning mathematics preservice teachers' preparation for teaching with technology: A qualitative cross-case analysis using TPACK lenses," *Computers & Education*, vol. 205, 2023, doi: 10.1016/j.compedu.2023.104895.

[3] S. Li, "Immersive technologies in health professions education: A bibliometric analysis," *Computers & Education: X Reality*, vol. 4, 2024, doi: 10.1016/j.cexr.2024.100051.

[4] S. Luo, D. Zou, and L. Kohnke, "A systematic review of research on xReality (XR) in the English classroom: Trends, research areas, benefits, and challenges," *Computers & Education: X Reality*, vol. 4, 2024, doi: 10.1016/j.cexr.2023.100049.

[5] B. Memarian and T. Doleck, "A novel ethical analysis of educational XR and AI in literature," *Computers & Education: X Reality*, vol. 4, 2024, doi: 10.1016/j.cexr.2024.100052.

[6] A. V. Oje, N. J. Hunsu, and D. May, "Virtual reality assisted engineering education: A multimedia learning perspective," *Computers & Education: X Reality*, vol. 3, 2023, doi: 10.1016/j.cexr.2023.100033.

[7] I. Radu, J. Yuan, X. Huang, and B. Schneider, "Charting opportunities and guidelines for augmented reality in makerspaces through prototyping and co-design research," *Computers & Education: X Reality*, vol. 2, 2023, doi: 10.1016/j.cexr.2023.100008.

[8] J. G. Wu, Z. Yang, S. Wu, and D. Zou, "Unveiling the synergy of peer feedback and the Metaverse," *Computers & Education: X Reality*, vol. 4, 2024, doi: 10.1016/j.cexr.2024.100056.

[9] X. Dong and B. Cai, "Balanar: Balancing deadline guarantee and Jain's fairness for inter-datacenter transfers," *Computer Networks*, vol. 235, 2023, doi: 10.1016/j.comnet.2023.109988.

[10] Z. Du, L. Liu, M. Huang, Y. Fu, and W. Zhang, "Bulwark: A proof-of-stake protocol with strong consistency and liveness," *Computer Networks*, vol. 242, 2024, doi: 10.1016/j.comnet.2024.110245.

[11] M. Mayahi, V. Loscrí, and A. M. Vegni, "INVISIBLE 2.0: An enhanced interference-based handover technique for visible light communications in vehicular networks," *Computer Networks*, vol. 242, 2024, doi: 10.1016/j.comnet.2024.110280.

[12] J. Miao, Z. Wang, M. Wang, S. Garg, M. S. Hossain, and J. J. P. C. Rodrigues, "Secure and efficient communication approaches for Industry 5.0 in edge computing," *Computer Networks*, vol. 242, 2024, doi: 10.1016/j.comnet.2024.110244.

[13] J. Min, Y. Kim, M. Kim, J. Paek, and R. Govindan, "Reinforcement learning based routing for time-aware shaper scheduling in time-sensitive networks," *Computer Networks*, vol. 235, 2023, doi: 10.1016/j.comnet.2023.109983.

[14] R. Mohamed, M. Avgeris, A. Leivadeas, I. Lambadaris, J. Chinneck, T. Morris, and P. Djukic, "Service function chain network planning through offline, online and infeasibility restoration techniques," *Computer Networks*, vol. 242, 2024, doi: 10.1016/j.comnet.2024.110241.

[15] K. von Lewinski, M. Beurskens, and S. Scherzinger, "Data modelling as a means of power: At the legal and computer science crossroads," *Computer Law & Security Review*, vol. 52, 2024, doi: 10.1016/j.clsr.2023.105865.

[16] R. Zhao, H. Yin, L. Wang, and Q. Yue, "Multiple stable dynamic responses based on interlayer and edge coupling effect in carbon nanotube transmission system," *Computational Materials Science*, vol. 190, 2021, doi: 10.1016/j.commatsci.2021.110305.

[17] L. Pangrazio and A. Bunn, "Assessing the privacy of digital products in Australian schools: Protecting the digital rights of children and young people," *Computers and Education Open*, vol. 6, 2024, doi: 10.1016/j.caeo.2024.100187.

[18] M. Parviz, "AI in education: Comparative perspectives from STEM and Non-STEM instructors," *Computers and Education Open*, vol. 6, 2024, doi: 10.1016/j.caeo.2024.100190.

[19] D. Dey and P. Kumar, "Do psychological attributes of online review play role in predicting rating? An empirical investigation," *Computers in Human Behavior*, vol. 148, 2023, doi: 10.1016/j.chb.2023.107895.

[20] D.-I. Danny Han and M. Orlowski, "Emotional responses to narrative content: A comparative study on consumer food choice intentions," *Computers in Human Behavior*, vol. 155, 2024, doi: 10.1016/j.chb.2024.108191.

[21] N. Urukovičová, E. Rošková, M. Schraggeová, and J. Smoroň, "Psychometric properties of the Technostress Creators Inventory among employed Slovak respondents," *Computers in Human Behavior Reports*, vol. 12, 2023, doi: 10.1016/j.chbr.2023.100324.

[22] S. Glisic, "Quantum vs post - quantum security for future networks: Survey," *Cyber Security and Applications*, vol. 2, 2024, doi: 10.1016/j.csa.2024.100039.

[23] E. S. Shombot, G. Dusserre, R. Bestak, and N. B. Ahmed, "An application for predicting phishing attacks: A case of implementing a support vector machine learning model," *Cyber Security and Applications*, vol. 2, 2024, doi: 10.1016/j.csa.2024.100036.

[24] Y. A. Kadakia, A. Suryavanshi, A. Alnajdi, F. Abdullah, and P. D. Christofides, "Integrating machine learning detection and encrypted control for enhanced cybersecurity of nonlinear processes," *Computers & Chemical Engineering*, vol. 180, 2024, doi: 10.1016/j.compchemeng.2023.108498.

[25] T. Wu, X. You, X. Xian, X. Pu, S. Qiao, and C. Wang, "Towards deep understanding of graph convolutional networks for relation extraction," *Data & Knowledge Engineering*, vol. 149, 2024, doi: 10.1016/j.datak.2023.102265.

[26] B. Yu, Y. Liu, S. Ren, Z. Zhou, and J. Liu, "METAseen: Analyzing network traffic and privacy policies in Web 3.0 based Metaverse," *Digital Communications and Networks*, 2023, doi: 10.1016/j.dcan.2023.11.006.

[27] A. Kostochka, D. Lin, and Z. Xiang, "Equitable coloring of planar graphs with maximum degree at least eight," *Discrete Mathematics*, vol. 347, no. 6, 2024, doi: 10.1016/j.disc.2024.113964.

[28] L. Rendón-Castrillón, M. Ramírez-Carmona, and C. Ocampo-López, "Training strategies from the undergraduate degree in chemical engineering focused on bioprocesses using PBL in the last decade," *Education for Chemical Engineers*, vol. 44, pp. 104-116, 2023, doi: 10.1016/j.ece.2023.05.008.

[29] V. Jordan-Vallverdú, M.-A. Plaza-Navas, J. Maria Raya, and J. Torres-Pruñonosa, "The Intellectual Structure of Esports Research," *Entertainment Computing*, vol. 49, 2024, doi: 10.1016/j.entcom.2023.100628.

[30] C. Li, Y. Cao, and J. Lv, "Design and Implementation of a Physical Education Teaching and Training Mode Management System," *Entertainment Computing*, vol. 50, 2024, doi: 10.1016/j.entcom.2024.100684.

[31] S. Flynn, "Convergent identities, compounded risk: Intersectionality and parenting capacity assessment for disabled children," *Children and Youth Services Review*, vol. 129, 2021, doi: 10.1016/j.childyouth.2021.106185.

[32] A. Fronzetti Colladon, G. Verdoliva, L. Segneri, and A. G. Vitali, "Analyzing gasoline prices in five Italian cities: Insights from social network analysis," *Cities,* vol. 150, 2024, doi: 10.1016/j.cities.2024.105075.
[33] T. García Alcaraz, "Embracing throwntogetherness: Unravelling the relational dynamics of borderlands in divided cities," *Cities,* vol. 150, 2024, doi: 10.1016/j.cities.2024.105048.
[34] E. G. Acuña Acuña, "Sustainable digital business management: Challenges and opportunities," presented at the Proceedings of the 22nd LACCEI International Multi-Conference for Engineering, Education and Technology (LACCEI 2024): "Sustainable Engineering for a Diverse, Equitable, and Inclusive Future at the Service of Education, Research, and Industry for a Society 5.0.", 2024.
[35] H. Hoekstra, "Vocation as tragedy: Love and knowledge in the lives of the Mills, the Webers, and the Russells," *Endeavour,* vol. 48, no. 1, p. 100918, Mar 2024, doi: 10.1016/j.endeavour.2024.100918.
[36] C. Alexandra and C. Wyborn, "Foresight in natural resource management: A case study in Australia," *Futures,* vol. 154, 2023, doi: 10.1016/j.futures.2023.103259.
[37] P. D. Andersen and A. Silvast, "Experts, stakeholders, technocracy, and technoeconomic input into energy scenarios," *Futures,* vol. 154, 2023, doi: 10.1016/j.futures.2023.103271.
[38] I. Hidayat-ur-Rehman and M. Alsolamy, "A SEM-ANN analysis to examine sustainable performance in SMEs: The moderating role of transformational leadership," *Journal of Open Innovation: Technology, Market, and Complexity,* vol. 9, no. 4, 2023, doi: 10.1016/j.joitmc.2023.100166.
[39] E. G. Acuña Acuña, "Assessment as a Fundamental Pillar in Engineering Education: Experiences in Research Projects," presented at the Proceedings of the 22nd LACCEI International Multi-Conference for Engineering, Education and Technology (LACCEI 2024): "Sustainable Engineering for a Diverse, Equitable, and Inclusive Future at the Service of Education, Research, and Industry for a Society 5.0.", 2024.
[40] A. Regina de Aguiar Dutra *et al.*, "Business models for the bottom of the pyramid: Frugal innovation applied to solutions for family farming in cassava production," in *Sustainable Cassava,* 2024, pp. 135-152.
[41] T. T. Sarı and G. Seçinti, "Using Centrality Based Topology Control for FANET Survivability Against Jamming," *Computer Networks,* vol. 242, 2024, doi: 10.1016/j.comnet.2024.110250.
[42] M. Shamoushaki and S. C. L. Koh, "Comparative life cycle assessment of integrated renewable energy-based power systems," *Sci Total Environ,* p. 174239, Jun 25 2024, doi: 10.1016/j.scitotenv.2024.174239.
[43] L. Massidda, F. Bettio, and M. Marrocu, "Probabilistic day-ahead prediction of PV generation. A comparative analysis of forecasting methodologies and of the factors influencing accuracy," *Solar Energy,* vol. 271, 2024, doi: 10.1016/j.solener.2024.112422.
[44] M. Amini Farsani, H. R. Jamali, M. Beikmohammadi, B. D. Ghorbani, and L. Soleimani, "Methodological orientations, academic citations, and scientific collaboration in applied linguistics: What do research synthesis and bibliometrics indicate?," *System,* vol. 100, 2021, doi: 10.1016/j.system.2021.102547.
[45] B. K. Prahani, I. A. Rizki, N. Suprapto, I. Irwanto, and M. A. Kurtuluş, "Mapping research on scientific creativity: A bibliometric review of the literature in the last 20 years," *Thinking Skills and Creativity,* vol. 52, 2024, doi: 10.1016/j.tsc.2024.101495.
[46] H. Nouri, S. H. Abtahi, M. Mazloumi, S. Samadikhadem, J. F. Arevalo, and H. Ahmadieh, "Optical coherence tomography angiography in diabetic retinopathy: A major review," *Surv Ophthalmol,* Mar 22 2024, doi: 10.1016/j.survophthal.2024.03.004.
[47] H. Yu and Q. Dai, "Self-supervised multi-task learning for medical image analysis," *Pattern Recognition,* vol. 150, 2024, doi: 10.1016/j.patcog.2024.110327.
[48] W. A. Awuah *et al.*, "Recent Outcomes and Challenges of Artificial Intelligence, Machine Learning, and Deep Learning in Neurosurgery," *World Neurosurg X,* vol. 23, p. 100301, Jul 2024, doi: 10.1016/j.wnsx.2024.100301.
[49] C. E. Okonkwo *et al.*, "Lignin polyphenol: From biomass to innovative food applications, and influence on gut microflora," *Industrial Crops and Products,* vol. 206, 2023, doi: 10.1016/j.indcrop.2023.117696.
[50] L. Sharma, B. Maurya, S. Pandey, K. K. Rai, and S. Pandey-Rai, "Structural and functional prediction of WsMYB34 transcription factor in Withania somnifera (L.) Dunal by deciphering its role in NaCl-induced secondary metabolism," *Industrial Crops and Products,* vol. 206, 2023, doi: 10.1016/j.indcrop.2023.117682.
[51] A. K and S. M, "Performance analyses of intelligent reflecting surface aided downlink multi-user rate-splitting multiple access system for 6G applications," *Computer Networks,* vol. 242, 2024, doi: 10.1016/j.comnet.2024.110271.