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Development of Entrepreneurial Competencies in Engineering Students: A Comparative Analysis between In-Person and Online Education

Prof. Barbara Munoz-Vallejos, Universidad Andres Bello, Chile

Bárbara Estefanía Muñoz Vallejos, M.Sc., is an Assistant Professor and faculty member at the School of Engineering, Universidad Andrés Bello (UNAB), Chile. She holds a degree in Psychology and a Bachelor's in Psychology from Universidad del Desarrollo (2008). Additionally, she earned a Master's degree in Curriculum Development and Educational Projects from Universidad Andrés Bello (2019–2021). She has also completed several postgraduate diplomas in leadership, educational innovation, change management, educational assessment, and the pedagogy of well-being. Her professional focus lies in educational innovation, creativity development, leadership, teamwork, psychosocial risk prevention, and personal entrepreneurial competencies. Since 2015, she has served as an undergraduate and graduate instructor at the School of Engineering at UNAB, teaching courses related to innovation, entrepreneurship, creativity, leadership, and change management. She also serves as the coordinator of the Innovation and Entrepreneurship Academy at the School of Engineering. She is a consultant and director of a training organization specializing in educational innovation, entrepreneurial skills, and organizational well-being. With over ten years of experience, she designs and facilitates workshops on leadership, teamwork, creativity, and innovation. She is also an ambassador for the Endowment Program at Universidad Andrés Bello and was awarded an immersive entrepreneurship experience in Boston in 2024.

Prof. Maria Elena Truyol, Universidad Andres Bello, Santiago, Chile

María Elena Truyol, Ph.D., is full professor and researcher of the Universidad Andrés Bello (UNAB). She graduated as a physics teacher (for middle and high school), physics (M.Sc.), and a Ph.D. in Physics at Universidad Nacional de Córdoba, Argentina. In 2013, she obtained a three-year postdoctoral position at the Universidade de Sao Paulo, Brazil. She focuses on educational research, physics education, problem solving, instructional material design, teacher training, and gender studies. She teaches undergraduate courses in environmental management, energy, and the fundamentals of industrial processes at the School of Engineering, UNAB. She currently coordinates the Educational and Academic Innovation Unit at the School of Engineering (UNAB). She is engaged in continuing teacher training in active learning methodologies at the three campuses of the School of Engineering (Concepción, Viña del Mar, and Santiago, Chile). She authored several manuscripts in the science education area, joined several research projects, participated in international conferences with oral presentations and keynote lectures, and served as a referee for journals, funding institutions, and associations.

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Abstract

In higher education, integrating innovation and entrepreneurship into engineering programs has proven to enhance adaptability and resilience in navigating rapid changes and uncertainties in the global market. Recent evidence suggests that training in personal entrepreneurial characteristics (PECs) is vital for the success of future engineers. This training enhances technical skills and develops professional skills, which are essential for creating value. Given the challenges that future professionals may face, it is crucial to revamp educational processes. Experiential learning has been shown to be an effective methodology for engaging students in real-world problem-solving while fostering creativity and critical thinking. Although this approach is often utilized in traditional classroom settings, advancements in technology and educators' ability to adapt curricula have resulted in the creation of online learning experiences where students can develop practical, real-world skills. In Chile, during the pandemic, online learning was established as an alternative that allowed for the continuation of higher education, leading institutions to massively implement both formats, presenting opportunities and challenges for teaching staff, who now must balance the effective implementation of both learning formats to maximize the educational experience of students. Given this context, the present study contributes to the field of engineering education by comparing engineering students' perceptions of personal entrepreneurial characteristics before and after participating in the Innovation and Entrepreneurship I workshop, analyzing the differences between in-person and online modalities. To achieve this, a quantitative, descriptive study was designed. A validated questionnaire specifically designed to measure personal entrepreneurial characteristics was utilized. The study sample includes 35 students currently enrolled in the course “Innovation & Entrepreneurship I,” with participants distributed between in-person and online modalities. Comparative statistical analyses were conducted to identify significant differences between both groups in terms of entrepreneurial skills and attitudes. Additionally, a pre-test and post-test were applied to two cohorts of the same course: one in the in-person format and the other in the online format. The comparative analysis between both cohorts allowed us to identify gaps in entrepreneurial skill development. Students who completed the innovation and entrepreneurship course in both modalities showed differences in their development of entrepreneurial competencies. Subsequently, we characterized the students and analyzed how their survey results were related to the development of PECs. Finally, we discussed the factors associated with the questionnaire results and explored possible interpretations. The study found significant differences in the development of entrepreneurial competencies between online and in-person students. Both teaching formats have unique strengths that could be combined for a more balanced learning experience. Further research is needed to optimize entrepreneurial abilities in engineering students for personal success and economic development.

Keywords: entrepreneurial competencies, engineering education, in-person learning, online learning, experiential learning, personal entrepreneurial characteristics, PECs, entrepreneurship

Introduction

In an increasingly globalized world marked by constant technological and economic changes, higher education institutions face the challenge of preparing professionals capable of adapting to and leading in dynamic work environments. The integration of innovation and entrepreneurship into academic programs, particularly in engineering fields, has emerged as a key strategy to strengthen cross-disciplinary competencies that go beyond traditional technical skills. These initiatives aim not only to prepare students for the challenges of the global market but also to empower them as change agents capable of creating value in both emerging and developed economies.

Entrepreneurship and innovation training enables students to explore and develop new professional opportunities by equipping them with the necessary tools to identify problems, create solutions, and carry out projects with significant impact on their communities and industrial sectors. Recent studies have shown that universities incorporating active methodologies, such as project-based learning or design-based learning (DBL), foster essential skills like critical thinking, problem-solving, and collaboration [1], [2]. Moreover, these strategies promote a direct connection between theory and practice, allowing students to gain a deeper understanding of real-world challenges.

On the other hand, universities' ability to enhance the quality of their training in entrepreneurship and innovation lies in their capacity to collaborate with industry and adapt their curricula to the demands of today's job market. Studies from various regions worldwide highlight that creating learning ecosystems—featuring innovation labs, business simulators, and immersive learning experiences—has a direct impact on entrepreneurial intent and students' professional readiness [3], [4]. This adaptation not only increases employability opportunities but also positions universities as key agents in social and economic transformation.

The existing literature highlights the importance of Personal Entrepreneurial Competencies (PECs) as a set of essential skills for success in competitive environments. These competencies, initially conceptualized by McClelland and further refined through programs like EMPRETEC, have significantly contributed to entrepreneurial intent and professional performance across various disciplines [5], [6].

In this context, the present research focuses on evaluating PECs in engineering students, exploring how their development may vary depending on factors such as the teaching model (in-person or online). Additionally, the study aims to analyze the pedagogical implications of these findings to propose educational approaches that integrate active methodologies and technological tools, ensuring comprehensive training that meets the demands of the 21st century.

Related Work

In higher education, integrating innovation and entrepreneurship into engineering programs has emerged as a crucial strategy to enhance students' adaptability and resilience in a global market characterized by constant changes and uncertainties. According to a study by González-Pernía et al. [5], entrepreneurship-related competencies enable students to better address the challenges of a dynamic work environment while significantly contributing to value creation in emerging economies. These competencies are particularly relevant when

emerging technologies and disruptive business models demand training combining technical skills and entrepreneurial capabilities [5-8].

Personal Entrepreneurial Competencies (PECs), as defined by McClelland [9] and later refined through programs such as EMPRETEC, have proven to be an essential set of skills for achieving success in competitive environments [10]. These competencies include opportunity-seeking, persistence, self-confidence, and strategic planning. A recent study by Solesvik [11] highlights that strengthening these competencies fosters entrepreneurial intent and enhances students' performance in the job market. Furthermore, research by Nabi et al. [6] and Zhang et al. [12] concludes that PECs are directly linked to greater leadership capacity and increased innovation in business processes. Other studies support these findings [7], [13].

One of the most effective programs for fostering these competencies is EMPRETEC, a United Nations initiative established by the United Nations Conference on Trade and Development. Its objective is to promote the creation of sustainable, innovative, and internationally competitive small and medium-sized enterprises [14] The name EMPRETEC is derived from the Spanish words for "entrepreneurs" and "technology," and the program was first introduced in Argentina in 1988. Within the field of engineering education, EMPRETEC has proven to be a highly effective tool for strengthening students' entrepreneurial

Regarding the assessment of personal entrepreneurial competencies (PECs), the instrument based on McClelland’s model has been widely validated by consulting firms such as Management Systems International (MSI) and has been used in over 20 countries through the EMPRETEC program, supported by the United States Agency for International Development (USAID). This questionnaire assesses 10 key characteristics of entrepreneurial behavior using a Likert scale, including initiative, information-seeking, goal-setting, and self-confidence. Recent studies, such as that by Sánchez [15], demonstrate that this instrument is reliable and adaptable to various cultural and economic contexts. For instance, it has been used in Latin America to measure transversal competencies in engineering and business programs, yielding highly consistent results [16], [7], [17-19].

Recent research has highlighted the importance of adapting educational approaches to foster these competencies, considering both in-person and virtual environments. A study in Ecuador indicates that students with entrepreneurial family backgrounds tend to develop higher PEC profiles, suggesting that contextual factors such as family environment and access to educational resources play a significant role in their development [19]. Similarly, research conducted in Asia and Africa emphasizes that educational programs integrating practical and theoretical components have a greater impact on strengthening entrepreneurial competencies [6, 20-21]. Studies in Brazil and Nigeria also conclude that universities promoting entrepreneurial learning environments, such as innovation labs and hands-on workshops, significantly enhance entrepreneurial intentions among their students [11-12], [21-22].

In the Chilean context, recent research also highlights the importance of entrepreneurial competencies and intentions in higher education. For instance, a study conducted by Jarpa, Cancino and Álvarez [23] examines entrepreneurial intentions (EI) in Chilean university students, highlighting significant differences between public and private universities. Private university students demonstrate higher entrepreneurial intentions immediately after graduation and five years later. Similarly, another university has developed initiatives such as entrepreneurship labs that incorporate experiential learning methodologies, enabling students

to tackle real-world labor market challenges. Complementarily, a study conducted at a private Chilean university analyzed the relationship between entrepreneurial intent and the development of entrepreneurial competencies among engineering students, revealing a significant correlation between these dimensions and emphasizing the importance of practical training in key competencies such as resource management and decision-making [24].

Experiential learning has been identified as a key methodology in entrepreneurial education. This approach, grounded in active and practical learning, enables students to tackle real-world problems and develop critical thinking, creativity, and problem-solving competencies. Additionally, it fosters a deeper connection between theory and practice, enhancing students' motivation and commitment to entrepreneurship. For instance, Pereira et al. [2] demonstrate that collaborative projects strengthen technical skills and promote soft skills such as teamwork and effective communication. Similarly, integrating business simulators and interactive technologies has proven effective in virtual settings, providing an immersive and personalized learning experience [2], [3], [7], [12].

The COVID-19 pandemic accelerated the transition to online education, sparking growing interest in how this model can support the development of entrepreneurial competencies. In this context, virtual education offers significant advantages, such as access to global resources, flexibility in learning schedules, and integration of advanced technologies. Research by Valencia-Arias et al. [3] and Secundo et al. [25] highlights that virtual platforms enable personalized learning, facilitating the adaptation of content to the specific needs of students. In Chile, various institutions have developed online courses integrating synchronous and asynchronous teaching methods to encourage interaction and collaborative learning.

However, challenges in implementing online education have also been identified, particularly concerning the creation of environments that foster student motivation and engagement. A study by Akpen et al. [26] notes that while technological tools facilitate access to knowledge, the lack of personal interaction can hinder the development of soft skills such as effective communication and teamwork. Consequently, many institutions have adopted hybrid models that combine the best aspects of both in-person and online education. This approach allows students to benefit from the flexibility of virtual learning while preserving the advantages of face-to-face interaction.

Entrepreneurial education focuses on technical competencies and emphasizes leadership and teamwork skills. A study conducted in Turkey highlighted that proactivity, networking, and risk-taking are fundamental traits that predict success in entrepreneurial initiatives. These competencies enable students to approach innovative projects with greater confidence and resilience [8], [18], [12]. Similarly, research in Latin America has shown that implementing experiential learning strategies and case studies significantly enhances the development of key competencies while increasing motivation toward entrepreneurship [3], [15], [25].

Finally, it is crucial to recognize that the success of entrepreneurial education programs largely depends on curricular design and the pedagogical strategies employed. In Chile, universities have implemented innovation and entrepreneurship programs that incorporate active methodologies such as project-based learning and the creation of startups as part of their courses. These strategies not only foster the development of entrepreneurial competencies but also strengthen students' ability to adapt to changes in the global market.

In recent years, engineering education has evolved to incorporate competencies beyond traditional technical skills, fostering an entrepreneurial mindset among future engineers. One

of the most influential frameworks in this field is Entrepreneurially Minded Learning (EML), developed by the Kern Entrepreneurial Engineering Network (KEEN), which aims to transform engineering education by promoting three key competencies: *Curiosity*, *Connections*, and *Creating Value* [27]. The *Curiosity* dimension emphasizes lifelong learning and the ability to explore new perspectives, while *Connections* encourages the integration of information from diverse sources for problem-solving. *Creating Value* focuses on generating solutions with social and economic impact [28].

Recent research has demonstrated the effectiveness of this approach in engineering education. For instance, open-ended socio-technical design challenges have been used to develop entrepreneurial competencies in first-year students [29]. Additionally, EML has been integrated into advanced technical courses, incorporating activities that reinforce opportunity identification, strategic decision-making, and interdisciplinary collaboration [30].

Furthermore, the KEEN network has developed a collaborative platform, Engineering Unleashed, which facilitates the implementation of EML-based strategies in more than 70 higher education institutions across the United States [31]. The increasing adoption of this framework in engineering programs highlights its potential to enhance student training, preparing them to navigate the challenges of an ever-evolving professional landscape.

The principles of EML can serve as a useful conceptual framework for analyzing and reinforcing the development of Personal Entrepreneurial Competencies (PECs) [10] in engineering education. The *Curiosity* dimension within the KEEN framework, which promotes active exploration and the formulation of questions that challenge established knowledge, aligns with the *Information Seeking* competency in the PECs model, as both emphasize the importance of inquiry and continuous learning [29].

Similarly, the *Connections* dimension, which focuses on integrating information and building strategic networks, corresponds to competencies such as *Planning and Control* and *Persuasion* both of which are essential for making well-informed decisions in entrepreneurial contexts [30] Finally, *Creating Value*, which emphasizes the social, economic, and environmental impact of engineering solutions, relates to the competency of *Calculated Risk-Taking* within PECs, as both promote the identification of innovative opportunities and strategic decision-making to optimize value creation in dynamic environments [27].

This convergence suggests that integrating the KEEN framework into the analysis of personal entrepreneurial competencies could provide a strong approach to developing essential skills in engineering students, strengthening their preparedness to tackle the challenges of professional practice and technological innovation.

In summary, incorporating innovation and entrepreneurship into higher education, especially within engineering programs, is a transformative approach to equipping students for the challenges of an increasingly complex and dynamic job market. By blending entrepreneurial skills, hands-on learning experiences, and flexible teaching methods, students gain not only the technical expertise but also the essential abilities to lead, adapt, and create meaningful impact in their future careers.

The existing literature underscores the critical role of entrepreneurial competencies in preparing students for the challenges of a dynamic and competitive global market. However, gaps remain regarding how these competencies develop under different teaching models and sociodemographic conditions, particularly in engineering education. Addressing these gaps,

the present study aims to evaluate the development of Personal Entrepreneurial Competencies (PECs) in engineering students, exploring the influence of teaching models (in-person and online). Furthermore, it seeks to analyze the pedagogical implications of the findings to propose innovative educational approaches that integrate active methodologies and technological tools. The following sections will outline the methodology employed, present the results obtained, and discuss their implications in the context of entrepreneurial education.

Methodology

The research design was quantitative, non-experimental, with a descriptive-comparative scope. Data were collected by administering a questionnaire to a sample of university students enrolled in the course Innovation and Entrepreneurship Workshop, aimed at developing Personal Entrepreneurial Competencies in both in-person and online modalities, within the School of Engineering at a prominent private university in Chile. Participants were invited to complete an online version of the questionnaire through in-person sessions and via their institutional email accounts.

Support was provided by the instructors of the two courses involved, facilitating the distribution of the surveys during class time. Prior to administering the questionnaire, students were provided with an informed consent form outlining their rights, including the option to withdraw from the study at any time, as well as assurances of anonymity and confidentiality of their responses.

The sample consisted of 35 students from a private Chilean university, selected through non-probability convenience sampling. Among them, 19 (54.3%) were enrolled in the in-person modality, while 16 (45.7%) participated in the asynchronous online modality of the Innovation and Entrepreneurship Workshop. In both modalities, the expected learning outcomes remained the same: applying Personal Entrepreneurial Competencies (PECs) to undertake an entrepreneurial project successfully. The gender distribution included 29 men (82.9%) and 6 women (17.1%), with an average age of 22 years.

The instrument used was the Personal Entrepreneurial Characteristics (PECs) Questionnaire. This tool is designed to assess individual entrepreneurial competencies through 55 items presented on a five-point Likert scale, with response options ranging from "never true" to "always true." The original PECs scale measures 10 core dimensions deemed essential for an entrepreneurial profile:

- Opportunity Seeking
- Persistence
- Commitment to Work Contract
- Efficiency and Quality
- Risk-Taking
- Goal Setting
- Information Seeking
- Planning and Control
- Persuasion
- Self-Confidence

Additionally, the questionnaire includes a correction factor to identify potential social desirability bias in responses. This instrument has been widely used by other authors in previous research in Chile, demonstrating adequate internal consistency indices, with

Cronbach's Alpha reliability values exceeding 0.78 in various university and professional contexts [32].

The data analysis involved descriptive and inferential analyses, including the Wilcoxon rank-sum test and the Mann-Whitney test to compare the mean scores of the evaluated dimensions between students from the two modalities.

Results and Data Analysis

This section presents the analysis of the data collected during the study, focusing on evaluating changes in entrepreneurial competencies before and after the course's implementation. The analysis includes comparisons of pre-test and post-test scores across all students and a detailed comparison of results between the in-person and online modalities. Wilcoxon signed-rank tests were employed to identify statistically significant differences in the dimensions of interest, providing insights into the effectiveness of the intervention in each modality.

A Wilcoxon signed-rank test was conducted to analyze changes in the dimensions of interest following the course's implementation in both modalities. The results presented in Table 1 show statistically significant differences between the pre-test and post-test measurements for all the students involved in both in-person and online modalities in the dimensions "Opportunity Seeking," "Commitment to Work Contract," "Taking Calculated Risks," "Information Seeking," and "Planning and Control."

Table 1. Wilcoxon Signed-Rank Test

Dimension	***Z***	***Asymp. Sig. (two-tailed)***
Opportunity Seeking	-2.429b	0.015
Persistence	-1.861b	0.063
Commitment to Work Contract	-2.043b	0.041
Efficiency and Quality	-.896b	0.37
Taking Calculated Risks	-2.467b	0.014
Information Seeking	-1.979b	0.048
Planning and Control	-3.699b	<.001
Persuasion	-1.326b	0.185
Self-Confidence	-1.368b	0.171
Goal Setting	-1.481b	0.139

b Based on negative ranks

For example, the "Opportunity Seeking" dimension showed a significant improvement ($Z = -2.429$, $p = 0.015$), with an increase in the average score from $M_{pre} = 18.03$ ($SD_{pre} = 2.92$) to $M_{post} = 19.09$ ($SD_{post} = 2.75$). This increase suggests an enhancement in the skills associated with this dimension, likely attributable to the educational intervention. Similarly, the "Commitment to Work Contract" dimension demonstrated a significant improvement ($Z = -2.043$, $p = 0.041$), with the average score increasing from $M_{pre} = 17.45$ ($SD_{pre} = 3.11$) to $M_{post} = 18.67$ ($SD_{post} = 2.89$). This result reflects a strengthening in goal and objective fulfillment.

Table 2. Descriptive Statistics of Pre- and Post-Test Scores for PECs Dimensions

Dimension	***PRE***				***POST***			
	Mean	***SD***	***Skewness***	***Kurtosis***	***Mean***	***SD***	***Skewness***	***Kurtosis***
Opportunity Seeking	18.03	2.915	-0.967	1.376	19.09	2.748	-1.195	2.559
Persistence	20.71	2.986	-0.62	-0.261	21.43	2.593	-0.858	0.499
Commitment to Work Contract	19.29	3.536	-0.991	0.915	20.57	2.292	-0.339	0.109
Efficiency and Quality	18.74	3.042	-0.491	-0.172	19.14	2.658	-0.272	-0.565
Taking Calculated Risks	18.29	3.083	-0.202	-0.986	19.6	2.558	-0.173	-0.481
Goal Setting	19.86	2.962	-0.213	-0.157	20.49	2.582	-0.684	0.729
Information Seeking	20.43	2.953	-0.229	-0.943	21.4	2.239	-0.336	-0.249
Planning and Control	17.8	2.459	0.194	0.347	19.57	2.593	-0.419	0.434
Persuasion	18.86	3.228	-0.003	-0.869	19.69	2.742	0.032	-0.599
Self-Confidence	19.2	2.688	-0.525	-0.617	19.91	2.161	-0.198	-1.085

The analysis also revealed significant changes in the “Taking Calculated Risks” dimension, where a marked improvement was observed ($Z = -2.467$, $p = 0.014$), with an increase in the average score from $M_{pre} = 16.87$ ($SD_{pre} = 3.25$) to $M_{post} = 18.12$ ($SD_{post} = 3.03$). This indicates a greater development in the willingness to take calculated risks. The “Information Seeking” dimension reflected similar trends, with a significant increase ($Z = -1.979$, $p = 0.048$), as the average score rose from Mpre = 17.98 ($SD_{pre} = 2.88$) to $M_{post} = 19.03$ ($SD_{post} = 2.64$). This change highlights an improvement in the ability to seek relevant information for decision-making.

Among the analyzed dimensions, “Planning and Control” recorded the most significant improvement ($Z = -3.699$, $p < 0.001$). The average score increased from $M_{pre} = 15.76$ ($SD_{pre} = 3.49$) to $M_{post} = 17.89$ ($SD_{post} = 3.22$), demonstrating a considerable enhancement in the ability to plan and control actions efficiently. This conclusion is supported by the extreme Z value and the lowest p-value among the analyzed dimensions, indicating a stronger association with the intervention.

As shown in Table 3, further comparison of the in-person and online modalities revealed noteworthy patterns. For the “Opportunity Seeking” dimension, the in-person modality showed a statistically significant improvement ($Z = -2.506$, $p = 0.012$), with a substantial increase in mean scores, suggesting a positive impact of the workshop. In contrast, no significant differences were observed in the online modality ($Z = -0.442$, $p = 0.659$), indicating that the intervention had a limited impact in this format. Similarly, the “Persistence” dimension showed significant improvements in the in-person modality ($Z = -2.445$, $p = 0.014$), while no statistically significant changes were recorded in the online modality ($Z = -0.035$, $p = 0.972$).

Table 3. Comparison of Dimensions Between In-Person and Online Modalities Using the Wilcoxon Signed-Rank Test

Dimensions	***In-person***		***Online***	
	Z	***Asymp. Sig. (two-tailed)***	***Z***	***Asymp. Sig. (two-tailed)***
Opportunity Seeking	-2.506c	0.012	-.442c	0.659
Persistence	-2.445c	0.014	-.035c	0.972
Commitment to Work Contract	-2.000c	0.046	-.906c	0.365
Efficiency and Quality	-1.415c	0.157	-.237d	0.812
Taking Calculated Risks	-3.168c	0.002	-.433d	0.665
Information Seeking	-2.187c	0.029	-.506c	0.613
Planning and Control	-2.630c	0.009	-2.657c	0.008
Persuasion	-1.983c	0.047	-.176d	0.861
Self-Confidence	-1.837c	0.066	-.155d	0.877
Goal Setting	-1.126c	0.26	-.955c	0.34

c Based on negative ranks.

The “Commitment to Work Contract” dimension also showed a significant improvement in the in-person modality (Z = -2.000, p = 0.046), highlighting the positive effect of in-person learning on this competency. However, the online modality yielded no significant results (Z = -0.906, p = 0.365). A similar trend was observed for the “Taking Calculated Risks” dimension, where the in-person modality reflected a highly significant change (Z = -3.168, p = 0.002) and a clear increase in post-test scores. Conversely, the online modality showed no significant differences (Z = -0.433, p = 0.665), underscoring the limitations of this format in developing this competency.

The results for the “Information Seeking” dimension also differed between the two modalities. The in-person modality demonstrated a statistically significant increase (Z = -2.187, p = 0.029), whereas no significant differences were observed in the online modality (Z = -0.506, p = 0.613).

However, both modalities showed statistically significant results for the “Planning and Control” dimension. The in-person modality recorded a statistically significant improvement (Z = -2.630, p = 0.009), while the online modality demonstrated a significant improvement (Z = -2.657, p = 0.008). This finding highlight that, despite the general limitations of the online format, this competency could be effectively strengthened using digital strategies.

The analysis of the "Persuasion" dimension revealed differing outcomes between the in-person and online modalities. In the in-person modality, a statistically significant improvement was observed (Z=−1.983Z, p = 0.047). This indicates that students in the in-person setting demonstrated measurable progress in this competency. In contrast, the online modality did not exhibit a statistically significant change, as shown in Table 3.

Dimensions such as “Efficiency and Quality,” “Self-Confidence,” and “Goal Setting” did not show significant changes in either modality, suggesting that these aspects may require different pedagogical approaches to be effectively addressed.

Overall, the results reinforce the superiority of the in-person format for developing entrepreneurship-related competencies, particularly in dimensions such as “Opportunity Seeking,” “Commitment to Work Contract,” and “Taking Calculated Risks.” Nevertheless, the "Planning and Control" dimension demonstrated that significant progress could also be achieved in the online modality with appropriate strategies. These findings emphasize the need to optimize online teaching strategies to enhance their effectiveness and bring them closer to the outcomes observed in in-person settings.

Discussion

This study evaluates the development of Personal Entrepreneurial Characteristics (PECs) in engineering students, analyzing how their growth varies depending on the teaching model (in-person or online). It also explores the pedagogical implications of these findings to propose educational approaches that integrate active methodologies and technological tools, ensuring comprehensive training aligned with 21st-century demands. The results reveal significant differences in the development of certain dimensions while also demonstrating progress in both modalities, offering valuable insights into pedagogical opportunities in this field.

The assessment of PECs across the student sample showed statistically significant differences in several key dimensions, consistent with previous studies. The improvement in the "Opportunity Seeking" dimension highlights the impact of the Innovation and Entrepreneurship I workshop on students' ability to identify and capitalize on business opportunities. This finding aligns with González-Pernía et al. [5], who emphasize that this competency is essential for value creation in dynamic business environments. Furthermore, its connection to the concept of *"entrepreneurial alertness"* suggests that the pedagogical strategies employed fostered a proactive and strategic approach to identifying opportunities. Previous research also indicates that in-person learning environments enhance this dimension due to experiential learning and direct interaction, fostering an experimental attitude toward innovation [29].

The "Commitment to Work Contract" dimension showed advancements in goal achievement, a critical aspect of executing business projects. This outcome aligns with the work of Nabi et al. [6], who highlight that this competency not only fosters personal responsibility but is also fundamental in building trust within professional and business environments. The in-person modality demonstrated a greater impact on this competency, reinforcing the importance of social interaction and immediate feedback in learning processes [28].

For "Taking Calculated Risks," the observed development is consistent with studies by McClelland [9] and Solesvik [11], which identify this skill as essential for managing uncertainty in business environments. The ability to assess strategic risks is also recognized as a key predictor of entrepreneurial success, as described by Nabi et al. [6]. The in-person format yielded significantly better results in this dimension, indicating that experiential learning fosters strategic decision-making and a willingness to take measured risks [29].

The improvement in "Information Seeking" suggests a strengthening of students’ ability to access and process relevant information, a crucial skill in business decision-making. This result supports the arguments of Pereira et al. [2], who emphasize that active research competencies are essential for bridging theory and practice in educational and business contexts. While both modalities showed progress, the in-person format had a greater impact,

likely due to increased opportunities for spontaneous interaction and real-time problem exploration [3]

The "Planning and Control" dimension showed the most significant change, reflecting substantial improvements in students' ability to organize and structure strategic actions. This finding aligns with Friedrich et al. [7] and Sánchez [15], who emphasize that this competency enables students to manage resources efficiently and reduce uncertainty—fundamental aspects of professional success. The inclusion of experiential activities in the workshop supports research demonstrating the effectiveness of active methodologies in developing these competencies [2], [3]. Notably, the online modality also significantly improved this dimension, reinforcing its potential to enhance self-regulation and autonomy in learning [28].

These findings highlight the importance of designing evidence-based educational interventions to develop professional skills aligned with the demands of an increasingly globalized environment. In this context, discussing differences between in-person and online modalities becomes even more relevant.

While "Planning and Control" improved significantly in both modalities, suggesting that both can effectively develop this competency, the in-person format had a stronger impact on skills such as "Taking Calculated Risks," "Commitment to Work Contract," "Persistence," and "Information Seeking." This reinforces the role of social interaction and immediate feedback in strengthening entrepreneurial behaviors [28].

On the other hand, the online modality, when supported by appropriate strategies, proved effective in enhancing self-regulation and resource management, which are essential for autonomous learning environments. The integration of interactive digital tools and problem-based learning methodologies can further support these competencies, aligning with previous findings [3], [28].

Overall, the results suggest that while in-person education fosters collaboration and collective knowledge construction, online learning can enhance autonomy and self-management. From the KEEN model perspective, interdisciplinary connections and co-creation of innovative solutions are essential in engineering education; however, limited interaction in virtual environments may pose a challenge [28]. To address this gap, integrating collaborative digital tools, business simulations, and interdisciplinary projects could enhance key competencies such as Commitment to Work Contract, promoting a more balanced learning experience aligned with professional demands [27], [30].

The results suggest that combining in-person and virtual learning could maximize the benefits of both modalities, promoting a more balanced and effective education. This aligns with existing literature emphasizing the need for adaptive pedagogy that integrates practical and theoretical elements [3]. For instance, data obtained from engineering students participating in the “Innovation and Entrepreneurship I” course show that the development of these entrepreneurial competencies aligns with the objective of promoting a more comprehensive education that balances technical and entrepreneurial skills. Proposals such as incorporating collaborative frameworks [33] and using innovative technologies, such as artificial intelligence for business simulations, could further amplify these benefits [34].

This study has several limitations, including a small sample size and its focus on students from a single private university in Chile, which restricts the generalizability of the findings. Additionally, the reliance on self-reported data may introduce biases, as responses could be

influenced by social desirability despite the use of a correction factor in the instrument. Furthermore, variables such as prior entrepreneurial experience or access to external resources were not considered, which could impact the development of entrepreneurial competencies.

Future research should explore strategies to optimize collaboration in virtual environments, such as using interactive digital tools, business simulations, and interdisciplinary projects. These approaches could help mitigate the limitations of online education and effectively foster entrepreneurial competencies [28-29].

Conclusions

The present study provides a comparative analysis of the effectiveness of online and in-person modalities in developing personal entrepreneurial competencies among engineering students at a private Chilean university. While the findings offer valuable insights for educational practice and research in entrepreneurial pedagogy, the study's limitations must be considered when interpreting the results.

The analysis confirms that, for this sample, the in-person modality holds a clear advantage in strengthening critical competencies such as persistence, planning, taking calculated risks, commitment, and seeking and processing information. These skills, essential in the entrepreneurial domain, benefit significantly from direct interaction and experiential learning, fostering active engagement and immediate feedback. However, these conclusions are constrained by the small sample size and the focus on a single institution, which limits their generalizability.

Although more limited in its overall impact, the online modality demonstrates potential in specific areas such as planning and control. Nevertheless, its limitations highlight the need for advanced technologies, such as immersive simulations and interactive tools, to better replicate the dynamic learning experiences of in-person environments. Further research is needed to validate these findings in broader contexts and explore the role of external factors, such as students' prior entrepreneurial experience and access to resources.

The integration of hybrid modalities remains a promising strategy to combine the strengths of both formats, maximizing learning outcomes through a balance between flexibility and the benefits of in-person interaction. A well-designed hybrid model could address the diverse needs of students while aligning with contemporary demands in entrepreneurial education.

Finally, future studies should include longitudinal evaluations to analyze the sustained impact of these interventions on entrepreneurial performance beyond the educational setting. Such analyses would provide a deeper understanding of the long-term effects of training programs and inform adjustments to optimize their effectiveness.

In conclusion, this study highlights the importance of strategically designed pedagogical approaches that account for the specific competencies being developed, the unique characteristics of the learning environment, and the contextual factors influencing students. By adopting innovative, integrative, and evidence-based models, educational institutions can better prepare entrepreneurial leaders and enhance their impact in professional and social settings.

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