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Virtual Internship Experiences in Engineering Education Programs: Assessing Competencies and Global Learning

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Dr. Renetta Garrison Tull, University of California, Davis

Renetta Garrison Tull, Ph.D., is the Vice Chancellor for Inclusive Excellence at the University of California Davis, and she is a past convenor for the University of California's system-wide (10 campus) Council of Vice Chancellors for Equity and Inclusion. Tull's undergraduate and doctoral degrees in electrical engineering and speech science are from Howard University and Northwestern University, respectively. She has had past faculty roles at UW-Madison, the University of Maryland College Park, and UMBC. At UC Davis, she is an Adjunct Professor in the Department of Electrical and Computer Engineering in the College of Engineering, and a faculty affiliate in the Interdepartmental Program on Human Rights Studies. As Vice Chancellor, her divisional portfolio includes the Davis-based Office of Campus Community Relations, and the Office for Advancing Mentoring and the Professoriate. The Sacramento headquarters houses the Office for Health Equity by Design for Inclusive Excellence, serving the medical school, nursing school, and medical center. Inclusive Excellence also covers medical clinics around California, and UC Davis' locations in the Bay Area and other parts of the state. Her portfolio also includes the Avanza initiative; the Police Accountability Board; the Center for Reducing Health Disparities; the Center for the Advancement of Multicultural Perspectives on Science; the Center for the Advancement of Multicultural Perspectives on Social Sciences, Arts, and the Humanities; and the Truth, Community Healing, and Transformation Center. She credits the success of Inclusive Excellence to talented teams and a supportive university environment. She is proud to be the Executive Sponsor for the UC Davis Principles of Community university-wide campus climate campaign, which highlights the key phrase, "We affirm the dignity inherent in all of us."

Before joining UC Davis in California, Tull was in Maryland at the University of Maryland Baltimore County (UMBC) and served as Assistant Dean for Graduate Student Development (GSD), Associate Vice Provost for GSD and Postdoctoral Affairs, and Associate Vice Provost for Strategic Initiatives. She later had a detail with the University System of Maryland (USM, 12 institutions), serving as the Director for USM Pipeline Professional Development Programs, and she had Co-PI and PI roles on National Science Foundation (NSF) grants within the LSAMP, Alliances for Graduate Education and the Professoriate, and ADVANCE programs. At Davis, she is PI for the NSF-funded PROMISE Engineering Institute (PEI - UC Davis and UMBC). PEI has developed an intergenerational mentoring engineering leadership network which has engaged engineering graduate students and senior leaders from UC Davis, UMBC, UC Irvine, UC Berkeley, UCLA, Stanford, University of Maryland College Park, Virginia State University, Rice University, George Mason University, and North Carolina A&T.

An international speaker on global inclusion in STEM, Dr. Tull, a member of Tau Beta Pi, has shared Humanitarian Engineering principles and work connected to the United Nations' Sustainable Development Goals at the United Nations Headquarters, and on every continent (except Antarctica). Through the Latin and Caribbean Consortium for Engineering Institutions (LACCEI), she has given bilingual talks across Latin America on topics related to engineering for all.

Tull was a finalist for the Global Engineering Deans Council/Airbus Diversity Award (announced in Italy and acknowledged in Dubai). In addition, she has received the ABET Claire L. Felbinger Award for Diversity, the Student Platform for Engineering Education Development Global Mentoring Award, and the Electrical and Computer Engineering Department Head Association's (ECEDHA) Diversity Award. She was a PI for Puerto Rico's ADVANCE Hispanic Women in STEM, she is the past President for LACCEI, and the current Vice President of Transformative Initiatives for the International Federation of Engineering Education Societies (IFEES). Tull is currently leading the "Alianza" project for LACCEI in partnership with the Organization of American States; she sits on the Board of Directors of the American Geophysical Union (AGU), one of the world's largest Earth and space science organizations; and recently, she has been invited to serve on engineering expert teams in Chile and China. Tull was a co-author for UNESCO Engineering Report II, and she participated in the UN Women CSW66 side event on "Role of Women in STEM in Addressing Climate Change" where she joined global leaders on the importance of women in engineering for climate action, disaster risk reduction, and sustainable development. She is an author of a chapter of "Rising to the Top," an IFEES book on global women in engineering, and was a co-author for the National Academies' "Impact of COVID-19 on the Careers of Women in Academic STEMM," and "The Science of Effective Mentoring in STEMM. She is also co-author for the "Matilda y las Mujeres en Ingeniería" series, and her book chapter with a collaborative team of authors from several continents, "Models for International Collaborations to Nurture Students into Global Engineers," in the Springer book, "Academic Leadership in Engineering Education: Learnings and Case Studies from Educational Leaders Around the Globe," was launched in Australia. Tull enjoys her work as a global education policy strategist and champion for equity. She often travels with her husband of more than 30 years, Dr. Damon Tull, with whom she collaborates on work such as "The Success Equation," and "Dark Matters: Metaphorical Black Holes…", which creatively couples math, physics, and social science.

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Virtual Internship Experiences in Engineering Education Programs: Assessing Competencies and Global Learning

Abstract

The global expansion of online education has fostered the development of virtual practical experiences designed to complement traditional academic training methods. These experiences are essential for strengthening the connection between theory and practice, particularly in fields such as engineering, where applied learning is a fundamental component of professional development (Kolb, 1984; Felder & Brent, 2003). The implementation of virtual internships has emerged as a response to challenges arising from geographic restrictions, mobility limitations, and structural changes in higher education following the COVID-19 pandemic (Smith et al., 2021). This study analyzes a virtual internship program designed for students in engineering and related fields, whose purpose was to promote the development of professional competencies through participation in supervised remote projects. A mixed-method descriptive and evaluative approach was adopted, integrating quantitative survey analysis with qualitative analysis of testimonies and interviews. The sample consisted of 17 student participants and 8 mentors and project supervisors. For the students, the study assessed levels of satisfaction, development of technical and transversal competencies, and identification of perceived challenges and opportunities. In the case of mentors, performance reports were analyzed and complemented with brief interviews aimed at exploring their perspectives on the training process. The results revealed a high level of satisfaction among students and a substantial improvement in digital competencies, professional communication, and collaborative work capacity. However, challenges related to asynchronous interaction, autonomous time management, and technological limitations were identified. The analysis suggests that virtual internships represent a valuable space for experiential learning and the development of key competencies required for contemporary professional practice. Finally, the pedagogical implications of this model are discussed, and recommendations are offered to strengthen its implementation and sustainability in future distance-education programs.

Keywords: virtual internships, online education, professional competencies, experiential learning, engineering education.

1. Introducción

Higher education has undergone rapid transformation over the last decade, driven by digitalization and the need to offer flexible and accessible learning experiences [1]. In this context, virtual internships have emerged as a strategic solution to provide practical experiences that mitigate the physical limitations of in-person learning and allow students to bridge the gap between theoretical academic knowledge and the demands of the labor market [2]. These modalities not only facilitate the acquisition of technical skills but also foster the development of remote collaboration skills, which are essential in the contemporary digital age.

The Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) is a non-profit organization whose mission is to facilitate and promote global collaboration in the advancement and continuous improvement of education, practice, research, and innovation in engineering and technology, linking institutions in Latin America and the Caribbean with the rest of the world.

Since 2015, the institution has implemented a virtual internship program for engineering students and those in related fields at member universities. The internships are completed over a 16-week period, with a minimum workload of 15 h per week, totaling at least 240 h. The interns' projects are linked to initiatives in diverse areas, namely, digital and technological transformation, management and optimization of administrative processes, specialized support for conferences and events, and strategic communication and marketing.

It is important to clarify the institutional nature of these programs. Unlike internships managed internally by faculty, these internships take place within LACCEI, an international non-profit organization that operates as a consortium of more than 200 engineering institutions. In this framework, LACCEI acts as the host organization, operating similarly to international bodies such as the OAS and multilateral agencies. The interns are students from various member universities who must meet professional performance standards outside their local academic environment and face challenges in intercultural communication and transnational coordination. This distinction is key, as it places the experience within the framework of virtual professional mobility, where the student is not accountable to a professor but rather to an organization that demands technical products of institutional value.

The application process included completing a form and submitting a letter from their university or corresponding department authorizing their participation in the program. There were no language or year-of-study restrictions for applicants. After applying, candidates are interviewed by the LACCEI team and assigned to a project with a supervisor and/or mentor.

This model responds to the growing need for work-based learning schemes that can emulate current work routines through online mentoring and asynchronous collaboration environments

[3]. By eliminating geographical barriers, these programs offer equitable opportunities for future professionals to strengthen their professional identity and self-management skills.

LACCEI promotes projects and initiatives that lead to development, innovation, and education in engineering fields. The mission is to establish strategic alliances that allow member institutions to forge common actions in support of engineering education, both in terms of technical knowledge and transversal training.

This study aims to analyze the experience of students in the first edition of the virtual internship program, evaluating their level of satisfaction, the learning acquired, and the challenges faced during its implementation. The theoretical framework is based on Kolb's Experiential Learning Theory, which posits that knowledge is the result of transforming experience through reflective observation and active experimentation [4]. This approach is relevant in the virtual modality, where student autonomy and mentor feedback are the pillars of professional knowledge construction.

This study seeks to determine the extent to which virtual internships provide triangulated empirical evidence from a Latin American context and highlight how infrastructural, organizational, and mentoring factors mediate the development of professional competencies in virtual engineering environments. Specifically, how do students perceive competency development during virtual internships? What challenges and enabling factors shape the learning outcomes? How do the mentors' evaluations align with the students' perceptions?

2. Literature Review

The scientific literature on virtual internships in higher education identifies this field as an emerging research area that converges experiential education, work-integrated learning (WIL), and digital transformation [1]. This section summarizes the evidence on the design, impact, and challenges of this modality and highlights the need for robust conceptual frameworks to capture the complexity of technology-mediated practical learning. We found that most studies to date have focused on specific contexts (e.g., information science or information technology), which limits the generalizability of the results to fields such as engineering, business administration, and health sciences. This opens up opportunities for comparative research across disciplines and cross-validation analyses of virtual internship quality models.

2.1. Internships as Practical

Experiences Internships have traditionally been recognized as essential practical experiences for professional training in engineering and other disciplines [4], [5]. The virtual modality of these

experiences emerged as a response to the expansion of distance education and the need to maintain the continuity of practical training during geographical restrictions or extraordinary situations, such as the COVID-19 pandemic [6].

Internships, understood as work-integrated learning experiences, allow students to apply theoretical knowledge in real work contexts. Traditionally, these assessments were conducted in person with direct supervision in workplaces; however, the emergence of online modalities has modified this paradigm [2]. These experiences are supported by theoretical frameworks such as experiential learning, which emphasizes active reflection on direct experience to construct meaningful knowledge. This approach proposes that practical experience with feedback generates competencies that are transferable to the professional context.

During the COVID-19 pandemic, many in-person internships were transformed into virtual internships in response to mobility restrictions and health measures, which accelerated their adoption in academic programs [7]. This shift not only responded to temporary needs but also generated a boom in structured programs that promise continuity even after in-person activities return to normal [7].

Recent studies distinguish between different forms of online work experience: online internships, virtual internships, and e-internships, which are used almost interchangeably, although some studies highlight the need for precise definitions to evaluate quality and outcomes [2].

Internship quality frameworks, such as the Internship Scorecard developed by the Center on College-Workforce Transitions, allow for the evaluation of dimensions such as program structure, supervision, alignment with academic objectives, and technological support, which are critical for comparing in-person and virtual internships [2].

One of the most cited studies was conducted by [7], who investigated the satisfaction of Information Technology students who completed virtual internships during the summer of 2020 in Saudi Arabia. In a sample of 147 participants, the majority expressed overall satisfaction with the virtual experience, especially when the activities were directly related to real work tasks and aligned with industry requirements. The results indicated that this type of internship promotes not only technical skills but also socio-emotional competencies, such as autonomy, time management, and communication strategies [7]. Similar studies have found that students value opportunities to apply knowledge in real-world contexts, even when the interaction is digitally mediated, although they highlight significant differences between well-structured experiences and those with limited support [8].

Furthermore, preliminary research with large samples, such as that conducted by [9] with more than 11,000 virtual interns in the United States, has shown that approximately 86% of young people participated in programs with educational quality comparable to their in-person equivalents. However, gaps were observed in the representation and quality of opportunities for certain groups (e.g., rural students or those with greater work responsibilities), which implies equity challenges in access to and the design of virtual experiences [9].

In contrast to spontaneous or unstructured experiences, virtual programs supported by educational institutions and industry partners tend to generate greater satisfaction and perceived skill development, especially if they include clear goals and objectives. These include continuous feedback systems and projects relevant to students' professional fields [2].

Among the benefits of virtual internships are greater flexibility and accessibility, as they allow students from different regions to participate without the need for physical travel [10]. They also foster the development of digital skills: students acquire proficiency in collaborative tools and communication in virtual environments [11], [6], [7], and they are integrated into work settings that utilize project-based learning frameworks, which encourage the practical application of theoretical concepts in supervised projects. However, challenges have also been identified, including limited direct interpersonal interaction, the need for autonomous time management, and the maintenance of student motivation in virtual environments [12].

Comparative studies between in-person and virtual internships suggest that, although both modalities can promote technical and communication skills, there are differences in the intensity and quality of interpersonal interactions. For example, in-person experiences offer greater opportunities to build informal relationships and extensive professional networks, which can enhance networking skills—an aspect that virtual internships have more difficulty replicating [2]. Nevertheless, empirical findings indicate that students who complete structured virtual internships can demonstrate similar growth in specific technical skills and professional confidence, especially when accompanied by active supervision and systematized reflective activities [7], [8].

2.2. The Role of Mentors

The presence of mentors has been identified as an essential component in the development of professional skills in online internships. In a study of 158 e-interns, [13] researchers analyzed how virtual mentoring experiences influence skill development. They found that mentoring was positively correlated with the growth of strategic communication, collaboration, and problem-solving skills compared to interns who did not receive mentor support [13].

In addition, broader research on mentoring in higher education indicates that effective approaches to academic and professional support contribute to the development of professional identity, networking, and preparation for the world of work, which is consistent with the results of virtual internships [14].

2.3. The Challenges of Virtual Internships

These challenges are linked to the impact of technological barriers, inequalities in access to digital infrastructure, and the need for self-directed learning skills, all of which can affect the

quality of the experience and the participants' perceptions [2], [9]. Furthermore, certain student groups face greater obstacles in accessing quality opportunities in a virtual format, suggesting the need for institutional policies that balance accessibility with the quality of learning and support for historically marginalized subgroups [9].

It has also been observed that poor alignment between assigned projects, learning expectations, and academic goals can decrease the perceived effectiveness of virtual internships, highlighting the importance of instructional design focused on competencies and clear objectives [7]. Despite the growth of empirical studies, there are clear gaps in the literature that require attention. First, longitudinal research is needed to examine how virtual internships influence medium- and long-term professional outcomes, such as employment and career progression [2].

3. Methodology

3.1 Study Design

The study adopted a descriptive and evaluative design utilizing a mixed-methods approach, aimed at analyzing the virtual internship experience from the perspectives of the participating students and the mentors responsible for the projects. This mixed approach allowed for the integration of quantitative and qualitative data to gain a more comprehensive understanding of the phenomenon under study, combining the measurement of perceptions and satisfaction levels with an in-depth analysis of the experiences, assessments, and challenges associated with virtual learning.

Although some mentors were affiliated with academic institutions, the projects involved authentic professional tasks, the resolution of industry-relevant problems, formal supervision, and competency-based assessment, all aligned with work-integrated learning frameworks. Consequently, these experiences fulfill the pedagogical and functional characteristics commonly associated with virtual internships in engineering education.

3.2. Participants

3.2.1. Students: Seventeen students participated in the first edition of the virtual internship program in 2025. This constituted a purposive sample comprising the entire cohort of students who completed the program during the analyzed period. The participants hailed from various Latin American countries: Peru, Ecuador, the Dominican Republic, Colombia, Costa Rica, and Panama. This distribution allowed for the exploration of the virtual internship experience within a multicultural and transnational context, a characteristic feature of online learning environments. Regarding their academic background, the students represented diverse disciplinary fields, primarily linked to engineering and applied sciences, including Software Engineering, Industrial Engineering, Computer Science, International Business, and Industrial

and Business Administration. This disciplinary diversity provides a broad perspective on the applicability of virtual internships across various professional fields. Most of the students were in their advanced years or cycles (4th or 5th year). We had only one intern from the 2nd year and one from the 3rd year. Of the 17 interns, seven were male and ten were female. Table 1 presents the distribution of students by their country of origin.

Table 1. Distribution of students

Country	Number of Students	Year of study	Gender
Peru	10	4th year and 5th year	6 female and 4 male
Ecuador	2	4th year	2 female
Dominican Republic	2	4th year and 5th year	2 male
Colombia	1	5th year	1 male
Costa Rica	1	3rd year	1 female
Panama	1	2nd year	1 female

3.2.2. Mentors: 3.2.2. Mentors: Eight mentors participated—professionals with experience in supervising academic and/or professional projects and in virtual education environments. The mentors were responsible for guiding, monitoring, and evaluating the students' performance throughout the internship period. Their participation enabled the incorporation of an expert perspective on the formative process, student performance, and the feasibility of the virtual internship model.

The mentors were selected based on their availability to perform these tasks. Although the mentors are educators and researchers from diverse disciplinary fields, they all possess extensive experience working in the industry. The mentors are affiliated with various Latin American or U.S. universities or are professionals within specific fields who work with LACCEI in project-related areas.

3.2.3. Developed Projects: The projects undertaken by the students were drawn from their respective professional domains. To ensure methodological transparency, Table 2 details the relationship between the LACCEI program's intervention areas and the specific competencies that the interns were required to apply to complete their final deliverables.

Table 2. Developed Projects

Project Area	Expected Final Product	Main Competency to be Developed
Digital and Technological Transformation	System development from scratch (programming), database management, and specialized technical support.	Computational thinking, software development, complex problem-solving, and technical autonomy.
Management and optimization of administrative processes.	Design, validation, and evaluation of procedure manuals for various areas of the organization. Analysis of administrative workflows, file digitization, and internal process improvement.	Time management, systems thinking, organization, and operational efficiency.
Specialized Support for Conferences and Events	Design and implementation of event management systems: Virtual logistical coordination, speaker management, and support on international event platforms.	Asynchronous teamwork, professional communication, and international stakeholder management.
Strategic Communication and Marketing	Strategic Communication Plan: Creation of creative materials (videos, posters), social media management, and content writing.	Multimodal communication, digital creativity, proficiency in design software, and attention to detail.

3.3. Data Collection Instruments

Three main instruments were used for data collection.

- Structured Survey: A survey was administered to students upon completion of their virtual internships. This instrument assessed overall satisfaction with the experience, perceived learning outcomes, and development of both technical and transversal competencies. Responses were recorded using a five-point Likert scale, where 1 corresponded to "strongly disagree" and 5 to "strongly agree." The structured survey consisted of 20 items directed toward students. The instrument evaluated four main dimensions: Management and Administration (10 items), Personal Performance (10 items), and qualitative perceptions. To ensure content validity, the instrument underwent expert review (by the LACCEI academic committee) and was aligned with established internship quality frameworks.

- Semi-structured Interviews: Semi-structured interviews were conducted with students (while their internships were in progress) and mentors. The purpose of these interviews was to explore in depth their experiences regarding supervision, the challenges identified within the virtual modality, and their recommendations for program improvement. These interviews yielded rich, contextualized qualitative data that complemented the quantitative data obtained from the surveys.

- Documentary Analysis: Performance reports and project deliverables produced by the students during their internships were analyzed. This analysis provided objective evidence regarding the fulfillment of objectives, quality of work performed, and level of professional competency development achieved.

3.4. Procedure

Data collection was conducted during the internships (with students) and upon completion of the virtual internships (with mentors and students). First, the students voluntarily completed an online survey. Subsequently, virtual interviews were conducted with the mentors—following prior informed consent—ensuring the anonymity of the participants and confidentiality of the information provided. Documents and performance reports were collected exclusively for academic and research purposes only.

3.5. Data Analysis

The quantitative data obtained from the surveys were processed using descriptive statistics (means, standard deviations, and frequencies) to identify trends in satisfaction levels and self-perceptions of competence.

For the qualitative component, a reflexive thematic analysis was employed, following the phases of familiarization, generation of initial codes, and theme development. The process was conducted using inductive coding, wherein two researchers independently labeled excerpts from the interviews and open-ended survey responses to ensure analytical consistency (Researcher Triangulation). Coding discrepancies were resolved through consensus, resulting in final categories such as: "Self-management in asynchronous environments," "Effectiveness of virtual mentorship," and "Technological infrastructure gaps." This approach allowed the quantitative findings to be complemented by a deep understanding of the meanings participants ascribed to their experiences. The organization and coding of qualitative data were facilitated using Excel. To integrate the findings, a Joint Display visualization technique was utilized, enabling a comparison of the quantitative survey results against qualitative evidence from the interviews and reports, organized by competence dimensions.

4. Results

The research findings are presented below, organized using a methodological triangulation strategy that integrates quantitative data from the structured survey, qualitative narratives from the interviews, and empirical evidence from the document analysis. To provide an overview of the virtual internship experience, the results were not presented by instrument but were instead organized into cross-cutting themes. This structure allows for a comparison of students' self-perceptions and mentors' perspectives with the objective performance reflected in deliverables. The analysis was developed through three main dimensions: the development of professional competencies, the dynamics of supervision in virtual environments, and overall satisfaction with the challenges of the modality.

4.1. Student Satisfaction Level

The quantitative results showed an overall positive evaluation of the experience, with a General Satisfaction score of 4.6 (SD=0.5). As shown in Table 2, the best-rated dimension was the Application of Knowledge (M=4.5), which directly correlated with the documentary evidence from the projects. The progress reports confirmed that the students successfully translated theory into tangible products, such as the "implementation estimate," deployment in Docker, and restructuring of project architectures. However, it is noteworthy that the Organization and Coordination dimension received the lowest score (M=4.0; SD=0.8) and the greatest dispersion of responses. This quantitative finding is explained by analyzing students' logs, where recurring logistical barriers were reported. For example, participants documented difficulties in "locating and gathering detailed information" from previous systems and delays beyond their control, such as interruptions in basic services or delays in credential delivery, which impacted coordination fluidity. For its part, Interaction with Mentors (M=4.2) reflected a positive but moderate evaluation. While the students highlighted in their reports having received "verbal praise" and validation of proposals, they also noted challenges in asynchronous communication that, at times, created bottlenecks in decision-making.

Table 2. Student satisfaction level (scale 1–5)

Dimension	Average	Standard deviation
Overall satisfaction	4.6	0.5
Learning technical skills	4.4	0.6
Interaction with mentors	4.2	0.7
Application of knowledge	4.5	0.5
Organization and coordination	4.0	0.8

4.2. Development of Professional Competencies

The analysis of progress reports and deliverables allowed for the identification of significant achievements in technical, organizational and transversal competencies. As detailed in Table 4, the program's authenticity indicators demonstrated a high perceived value added and professional growth.

One of the most robust findings was the consolidation of the self-management skills. Reports provide evidence that students moved beyond merely following instructions to create their own organizational structures, explicitly documenting that they had "organized a 15-week work plan" to fulfill the required hours. This suggests that the asynchronous nature of the virtual modality acted as a catalyst for professional discipline and autonomous time management (Zimmerman, 2002).

In the technical realm, the documents validate the application of complex engineering skills. Deliverables ranged from "cost and feasibility analysis" to advanced implementations such as "reproducible deployment in Docker," web platform development, and API integration. These data, cross-referenced with mentor evaluations, confirm that the internship effectively bridged the gap between academic theory and industry practice.

Finally, a notable development in critical thinking was observed. An illustrative case demonstrates the transition from operational execution to strategic contribution: "At first, I thought I had to draft... from scratch, but later I understood that my primary task was to ensure continuity... verifying that it remained coherent." This ability to detect inconsistencies and propose improvements to manuals and diagrams demonstrates deep immersion in the organization's professional culture.

4.3 Perceived Challenges

Data triangulation revealed that although satisfaction levels were high, significant structural and contextual barriers existed. An analysis of performance reports revealed several challenges that nuanced the educational experience (see Table 4).

First, limitations regarding access to information hindered technical analysis. Unlike in a face-to-face setting, where data are typically centralized, students reported difficulties in "locating and gathering detailed information" from legacy systems, as well as "restricted access to comprehensive metrics" for social media projects. This constrained the initial analytical depth, necessitating the redefinition of the scope of certain deliverables.

Second, tension emerged regarding time management and technical competencies. The learning curve was impacted by specific knowledge gaps—such as a "lack of proficiency in tools like Power BI"—which necessitated additional hours of self-study. Compounding this issue was the overlap of academic schedules; specifically, the "start of university classes" was cited as a factor that "slowed the pace of progress" compared to the initial weeks of full-time dedication.

Finally, contextual factors and *force majeure* events emerged as critical variables inherent to virtual modalities. A documentary analysis recorded unplanned interruptions stemming from personal health issues and severe infrastructure failures—including power outages triggered by the "passage of a cyclone." These findings underscore that scheduling flexibility is not merely an advantage of the virtual modality but an indispensable requirement for mitigating external contingencies.

Table 4 presents a visualized and integrated overview of the data analyzed by dimension.

Table 4. Joint display matrix of findings by dimension

Analysis Dimension	Quantitative Finding (Survey)	Documentary and Qualitative Evidence (Log Analysis)	Integration (Meta-inference)
Development of Technical Skills	High rating (Average: 4.4). Students perceive a high level of technical learning.	Evidence of real-world application: Reports document complex milestones such as *"Reproducible deployment in Docker," "Web platform development," and "Cost and feasibility analysis."*[1]	The perceived learning is objectively validated by the delivery of advanced engineering products that go beyond basic theory.

Organization and Self-Management	Moderate rating (Average: 4.0). This is the lowest score and has the highest standard deviation (0.8).	Capacity vs. Obstacles: Although they managed to structure "15-week work plans,"[2] they reported scheduling conflicts due to the start of university classes and a lack of "knowledge in Power BI," which delayed progress.[3]	The lower score in organization does not reflect a lack of planning, but rather the difficulty of managing the simultaneous academic workload and initial technical gaps.
Contextual and External Factors	(Not explicitly measured on the Likert scale, but inferred from the overall satisfaction score of 4.6).	Environmental impact: Serious disruptions due to force majeure were documented, such as "power outages caused by a cyclone"[4] and personal health issues.	The high overall satisfaction (4.6) is noteworthy considering that it was maintained despite serious infrastructure and personal contextual disruptions.
Access to Information	Impact on efficiency (Reflected in the deviation of the "Application" dimension).	Barrera recurrente: Dificultad para *"localizar y recopilar información Recurring barrier: Difficulty in "locating and gathering detailed information" from previous systems or accessing "more comprehensive metrics" on social media.[5]"*	The lack of data centralization in the receiving organizations was the main technical obstacle, forcing students to redefine the scope of their analyses.

4.4. Dynamics of Supervision and Mentoring:

To gain a deeper understanding of the formative process, the mentors' testimonies were compared with the students' perceptions. This analysis made it possible to identify points of convergence (recurrences) regarding the achievements attained, as well as areas of divergence (discrepancies) concerning the challenges of virtual modality. Table 5 summarizes the main findings of the semi-structured interviews.

Table 5. Recurrences and discrepancies between mentors and students

Analysis Framework	Recurrences (Similarities)	Discrepancies (Differences)
Quality of Reports	Both groups agree that the final products (Platforms, Manuals, Docker, Simulators) met high technical standards and demonstrated institutional usefulness..	While the students view the product as a technical achievement, the mentors emphasize that the real value lay in the ability to "adapt to pre-existing processes." The mentors also observed that artificial intelligence became a recurring topic of discussion in meetings, as one of them put it, "They use AI as the only coding option, and when you ask them a question, they draw a blank."
Autonomy and Management	Both parties highlighted that the student showed initiative in resolving technical issues independently (e.g., learning Power BI on their own or a programming language).	Students: They felt their organization was good. Mentors: They reported that some students initially had difficulty understanding the institutional hierarchy in the virtual environment.
Virtual Communication	They agreed that synchronous meetings were effective for validating milestones (verbal congratulations reported by both parties).	Students: They felt that the lack of immediate information delayed their progress. Mentors: They perceived that the students sometimes expected overly detailed instructions instead of proposing solutions themselves. On the other hand, the meetings also served as an opportunity to learn certain study practices or problem-solving techniques.
Environmental Challenges	Both identify external factors (weather/connectivity) as the main barrier to strict adherence to the schedule.	Mentors perceive that the start of university classes impacts the quality of work more than the student is willing to admit in their reports.

5. Discussion

The discussion of the findings confirms that virtual internships at LACCEI act as an effective catalyst for experiential learning, although their success is mediated by critical infrastructure and instructional design. A comparison of the results with those of the existing literature reveals three fundamental areas of tension.

5.1. Convergence between Theory and Technical Practice

The results demonstrate a high capacity among students to integrate complex knowledge, as evidenced by milestones such as deployment in Docker and the development of software architectures. This finding validates the thesis of [4] on the learning cycle, where "active experimentation" in real-world environments consolidates technical knowledge. In line with [7], intern satisfaction is intrinsically linked to the relevance of the tasks; the fact that the students made tangible contributions to manuals, institutional platforms, software development, and other projects strengthened their professional identity, thus surpassing the view of the internship as a mere administrative requirement [9].

5.2. The Paradox of Flexibility: Between Autonomy and Precariousness

A significant tension arises regarding the "Organization and Coordination" dimension, which received the lowest rating (M=4.0). While authors such as [1] highlight flexibility as the greatest advantage of virtuality, our data reveal that this flexibility is vulnerable to uncontrollable external factors. Reports of delays due to a "cyclone" and power outages demonstrate that the effectiveness of virtual internships in developing countries depends on a digital infrastructure that Anglo-Saxon literature often takes for granted [7].

Similarly, the difficulty reported by students in "locating and gathering detailed information" contradicts the notion that digitalization facilitates information access. In this study, the decentralization of organizational data acted as a barrier that [2] identified as a risk of remote work environments that are under development or poorly structured, where the lack of a centralized repository affects the initial learning curve.

These findings can be interpreted from the perspective of the self-regulated learning theory. According to [17], self-regulated learners actively plan, monitor, and evaluate their learning processes, specifically in contexts that demand high levels of autonomy. In this study, students who reported greater difficulties with time management and task organization were often those facing simultaneous academic demands, suggesting that virtual internships impose greater cognitive and organizational demands on students' self-regulation abilities. Rather than constituting a limitation of the virtual modality itself, these challenges highlight the importance of explicitly supporting self-regulated learning strategies in the design of virtual internships in the future.

The challenges related to asynchronous interaction and coordination align with the research on distributed work and virtual teams. The literature on distributed work emphasizes that temporal and spatial dispersion requires explicit communication protocols, shared documentation and clearly defined responsibilities. From this perspective, the difficulties reported by the participants reflect real professional conditions rather than deficiencies in the learning experience, which positions virtual internships as realistic preparation for contemporary distributed work environments.

5.3. The Role of the Mentor and Professional Proactivity

The observed discrepancy between the students (who feel satisfied) and the mentors' (who perceive a lack of initiative) perspectives is consistent with the findings of [13]. Although virtual mentoring was positively evaluated, the reported communication "bottleneck" suggests that technological mediation may inhibit proactivity. This reinforces the need to shift from supervision based on milestone validation to strategic mentoring that fosters networking and problem-solving in a more dynamic way, mitigating the isolation that [12] warns against in these models.

The role of mentors in this study goes beyond technical supervision and can be interpreted within the framework of communities of practice (CoPs) [16, 20]. From this perspective, virtual practices function as spaces for legitimate peripheral participation, where students progressively engage in authentic professional practices through guided interactions with more experienced members. Mentor feedback, task delegation, and outcome evaluation facilitated students' progress toward fuller participation, supporting the development of their professional identity, even in the absence of physical co-presence.

Finally, the emergence of unexpected technical gaps (e.g., Power BI) and the conflict with the start of university classes suggest that institutions should design pre-internship leveling periods and protected schedules to avoid such conflicts. As the OECD [15] indicates, virtual internships should not be seen as a secondary activity, but as a workload that requires the same time and resource guarantees as in-person internships.

Taken together, the quantitative and qualitative findings suggest that competence development in virtual internships cannot be explained by a single factor or by virtual modality alone. Rather, the results point to a set of interacting dimensions that shape students' experiences and learning outcomes. To synthesize these relationships and offer an integrative interpretation of the findings, an emergent conceptual model was proposed. The model illustrates how project design, mentoring quality, access to information, infrastructure conditions, and student self-regulation interact in a virtual and distributed work environment to determine the learning outcomes.

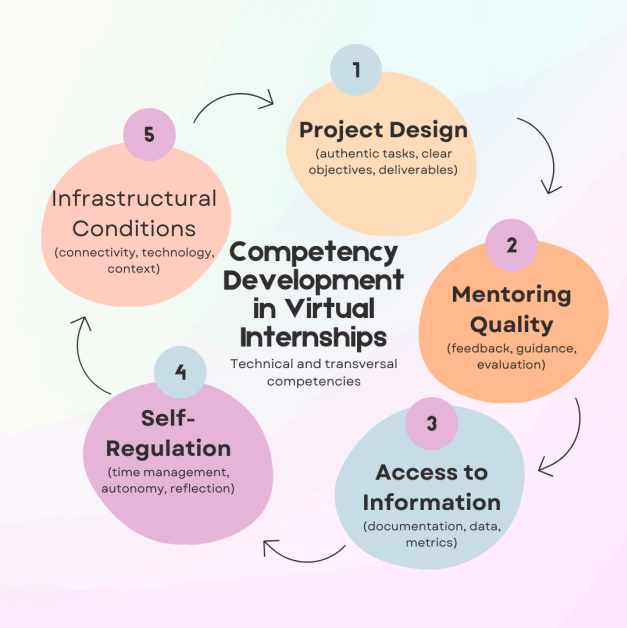

Figura 1. Modelo conceptual emergente de desarrollo de competencias en prácticas virtuales. The model is derived from an integrated analysis of quantitative and qualitative data.

As illustrated in Figure 1, competence development arises from dynamic interactions among pedagogical, social, contextual, and individual dimensions. Well-designed projects and continuous mentoring can mitigate challenges related to asynchronous communication and limited access to information, whereas student self-regulation plays a crucial mediating role in navigating distributed work environments. The model emphasizes that infrastructure conditions operate as a contextual layer influencing all other dimensions, particularly in regions where connectivity and technological stability vary. This integrative perspective helps explain the variability observed in participants' experiences and highlights key areas for improving the design of virtual practices.

6. Conclusions and Recommendations

This study aimed to analyze the experience of a virtual internship program from a mixed-methods perspective, considering both students' perceptions, mentors' evaluations, and the documentary evidence generated during the development of the projects. The results allow us to draw relevant conclusions about the formative potential of virtual internships and the challenges that persist in their implementation.

First, the findings show that virtual internships can constitute valid environments for experiential learning, capable of fostering the development of technical and transversal competencies in engineering students and related fields. The triangulation of data shows consistency between the

positive perception of the students, the performance reports of the mentors, and the deliverables produced, suggesting that learning is not limited to a subjective assessment but is materialized in verifiable products and processes.

Second, this study highlights the central role of mentoring and program structure. The presence of regular supervision, timely feedback, and clearly defined objectives emerged as key factors for the progress of the projects and for strengthening competencies such as professional communication, work planning, and problem-solving in remote contexts. These results reinforce the idea that the quality of the virtual experience depends less on the format itself and more on the pedagogical design that supports it.

Likewise, the results show that the virtual modality introduces specific challenges, particularly related to autonomous time management, asynchronous interaction and technological limitations. These challenges do not invalidate the model but underscore the need for institutional strategies that include flexibility, support, and clear criteria for evaluating performance in digital environments.

A relevant contribution of this study is the highlighting of contextual factors specific to Latin American environments that influence the development of virtual internships, such as irregular connectivity, socioeconomic conditions, and the coexistence of multiple academic demands. These elements provide situated evidence that complements the international literature, which is mostly focused on contexts with greater technological stability. Finally, while the sample size limits the generalizability of the results, the study provides consistent empirical evidence that contributes to understanding the phenomenon of virtual internships as a viable and complementary training alternative to in-person training. Future research could expand on this work through longitudinal studies, larger samples, and systematic comparisons between modalities to delve deeper into the medium- and long-term impact of these experiences on students' career paths.

7. Implications for Engineering Education Practice

The findings of this study have several implications for designing and implementing virtual internships in engineering education. First, the results underscore the importance of intentional design. Virtual internships should be structured around authentic engineering tasks with clearly defined objectives, milestones, and deliverables, allowing students to apply their disciplinary knowledge in meaningful ways and demonstrate competence development through tangible results.

Second, the central role of mentorship highlights the need to prepare mentors not only as technical supervisors but also as facilitators of learning in distributed environments.

Regular feedback, explicit expectations, and guided reflection emerged as fundamental elements in supporting students' professional growth and integration into engineering practices, even in the absence of face-to-face interaction.

Third, the findings suggest that virtual internships require greater self-regulation skills from students. Engineering programs can benefit from incorporating explicit support for time management, goal-setting, and reflective practices, particularly for students with little prior experience in remote or project-based work environments.

Furthermore, access to information and infrastructure conditions significantly influenced learning experiences. Institutions implementing virtual internships should consider strategies to mitigate inequalities related to connectivity and access to resources, particularly in regions with heterogeneous technological infrastructures. Flexible deadlines, asynchronous communication strategies, and shared documentation systems can help address these challenges while maintaining academic rigor in the course.

Finally, virtual internships should be recognized as a complementary modality in engineering education rather than a replacement for in-person experiences. When carefully designed, they can broaden access to professional practice opportunities, support international and interdisciplinary collaboration, and prepare students for the distributed and digital nature of contemporary engineering work that is increasingly prevalent.

8. Limitations and Future Research

This study has several limitations that should be considered when interpreting the results. The relatively small sample size and focus on a single program limit the generalizability of the findings. Furthermore, the study relied primarily on self-reported data and short-term performance indicators that do not reflect long-term career outcomes.

Future research should explore virtual internships using longitudinal designs to examine their impact on graduates' career trajectories, professional identity development, and employability. Comparative studies between virtual, hybrid, and in-person internships across different engineering disciplines would provide a better understanding of the conditions under which each modality is effective.

It is also necessary to investigate the role of contextual factors such as infrastructure and institutional support, particularly in underrepresented or resource-limited regions. Expanding empirical research across diverse global contexts will contribute to the creation of more inclusive and robust models of work-integrated learning in engineering education.

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