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Educational innovation and scientific entrepreneurship in Latin American universities: Guatemala, Colombia, and Mexico

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Abstract
This study examined the impact of the OpenEdR4C web platform on the development of scientific entrepreneurship skills among university students in three Latin American institutions: Tecnológico de Monterrey (Mexico), Universidad Sergio Arboleda (Colombia), and Universidad Rafael Landívar (Guatemala). A quasi-experimental design without a control group was applied, using a purposive sample of 409 students who participated in a face-to-face workshop supported by the platform. The university-ec questionnaire, validated by experts (Aiken's V = 0.8838), was used to assess four dimensions: collaboration, knowledge, project design, and research skills. The analysis included descriptive statistics, data visualization, and Student's t-tests. Results showed that students from Universidad Sergio Arboleda achieved the highest means across all dimensions with the least dispersion in their responses, suggesting a more homogeneous formative experience. In contrast, students from Tecnológico de Monterrey and Universidad Rafael Landívar exhibited more variability in their self-assessments. No statistically significant differences were found between universities or genders. The study concludes that the platform fosters students' positive perceptions about developing entrepreneurial skills and highlights its potential as a digital educational tool in diverse university settings.

Keywords
Scientific Entrepreneurship, Comparative Study, Complex Thinking, Educational Innovation, Higher Education

1. Introduction
Diverse international organizations, such as UNESCO (2009) and the World Economic Forum (2023), have urged higher education institutions to adopt an entrepreneurial culture that enables them to anticipate and respond to the social needs and job requirements of the future (Carroz et al., 2023). In this context, universities play a crucial role in creating and strengthening entrepreneurial ecosystems (Calanchez et al., 2022). However, in Latin America, the lack of adequate business education remains a significant obstacle to fostering employment and entrepreneurship (Uribe-Toril et al., 2019). Additionally, the limited availability of financing and resources necessary for implementing entrepreneurial ideas significantly restricts the opportunities for students and emerging entrepreneurs in the region (Bahena-Álvarez et al., 2019).

Institutions and governments worldwide have impelled the adoption of a more innovative, sustainable, and critical mindset for future generations (Banha et al., 2022). Preparing young people to assume active and dynamic roles requires providing them with the necessary tools to meet challenges and excel in an increasingly competitive world (Alourhzal et al., 2021). This, in turn, fosters the development of engaged and empowered citizens who create innovative solutions that have a positive impact on society (Sneader & Singhal, 2021).

In this context, universities emerge as essential environments for promoting entrepreneurship, as they provide the necessary ecosystems that support scientific entrepreneurship (Chepurenko et al., 2019), boosting science and technology, and offering adequate infrastructure and financing (Bojko et al., 2021). Implementing strategies that promote science entrepreneurship education for students can significantly contribute to generating creative and practical solutions to complex challenges, thereby boosting innovation, progress, economic growth, and job creation (Cerver et al., 2021).

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Despite the recognition of the importance of scientific entrepreneurship, significant gaps persist, such as the lack of integration into the curriculum, limited access to financing and resources, a deficit in the training of entrepreneurial skills, and the disconnect between what is taught in universities and what happens in the local and international entrepreneurial ecosystems (Banha et al., 2022). Therefore, curricula must strike a balance between theoretical and practical knowledge of scientific entrepreneurship and offer additional courses related to the topic (Valenzuela-Keller, 2022).

Moreover, digital platforms are fundamental tools for promoting scientific entrepreneurship (Stoliarchuk et al., 2022), as they offer educational materials, online courses, tutorials, simulations, and interactive environments that facilitate the safe acquisition of knowledge and technical skills (Wang & Li, 2022). These platforms not only support the transformation of ideas into successful projects but also bring students closer to the reality of the business world (González-Calatayud et al., 2022; García-Tudela et al., 2021).

Although incorporating a digital platform to develop scientific entrepreneurship skills in Latin American university students is a methodological innovation, it is pertinent to situate this study's contributions in dialogue with previous research. Beyond studies such as those by Blankesteijn et al. (2021) and Kantis and Angelelli (2020), which documented the structural and pedagogical challenges of entrepreneurship education in Latin America, this research provides empirical evidence on using digital resources to facilitate more homogeneous and effective training experiences. Unlike approaches that focus exclusively on technology transfer or creating spin-offs, this study values scientific entrepreneurship as a comprehensive training process, grounded in complex thinking, collaboration, and self-assessment of skills. This approach broadens the traditional perspective of the field, proposing new routes for educational transformation using a comparative and digitally mediated logic.

This research compares students' perceptions of scientific entrepreneurship skills in three Latin American universities after they participated in a training experience mediated by a web platform called OpenEdR4C. The question guiding the study was: How does the self-assessment of scientific entrepreneurship skills vary among university students in Guatemala, Colombia, and Mexico after using the OpenEdR4C platform?

2. Theoretical framework

2.1 Scientific entrepreneurship in higher education

Events such as the COVID-19 pandemic have highlighted the need for higher education to evolve, equipping students with the necessary skills for specialized training and the ability to navigate challenges in uncertain situations (Montes et al., 2020; Bernate & Fonseca, 2023). In this context, scientific entrepreneurship in education serves as a catalyst to leverage opportunities, as it enables the transformation of knowledge and innovations generated through scientific research into products, services, or companies (Vernaza et al., 2020).

Scientific entrepreneurship is defined as a transformative solution for existing problems and unmet needs in the social environment, benefiting from a dynamic ecosystem that integrates the academic, private, public, and social sectors (Fernández et al., 2022; Zúñiga et al., 2021). Collaboration among these sectors drives an innovation propeller, which is key to technology transfer, the development of innovative products, and the promotion of economic and sustainable development (Olumekor, 2022). Additionally, a favorable regulatory environment that prioritizes social responsibility ensures that innovations contribute to the greater good (Corona-Treviño, 2023).

This encompasses technology transfer, the creation of university spin-offs and scientific startups, as well as collaboration between academia and industry to commercialize innovations, and acting as a key source of innovation and job creation (Becker et al., 2022; Piñeiro-Chousa, 2020). This approach fosters the development of entrepreneurial knowledge and skills among students, academics, and researchers. It boosts the creation of new businesses and jobs, improves living conditions, and fosters economic growth in countries and regions (Colombelli et al., 2021).

Strengthening partnerships between higher education institutions and the private, governmental, and social sectors is crucial to maximizing the impact of scientific entrepreneurship (Rincón et al., 2022). This collaboration not only facilitates the transfer of knowledge and technologies but also creates a framework of mutual support that drives innovative and sustainable solutions aligned with market and societal needs (Pardo et al., 2020). At the same time, scientific entrepreneurship in higher education fosters the entrepreneurial spirit in students, academicians, and researchers (Maza-Ávila et al., 2024), preparing them to face global challenges and promoting a culture of collaboration and continuous learning (Kreiterling, 2023), where universities are catalysts for innovation and social progress (Stoliarchuk et al., 2022).

Despite their relevance, competencies in scientific-technological entrepreneurship remain insufficient to address current labor challenges (Cheng, 2022). Given university education's decisive role in innovation,

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technological development, job creation, economic growth, and the strengthening of innovation ecosystems, its programs and activities must promote competencies in critical thinking, problem-solving, research, creativity, innovation, and project management (Mindt & Rieckmann, 2017). Studies on this topic tend to focus on local contexts or specific levels of training, leaving a comparative evaluation of digital educational platforms as mediators in the acquisition of entrepreneurial skills pending.

2.2 Challenges of scientific entrepreneurship in universities

On the Asian continent, countries such as Japan, South Korea, Hong Kong, Singapore, and Taiwan have implemented national innovation systems that promote research and development (Blankesteijn et al., 2021). In contrast, Latin America faces the challenge of keeping pace with rapid advances in scientific and technological entrepreneurship, despite several countries in the region having increased public investment in research and development (Kantis & Angelelli, 2020). Unlike its Asian counterparts, which have a strategic articulation between government, universities, and industry to guarantee the continuity and effectiveness of innovation ecosystems, in Latin America, institutional fragmentation, lack of fiscal incentives, and limited implementation of sustained public policies predominate. While in Asia, scientific entrepreneurship is promoted as a national priority and supported by stable regulatory frameworks and scalable financing, in Latin America, structural barriers persist that prevent investments in R&D from translating into tangible impacts on the knowledge economy (Giraudo et al., 2019).

It is essential to have an ecosystem that prioritizes basic skills, innovation, research, and investment in sustainable technologies and resources (Banha et al., 2022). Investment in human resources, research capacity in specific areas, and the acquisition of equipment, specialized software, and digital technology is crucial to promote technical-scientific entrepreneurship (Stoliarchuk et al., 2022). Adequate financing and a robust research and development system are decisive for innovation and entrepreneurship to transcend the local level and achieve a significant economic and social impact (Bojko et al., 2021). Without a solid foundation that enables innovation to thrive in a competitive market, any venture risks failing prematurely.

Creating and developing scientific entrepreneurship depend on organizational and systemic conditions, which include aligning research agendas with social problems and business needs, as well as an institutional culture that facilitates the creation of scientific ventures (Kantis & Angelelli, 2020). However, progress in this area is hindered by the weak contribution of science and technology platforms and the lack of innovative proposals by companies. In addition, university research agendas are often decoupled from societal issues, underscoring the need for greater integration and collaboration among academic institutions, businesses, and governments to strengthen the innovation ecosystem and effectively address current socioeconomic challenges (Chepurenko et al., 2019).

Moreover, students often face a lack of solid business training and insufficient practical management experience, which limits their ability to anticipate changes and solve entrepreneurial problems (Cheng, 2022). Additionally, the absence of support and mentoring networks within universities is a significant barrier, as these networks are essential for offering guidance, sharing experiences, and facilitating opportunities for collaboration (Kosmynin, 2022). Lacking these resources can restrict students' ability to develop and sustain entrepreneurial initiatives, underscoring the importance of an educational environment that balances theory with practice and promotes connection with professionals in the sector.

Therefore, university scientific entrepreneurship faces multiple challenges, ranging from the need for adequate infrastructure and financing to the lack of solid business training and support networks for students (Kreiterling, 2023). Although progress has been made in some regions, facilitative interdependence between research, innovation, and financing is essential to achieve significant economic and social impact (Calanchez et al., 2022).

2.3 Education for scientific entrepreneurship

The World Economic Forum's 2023 *Future of Jobs Report* emphasizes the need for education systems to adapt to the technological and social changes that will shape the jobs of the future. In this context, universities need to develop key skills in students such as analytical thinking, creativity, digital literacy, and entrepreneurship (Bhatia & Levina, 2020). In Latin America, the implementation of entrepreneurial education has been uneven, facing barriers such as curricular rigidity, low institutionalization of these competencies, and the disconnect between academia and productive environments (Valenzuela-Keller, 2022; Martínez et al., 2019).

In light of this, university leaders and decision-makers in the region must reassess how to integrate interdisciplinary approaches and interactive practices that enable training to be aligned with the real-world

demands of the environment (Cunningham & Menter, 2021). The specialized literature recognizes that entrepreneurial education not only enhances the entrepreneurial mindset but also contributes to socioeconomic development by stimulating competencies such as creativity, practical intelligence, and social commitment (Blankesteijn et al., 2021; Azqueta & Naval, 2023; Calanchez et al., 2022).

In addition, several studies have documented concrete benefits, including increased motivation, willingness to take risks, and interest in solving social problems through scientific and technological knowledge (Gavilanes et al., 2021; Alves et al., 2019). In this sense, the present study contributes to the field by analyzing the effectiveness of OpenEdR4C, a digital educational platform focused on scientific entrepreneurship and complex thinking, applied in Latin American contexts.

This tool not only enables students to design socially focused projects but also promotes their self-assessment of key competencies in collaboration, design, and research. Thus, the training experience supported by OpenEdR4C responds to the regional need to consolidate innovative educational practices that aim to resolve the contemporary challenges of development and employment (Rincón et al., 2022).

2.4 Digital educational platforms to teach scientific entrepreneurship

The growing demand for innovation capacity in today's society has made it a fundamental criterion for business hiring (Wang & Li, 2022). Implementing technology, digital tools, educational platforms, and artificial intelligence in higher education is crucial for enhancing scientific entrepreneurship and improving competencies in innovation and entrepreneurship (Tkachenko et al., 2019). These educational platforms, by providing interactive environments, up-to-date resources, and innovative pedagogical methods, promote the development of entrepreneurial skills and prepare students to face the challenges of the contemporary labor market (Tohanean & Weiss, 2019).

Technology-mediated education has gained significant relevance over the last decade, offering a valuable opportunity to cultivate innovative talents through the use of online digital tools and resources (Wang & Li, 2022). The integration of virtual technology in the teaching and learning process is not only a current issue; it can also significantly enhance innovation skills in students, academicians, and researchers, promoting a culture of innovation and entrepreneurship in the academic field (Tkachenko et al., 2019).

These platforms offer an advanced online educational experience, integrating artificial intelligence, multimedia, interactive user interfaces, and gamification driven by Industry 4.0 (Lopez-Caudana et al., 2024). In addition, they facilitate the development of key competencies and empower students to create social entrepreneurship projects (Cruz-Sandoval et al., 2022), promoting the development of initiatives based on complex thinking through the use of open educational resources (Vázquez-Parra et al., 2024). Accordingly, the OpenEdR4C platform is a tool that articulates these emerging components through a self-managed and transdisciplinary training proposal, aimed at promoting scientific, social, and technological entrepreneurship. Its design enables students to develop practical skills based on a contextualized innovation logic, fostering the critical appropriation of knowledge and its application in real-world solutions. Thus, these technologies not only transform teaching methods but also reconfigure the possibilities of entrepreneurial learning in Latin American university environments.

3. Methodology

This quantitative study, employing a quasi-experimental design, utilized purposive sampling without a control group (Althubaiti & Althubaiti, 2024). The choice of this design was due to the applied nature of the study and institutional constraints that prevented the random assignment of participants or the inclusion of a comparison group. Instead of using a pre-test-post-test design, a post-intervention evaluation was chosen to collect students' perceptions of their skills in scientific entrepreneurship after participating in a training experience mediated by the OpenEdR4C web platform. This methodological decision was justified by the exploratory objective of the study, which focused on assessing students' self-assessments in a real implementation context rather than establishing direct causality. The study was conducted in April 2024 and involved students from three Latin American universities, enabling a comparative analysis across diverse institutional contexts.

3.1 Participants

Four hundred nine university students enrolled in various professional-level educational programs participated: 221 from Tecnológico de Monterrey (ITESM), 82 from Sergio Arboleda University (Spanish acronym USA), and 106 from Rafael Landivar University (Spanish acronym URL). Sampling was non-probabilistic for convenience (Novielli et al., 2023). No previous calculation of the sample size was made, given

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the exploratory nature of the study and the specific logistical conditions of each institution. All students participated in a face-to-face workshop entitled "Scientific Entrepreneurship for the Future of Education." Previously, the students learned about the contents and activities to be performed by entering and registering on the OpenEDR4C digital platform (https://openedr4c.world), which is an open, self-managed platform focused on teaching scientific, social, and technological entrepreneurship. Table 1 shows the sample composition.

Table 1.
Sample composition by university

University	N	%	Male	Female
Tecnológico de Monterrey	221	54%	109 (49.3%)	112 (50.7%)
Universidad Sergio Arboleda	82	20%	43 (52.4%)	39 (47.6)
Universidad Rafael Landivar	106	26%	55 (51.9%)	51 (48.1%)
Total	**409**	**100%**	**207 (50.6%)**	**202 (49.4%)**

Source: Self-elaborated.

3.2 Ethics

All information provided by participants was collected with their consent (https://comiteinstitucionaletica.tec.mx/es/formatos) and anonymized. The implementation was regulated and approved by the Ethics Committee of Tecnológico de Monterrey-IFE-2024-001 and supervised by the interdisciplinary research group “R4C-IRG: Scaling Complex Thinking for All” with the technical support of the Writing Lab of the Institute for the Future of Education at Tecnológico de Monterrey, Mexico. All the information collected was protected in accordance with the criteria established in the Federal Law on the Protection of Personal Data in Possession of Private Parties, which is in force in Mexico.

3.3 Instrument

The “University-EC Questionnaire: Measurement of Scientific Entrepreneurship in University Students” was used, which was adapted from the proposal by George-Reyes et al. (2023) and the authors cited in Table 2. This questionnaire comprises four dimensions: Collaboration, Knowledge, Project Design, and Research. It uses a four-point Likert scale with the following item response options: 1) strongly disagree, 2) disagree, 3) agree, and 4) strongly agree. Nineteen experts in Education Sciences and Educational Entrepreneurship validated the questionnaire, which attained a high Aiken V coefficient (0.8838) (Merino-Soto, 2023). Additionally, an internal reliability analysis was conducted, yielding a Cronbach's alpha coefficient of 0.817, indicating adequate internal consistency of the instrument for educational research purposes.

Table 2.
Instrument dimensions and items.

Dimension	Item	Citations
Collaboration	I have experience collaborating or leading scientific entrepreneurship projects.	Elenurm (2022) Porkodi et al. (2023)
	My professional training has included collaboration in scientific entrepreneurship experiences.	
	I have collaborated in the development of services based on science and technology.	
	I have collaborated in the development of products based on science and technology.	
	I know how to integrate the tasks of a work team to construct the stages of a project.	
Knowledge	I possess the necessary disciplinary knowledge to participate in a scientific entrepreneurship project.	Tatpuje et al. (2021) Thian et al. (2022)
	I can identify the trends relevant to scientific entrepreneurship.	
	I can develop entrepreneurial ideas that aim to solve scientific and technological problems.	
	I am familiar with the procedure for intellectual property registration.	
	I can differentiate between what can be registered as intellectual property and what cannot.	

	I can design strategies to register intellectual property of the various components of a scientific undertaking.	
Project Design	I can complete the stages of a scientific undertaking in a short time.	Shuhod & Rashid (2023) Rui (2020)
	I can segment projects and adapt a scientific endeavor on the fly.	
	I know how to design strategies that, with minimal expense and effort, increase the volume of users, revenue, or project impact.	
	I know how to apply methodologies to analyze user and market behavior data to create growth strategies.	
	I know how to design metrics and data to inform decisions and guide the formulation of a scientific undertaking.	
	I am familiar with models to guide decision-making based on information management.	
	I can effectively design scientific entrepreneurship projects.	
Research skills	I identify the sources of information for technological trends.	Lee (2022) Sousa, et al., (2023).
	I can choose from various technological trends which one to adapt in my scientific entrepreneurship project.	
	I can look for out-of-the-ordinary solutions to the most common challenges.	
	I am familiar with methodologies for evaluating the adoption of scientific venture technology.	
	I am familiar with methodologies for evaluating the user experience of a scientific venture.	
	I know how to develop logical, systematic, qualitative, and quantitative processes to identify the most essential factors in establishing a scientific undertaking.	

4. Results

Various analyses were conducted to evaluate students' perceptions of their scientific entrepreneurship skills. First, a normality analysis was carried out on the scores obtained in the four key dimensions: Collaboration, Knowledge, Project Design, and Research Skills. This analysis confirmed the approximately normal distribution of the data, which justified the use of parametric tests in the statistical treatment. Subsequently, a descriptive analysis was conducted to compare the means and variability between universities in these dimensions. Histograms and matrices help to visualize differences and similarities in perceptions. Similarly, a gender analysis looked for potential differences in the self-assessment of entrepreneurial skills between men and women. Finally, Student's t-tests for independent samples were applied to evaluate the statistical significance of the observed differences.

4.1 Comparison and variability of means

Table 3 compares ITESM, URL, and USA. In the Collaboration dimension, the USA has the highest mean (2.9732), while ITESM and URL have similar means (2.8796 and 2.8453, respectively). ITESM has the highest standard deviation (0.7195) and variance (0.5176), indicating more data dispersion than the URL and the USA. This dispersion suggests greater heterogeneity in students' perceptions of Collaboration within ITESM. In the Knowledge dimension, the USA also attained the highest mean (2.9085), followed by ITESM (2.7383) and URL (2.6619). The standard deviation and variance are higher for the URL (0.8147 and 0.6637), indicating more dispersion from the mean compared to the other universities. The symmetry of the data indicates a slight positive trend for the URL (0.27), whereas ITESM and the USA exhibit negative values (asymmetry), in their slight trend towards lower values. These findings align with studies that emphasize the importance of diversity in developing knowledge competencies in educational settings (Teodoro et al., 2022; Sun, 2022).

Regarding the Project Design dimension, the USA attained the highest mean (2.8089), while the ITESM and the URL means were 2.6440 and 2.5676, respectively. The URL exhibits the highest standard deviation (0.8457) and variance (0.7152), indicating more data variability than ITESM and USA. Regarding asymmetry, the URL shows a slight positive trend (0.29), whereas the ITESM and the USA display negative values. This data pattern is consistent with the literature, which suggests that varied educational contexts can influence the perception and development of project design skills (Mavlutova et al., 2023; Linzalone et al., 2020).

Finally, in the Research Skills dimension, the USA attained the highest mean (2.7947), followed by ITESM (2.6290) and URL (2.5943). The URL again had the highest standard deviation (0.8389) and variance (0.7037), indicating more dispersion than the other two universities. The asymmetry is close to zero for ITESM, suggesting an almost symmetrical distribution, while the URL and the USA exhibit slight positive and negative

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trends, respectively. Table 3 presents the descriptive statistics by university. These results highlight the importance of a balanced approach in teaching research skills to minimize dispersion and improve educational outcomes (Ai, 2021).

Table 3.
Descriptive statistics per university.

Variable	University	Mean	Std. Dev.	Variance	Asymmetry	Kurtosis
Collaboration	ITESM	2.8796	0.7195	0.5176	-0.33	-0.48
	URL	2.8453	0.6908	0.4772	0.15	-0.79
	USA	2.9732	0.6891	0.4748	-0.38	-0.28
Knowledge	ITESM	2.7383	0.7551	0.5702	-0.17	-0.82
	URL	2.6619	0.8147	0.6637	0.27	-0.86
	USA	2.9085	0.7614	0.5797	-0.32	-0.87
Project Design	ITESM	2.6440	0.7689	0.5912	-0.07	-0.85
	URL	2.5676	0.8457	0.7152	0.29	-0.85
	USA	2.8089	0.7640	0.5838	-0.25	-0.89
Research Skills	ITESM	2.6290	0.7645	0.5844	-0.00	-0.86
	URL	2.5943	0.8389	0.7037	0.20	-0.79
	USA	2.7947	0.7413	0.5496	-0.18	-0.85

Figure 1 highlights the differences and similarities between the universities through histograms and density curves. In the Collaboration dimension, the USA leads with a mean of 3.0 and exhibits the lowest dispersion (SD = 0.6891), indicating a more consistent perception of collaboration among its students. In contrast, ITESM and URL have means of 2.9 and 2.8, respectively. In the Knowledge dimension, the USA also stands out with the highest mean of 2.9 and the lowest variability (SD = 0.7614), compared to ITESM (M = 2.7, SD = 0.7551) and URL (M = 2.6, SD = 0.8147), which reflects the USA's more homogeneous perception of the knowledge acquired.

Regarding the Project Design dimension, the USA again exceeds the others, with a mean of 2.8 and the lowest dispersion (SD = 0.7640). In contrast, ITESM and URL have means of 2.6 and 2.5, respectively, indicating more variability in perceptions. Finally, in the dimension of Research Skills, the USA continues to be the most uniform, with a mean of 2.7 and the lowest dispersion (SD = 0.7413), compared to ITESM (M = 2.6, SD = 0.7645) and URL (M = 2.5, SD = 0.8389). These results underscore the effectiveness of the workshop in fostering more uniform and positive perceptions among students on the topic of scientific entrepreneurship, especially in the USA, highlighting the importance of a balanced and consistent approach to teaching these skills using digital platforms.

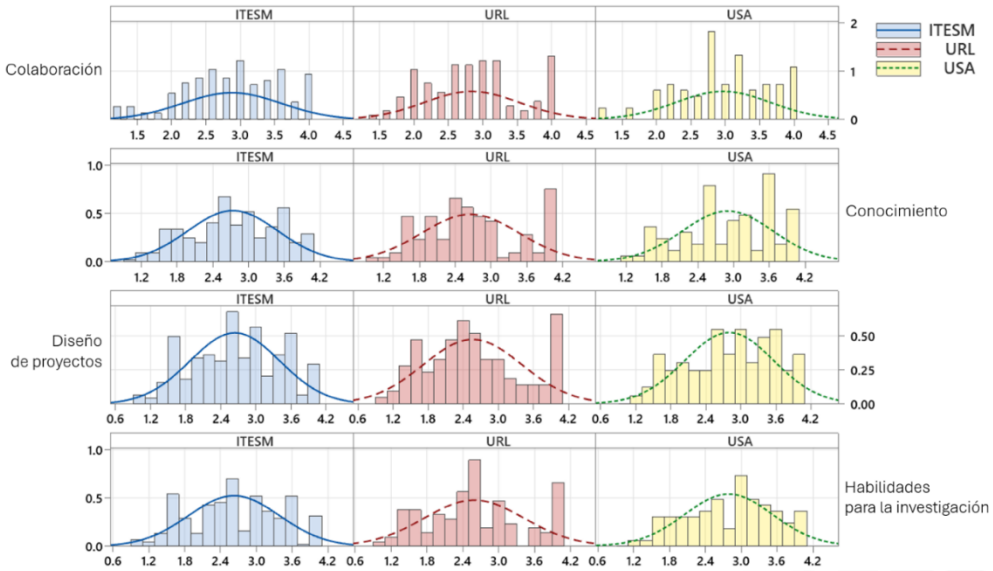

Figure 1. Histogram by university.

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4.2 Dimension matrix and probability analysis by gender

Figure 2 shows a matrix graph of the dimensions, indicating that the Collaboration dimension exhibits significant dispersion between the three universities. The ITESM (blue dots) has a higher concentration of responses in the range of 2.5 to 3.5, suggesting a relatively high perception of collaboration. In comparison, the URL (red squares) presents a wider dispersion, with responses ranging from 1.5 to 4.0, indicating more variability in the students' perception of collaboration. The USA (green diamonds), on the other hand, exhibits a similar trend to ITESM, but with a slight inclination towards higher collaboration values. Recent studies have shown that effective collaboration in educational settings can significantly improve academic outcomes and entrepreneurial skills (Pano & Gjika, 2020; Kujala et al., 2021).

In the Knowledge dimension, the ITESM and USA student responses are primarily concentrated between 2.0 and 3.5, indicating a uniform and positive perception of the knowledge acquired. On the other hand, the URL presents more dispersion, with responses ranging from 1.5 to 3.5, indicating considerable variability in knowledge. This may reflect differences in the workshop's implementation methods at each university.

The Project Design dimension correlates positively with the Knowledge and Collaboration dimensions in all universities. ITESM and USA present more concentrated distributions, suggesting a uniform perception of project design skills. The URL, on the other hand, shows greater variability in its responses, which may indicate differences in how these skills are perceived and taught. The consistency in perceptions within ITESM and the USA could be related to the presence of formative experiences within universities that contribute to the development of entrepreneurial skills.

The Research Skills dimension shows a positive correlation with the other three dimensions in all universities. ITESM and USA have more concentrated and less dispersed distributions, suggesting that students have a more uniform and positive perception of these skills. The URL, however, presents more dispersion in values, suggesting considerable variability in the perception of research skills among its students (Cao, 2021).

When comparing the different dimensions, it is observed that the correlation between the Knowledge and Collaboration dimensions is notably strong in ITESM and the USA, where the responses are more concentrated in high values. This suggests that students who perceive high levels of collaboration also tend to value the knowledge they have acquired positively. In the URL, although the correlation is positive, the greater dispersion indicates a less uniform perception. The results of this comparison underscore the importance of implementing educational experiences that effectively integrate entrepreneurial knowledge.

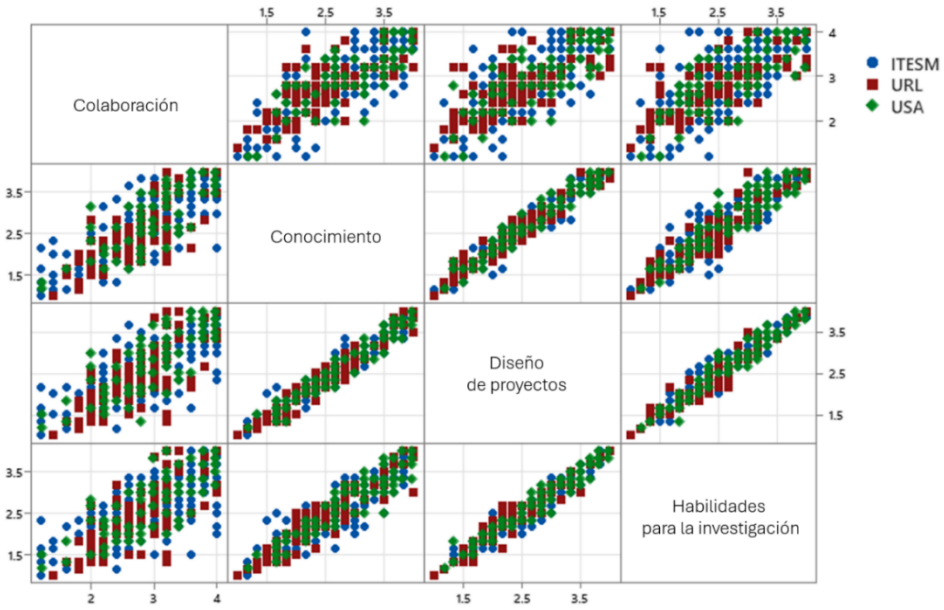

Figure 2. Dimensions Matrix Graph.

The gender analysis (Figure 3) reveals an upward trend in the probabilities of agreement across all universities for both men and women in the Collaboration dimension, with notable differences. The URL men

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have a higher concentration of positive responses than those from ITESM and the USA. For women, the university curves are more similar, although ITESM and URL appear to have a slight advantage over the USA. This suggests that, in general, both men and women at the URL have higher perceptions of collaboration than at the other universities; however, this perception is less pronounced among women. This observation aligns with studies that emphasize the significance of collaboration in educational settings (García-Tudela et al., 2021).

Regarding the Knowledge dimension, the gender curves similarly trend at all three universities. The ITESM, URL, and USA present a probability curve that suggests a high level of agreement that the knowledge imparted in the workshop was adequate. Nonetheless, the URL scores have slightly higher superiority, especially among men. This homogeneity in responses between genders and universities could reflect a perception of comparable entrepreneurial skills in the three institutions (Martínez et al., 2019).

In the Project Design dimension, the probability of agreement is remarkably high in all cases. Among men, the URL curve is slightly higher, which may suggest a perception of greater skill after participating in the workshop. Among women, the difference among the universities is less pronounced, although ITESM seems to have a slight advantage. This consistency across genders and universities may be indicative that the workshop provided participants with strategies for developing scientific entrepreneurship projects.

Finally, in the dimension of Research Skills, the probability curves are quite similar for both genders in the three universities. However, there is a slight advantage for ITESM and URL compared to the USA. This finding suggests that both men and women at ITESM and URL feel better prepared in terms of research skills after having participated in the workshop. Comparing the three universities, the URL presents the curves with the steepest slopes, which indicates a more positive perception in all dimensions, especially in collaboration and project design among men. ITESM also shows good results, particularly in research skills. The USA, although comparatively lower in some areas, maintains a uniform curve, suggesting a stable but less prominent perception in these dimensions.

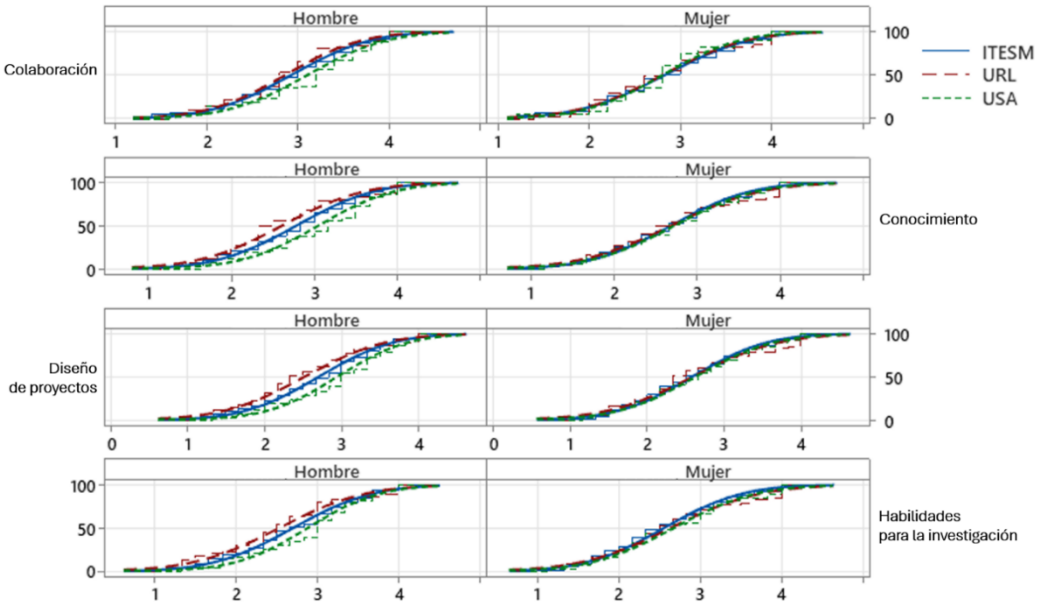

Figure 3. Probability Graphs of the Dimensions by Gender. (Hombre =Man; Mujer = Woman)

4.3 Testing of Independent Gender Samples

Student's t-tests were performed. Table 4 shows the Student's t-test results. The Collaboration dimension's statistics were 1.866 with 407 degrees of freedom and a p-value of 0.063. Welch's test reported 1.865 with 404.584 degrees of freedom and a p-value of 0.063. These p-values indicate no statistically significant difference in the perception of collaboration between men and women. The effect size was small (Cohen's d = 0.185) with a standard error of 0.099.

On the other hand, in the Knowledge dimension, a statistic of 1.260 emerged with 407 degrees of freedom and a p-value of 0.208. Welch's test reported a value of 1.260 with 405.833 degrees of freedom and a p-value of 0.209. These p-values indicate that there is no statistically significant difference in the perception of knowledge between men and women. The effect size was small (Cohen's d = 0.125), with a standard error of 0.099, which reinforces the conclusion that the observed differences were not statistically significant (Peacock & Peacock, 2020).

Regarding the Project Design dimension, the test yielded a statistic of 1.411 with 407 degrees of freedom and a p-value of 0.159. Welch's test showed similar results with a statistic of 1.411 and 406.053 degrees of freedom, and a p-value of 0.159. These p-values reflect insufficient evidence to reject the null hypothesis of gender equality. The effect size was somewhat larger (Cohen's d = 0.140), but still small, with a standard error of 0.099, indicating that the differences in perception of project design between men and women were not statistically significant (Han et al., 2023; Teli et al., 2023).

The test of the Research Skills dimension yielded a statistic of 1.197 with 407 degrees of freedom and a p-value of 0.232, while the Welch test reported a statistic of 1.196 with 406.277 degrees of freedom and a p-value of 0.232. These p-values indicate that there was no statistically significant difference between men and women in the perception of their research skills. The effect size was small (Cohen's d = 0.118) with a standard error of 0.099, indicating that the observed differences were not statistically significant and could be due to chance (Penchev, 2021).

The results of the independent sample T-tests indicated that there were no statistically significant differences between men and women in these areas. Although the Collaboration dimension showed a trend towards significance, the effect sizes across all dimensions were small, indicating that the observed differences were not large enough to reject the null hypothesis of gender equality. These findings suggest that students' perceptions of these dimensions of scientific entrepreneurship were similar between men and women (Bangdiwala, 2021).

Table 4.
Independent Samples T-Test.

	Test	Statistic	df	p	VS-MPR*	Cohen's d	SE Cohen's d
Colaboración	Student	1.866	407.000	0.063	2.117	0.185	0.099
	Welch	1.865	404.584	0.063	2.114	0.184	0.099
Conocimiento	Student	1.260	407.000	0.208	1.126	0.125	0.099
	Welch	1.260	405.833	0.209	1.125	0.125	0.099
Diseño de proyectos	Student	1.411	407.000	0.159	1.259	0.140	0.099
	Welch	1.411	406.053	0.159	1.258	0.140	0.099
Habilidades para la investigación	Student	1.197	407.000	0.232	1.085	0.118	0.099
	Welch	1.196	406.277	0.232	1.085	0.118	0.099

* Vovk-Sellke Maximum *p*-Ratio: Based on a two-sided *p*-value, the maximum possible odds in favor of H_1 over H_0 equals 1/(-e *p* log(*p*)) for $p \leq .37$

6. Discussion

This section highlights the most relevant and novel findings related to scientific entrepreneurship skills as perceived by students from the three universities in this study, across various key dimensions, notably collaboration, knowledge, project design, and research skills. The development of competencies for scientific entrepreneurship shows a strong correlation with the university students' perception of collaboration. The data reveal that the USA leads in this dimension, presenting the highest mean of 2.9732 and the lowest dispersion (SD = 0.6891). This finding aligns with previous studies that emphasize the significance of effective collaboration in educational settings for enhancing academic outcomes and fostering the development of entrepreneurial skills (Kreiterling, 2023; Pano & Gjika, 2020). It suggests that focusing on collaboration may be vital to improving entrepreneurial skills in higher education.

The perception of knowledge acquired in scientific entrepreneurship varies significantly among the universities studied, with the USA again showing a higher mean (2.9085) and lower variability (SD = 0.7614). This resonates with the conclusions of Teodoro et al. (2022) and Sun (2022), who emphasized the importance of diversity in the development of knowledge competencies in educational settings. These results highlight the need for learning environments to develop knowledge, but also ensure a uniform and positive perception of it among students. Regarding project design, the USA students also achieved the highest mean (2.8089), with

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a more concentrated distribution of responses, indicating a more consistent perception of the skills acquired in this dimension. This finding is consistent with the literature, which suggests that consistency in perceptions within educational institutions is related to compelling formative experiences (Mavlutova et al., 2023; Linzalone et al., 2020). Uniformity in the perception of these skills could be an indicator of a more robust and practice-focused educational approach.

Research skills also exhibit a similar trend, with the USA showing the highest mean (2.7947) and the lowest dispersion (SD = 0.7413) compared to ITESM and URL. This finding aligns with previous research that underscores the importance of a balanced approach in teaching research skills to improve educational outcomes (Cao, 2021; Ai, 2021). The consistency in the perception of these skills suggests that the face-to-face workshop "Scientific Entrepreneurship for the Future of Education" was effective in standardizing and improving students' preparation in this critical area.

When comparing the different dimensions, the correlation between knowledge and collaboration is particularly strong in the USA, where the responses are concentrated in high values, indicating that students who perceive high levels of collaboration also value the knowledge acquired positively. This aligns with studies that emphasize the interdependence of these competencies in the context of scientific entrepreneurship (Kujala et al., 2021). This finding highlights the importance of an integrated educational approach that effectively links collaboration and knowledge.

The results indicate that Sergio Arboleda University (USA) achieved the highest means in all the dimensions evaluated—collaboration, knowledge, project design, and research skills, which reflects a stronger perception of the development of competencies in scientific entrepreneurship. In contrast, Tecnológico de Monterrey (ITESM) and Rafael Landívar University (URL) showed more dispersion in their analyses, indicating areas for improvement in their training environments. These findings prompt us to reflect on the need to adapt educational programs to reduce institutional gaps (Valenzuela-Keller, 2022), as well as to consider the USA's pedagogical model as a regional benchmark for strengthening entrepreneurial competencies in Latin American universities. Finally, the Student’s t-tests carried out indicate that there were no statistically significant differences between men and women in the perception of the skills acquired, suggesting that the platform was equally effective for both genders. These results indicate that the perception of the competencies developed was uniform among the students, regardless of gender, which reinforces the effectiveness of the platform in providing inclusive and equitable education in the field of scientific entrepreneurship (Bangdiwala, 2021). They also confirm that integrating virtual technology in the teaching and learning process can promote a culture of innovation and entrepreneurship in the academic field (Tkachenko et al., 2019).

7. Conclusions

This study aimed to compare the skills for scientific entrepreneurship perceived by students in three Latin American universities after participating in a training experience mediated by the OpenEdR4C web platform. Students at the University of San Andrés (USA) in Colombia perceived a significant improvement in their scientific entrepreneurship skills after using the platform. In contrast, students from Tecnológico de Monterrey (ITESM) in Mexico and Universidad Rafael Landívar (URL) in Guatemala exhibited greater dispersion in their self-assessments, indicating broader variations in their perception of the platform's impact on these dimensions.

The results reflect the advantage of using advanced technological tools to foster key skills among university students, such as collaboration, knowledge, project design, and research skills. The consistency and uniformity of the students' perceptions, especially in the USA, highlight the relevance of this educational approach in developing entrepreneurial skills that are essential for addressing current global challenges.

One limitation of the study is its quasi-experimental research design, which may restrict the generalizability of the results to other populations or educational contexts. In addition, the sample used, although representative of the universities studied, is not large enough to capture the diversity of experiences and perceptions that could exist in other institutions. It is also important to note that the assessment of competencies was based on the students' perception, which could be influenced by subjective factors and may not fully reflect the actual development of these skills.

Finally, the study was based on the perceptions of university students; it was not possible to visit the universities to learn about the pedagogical approaches used to teach the skills analyzed. The limitations mentioned above outline potential areas for future research, which could explore in more depth the contextual differences between the participating universities and the influence of additional variables, such as the socioeconomic environment, the available technological infrastructure, and institutional policies that support entrepreneurship development.

Additionally, it would be valuable to investigate the long-term impact of training in scientific entrepreneurship using technological platforms, to assess how these competencies translate into students' professional practice once they enter the workforce. This would enable a better understanding of the sustainability and lasting impact of this educational approach on preparing future professionals to meet the challenges of an ever-evolving work environment.

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