ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #37392

Work in Progress: Collaborative Environments in Architecture and Civil Engineering Education – Case Study

Johanna Acosta

Jacoba Ubidia

Jacoba Ubidia is a research assistant at Universidad San Francisco de Quito in the Civil Engineering department. She holds a B.A. on Architectural Studies & Environmental Science from the University of Toronto and a B.Sc. in Civil Engineering from Universidad San Francisco de Quito.

Miguel Andrés Guerra (Professor of Civil Engineering and Architecture)

Miguel Andrés is an Assistant Professor in the departments of Civil Engineering and Architecture at Universidad San Francisco de Quito USFQ, in Ecuador. Miguel Andrés is a civil engineer from USFQ (2009), was awarded a MSc in Civil Engineering – Construction Engineering and Management at Iowa State University (Fulbright scholar, 2012)and his PhD in Civil Engineering at Virginia Tech (2019), as well as two Graduate Certificate in Engineering Education and Future Professoriate. (i) ENGINEERING EXPERIENCE: Miguel Andrés was Project Manager of PREINGESA where he has directed construction projects in the development of urban infrastructure for urbanizations such as earthworks, drinking water works, sewerage, underground electrical cables and fiber optics, roads, aqueducts, water reservoirs, housing construction, among others. He was also a Project Management Associate for a Habitat For Humanity housing project in the USA. (ii) RESEARCH: Miguel Andrés' research focuses on (1) decision-making for the design and construction of infrastructure projects, (2) the planning of sustainable, smart and resilient cities, and (3) the development of engineers who not only have solid technical and practical knowledge, but also social understanding for, through infrastructure, address local and global challenges on humanitarian, environmental, social and equity issues. (iii) EDUCATION RESEARCH: Related to STEM education, Miguel Andrés is developing and applying contemporary pedagogies and tools for innovation and student empowerment to address climate change. Currently, Miguel Andrés is developing teaching and evaluation pedagogy that directs a philosophy of seeking excellence as a pillar to eradicate corruption.

Vanessa Guerra (Assistant Professor)

Cristina Gallardo

Work in Progress: Collaborative Learning in Architecture and Civil Engineering Education – Case Study

Johanna Acosta[1], Jacoba Ubidia[1], MiguelAndrés Guerra[2*], Vanessa Guerra[3], Cristina Gallardo[1]

1 Undergraduate student, Universidad San Francisco de Quito USFQ, Colegio de Ciencias e Ingenierías, Departamento de Ingeniería Civil, Casilla Postal 17-1200-841, Quito 170901, Ecuador.
2 Assistant Professor, Universidad San Francisco de Quito USFQ, Colegio de Ciencias e Ingenierías, Departamento de Ingeniería Civil, Casilla Postal 17-1200-841, Quito 170901, Ecuador.
3 Assistant Professor, University of Virginia, School of Architecture, Department of Urban and Environmental Planning, Charlottesville, VA, 22904, USA.

* Correspondence: MiguelAndrés Guerra, MAGuerra@usfq.edu.ec.

Abstract

Developing infrastructure involves complex processes that require the effective integration of interdisciplinary professionals. Consequently, coordination is essential for the development of construction projects at any scale. Probably, the most important cohesion that needs to happen within said projects is between architects and civil engineers, but often they seem to be at opposite ends of the spectrum. Friction between these professionals often translates to delays, higher costs, and lower quality in the end-product. This preliminary exploratory study aims to understand civil engineering and architecture students' perspectives on collaboration through the creation of hands-on groups tasks that host students from both architecture and civil engineering. This pilot study combined three modules of second-year courses from both majors (n=78 students) that required students to work in teams for four weeks. After the courses were finished, the authors administered a survey with open - and closed-ended questions to gather qualitative data on self-reported perspectives on collaboration. The results of the pilot study suggest that students working together from early stages have the opportunity to develop soft skills, expand their networks, and, most importantly, appreciate their counterpart's perspectives. Finally, the authors reflect on future research paths in collaborative learning as well as in soft skills training and development for majors from the construction industry.

Introduction

Globalization of the construction industry has elucidated the lack of cooperation required from architects and civil engineers to work together in projects at a national and international level worldwide [1]–[4]. This often translates to delays and economic losses in building projects. As a result, academic efforts are needed to move away from traditional methods of teaching that place a large distance between both majors, limiting spaces for cooperation and understanding from the start. In general, there is a gap between academic requirements and industry expectations of collaboration [1], [5]–[8]. Thus, having professionals who understand the contributions of their counterparts is key to improving the construction process [9]. In fact, working together and contrasting their intrinsic professional perspectives early in the academic path may push boundaries of efficiency and creativity while developing the necessary soft skills to reduce friction in the future [10].

This research focuses on the execution of an early academic pedagogical intervention which aimed to understand civil engineering and architecture students' perspectives on collaboration. The academic pedagogical intervention consisted of bringing together architecture and engineering students into groups that would develop hands-on activities on topics they had seen in their respective Statics and Structures 1 courses. In the end, the study gathered self-reported qualitative data from students to explore the value placed on working with their counterparts. The mechanism behind this pedagogical intervention was to foster a space of collaboration resembling a professional environment where both majors had crucial roles to effectively complete their tasks. After the pedagogical intervention, students placed high value on certain benefits of collaboration and a newfound appreciation for their counterparts. Additionally, students expressed that the implementation of soft skills or lack thereof could predict their team's successful performance.

Background

Academic interventions for collaborative learning at the undergraduate level in construction-related majors

Efforts to create spaces of collaboration between majors involved in the construction industry are starting to move from traditional lecture-based pedagogy to more interdisciplinary, hands-on and student-centered approaches. In fact, recent research has focused on the implementation of interdisciplinary project-based learning modules to promote collaboration between construction-related majors [1]–[3], [19]. Interventions range from making use of technology to create Building Information Models (BIM), where students can directly appreciate the benefits of collaboration in a design of the built environment or infrastructure project [22], [23], to designing activities that require complex problem solving where tools such as communication and teamwork are essential [24]. According to several authors, the implementation of this type of pedagogical approach has the potential to increase reflective thought, creativity, communication, and effective groupwork [1]–[3], [25], [26].

To develop educational modules that encompass both majors, several factors must be considered such as the application domain, development tools, educational systems, teaching devices and pedagogies, and learning strategies [32]. Pedagogical modules that welcome civil engineering and architecture students can take advantage of the bottom-up pedagogical effort made in universities [32]. Since construction majors are inextricably connected to real-world practice [33]–[35], pedagogical modules may implement problem-based [17], [28], project-based [22], experiential learning [16], [27], role playing [36], and other techniques for students to face interdisciplinary challenges [37]. Undoubtedly, providing society with civil engineers and architects who can understand each other's way of acting and thinking will help advance the construction area. If there is an early understanding between both professions, performance improvement can even be expected [14], [38].

Soft skills in the construction industry

The current construction industry requires engineers and architects to communicate effectively, work within interdisciplinary teams, and adapt to a changing field. However, these qualities are not intentionally developed in academic settings, widening the gap between recent graduates' employability and industry expectations. This paper uses Mahasneh and Thabot's (2015) definition of soft skills which refer to the set of essential non-technical skills that may include, but are not limited to, management and communication skills, collaboration skills, conflict resolution, workplace professionalism, social intelligence, planning, and organization.

Research suggests that universities and students place a higher value on developing technical skills rather than catering to what the job market also needs in terms of soft skills [5], [29], [39]. Several surveys on companies' satisfaction reveal that while graduates successfully deploy their hard skills, they fall short in effective communication, management, and teamwork [5], [6]. Consequently, several attempts to promote soft skills in different stages of professional development have been put into place [4], [25], [33], [39]. However, there is often a lack of rigor in defining what soft skills are, how to quantify them, and how to decide which ones are particularly required for the construction industry [4].

This study found that encouraging collaborative spaces, such as the proposed pedagogical intervention, may foster the development of certain soft skills such as communication, teamwork, empathy, and problem solving. Communication refers to oral, written, presenting, and listening abilities. Furthermore, teamwork relates to cooperation, getting along with others, supportiveness, and helpfulness. At the same time, empathy is a crucial component of interpersonal skills that allows an individual to understand different perspectives. Finally, problem solving is the ability to find and effectively apply solutions to issues that may arise.

The following sections present the methodological approach for designing the interdisciplinary educational module and how the researchers assessed the experience of students from both majors. Then, the results are presented and contrasted with the existing knowledge. The authors reflect on future research paths in collaborative learning as well as in soft skills training and development for majors from the construction industry. Implications for research and practice are provided.

Methodology

The first part of this exploratory study, which is reported in this article, uses a qualitative method approach to measure the performance cognition among civil engineering and architecture students when working together. The data was collected during the Fall 2021 semester with students from the engineering course Statics (n=38 students) and two sections of the architecture course Structures-1 (n=20, n=20 students) for a total sample size of n= 78 students. The instructor remained the same for all courses in this study. Students were divided into groups of 3 members with at least 1 member from the other major and worked together for the weekly assignments for four weeks. Before the final assignment, a hands-on workshop, students were divided again into new groups. Then, researchers administered a survey to the students participating in the experimental process (n=78 students). The survey, developed by the researchers, contained both closed- and open-ended questions. In the survey students self-reported their experiences when working in multidisciplinary groups, identifying the benefits they obtained and the challenges that arose while solving the different tasks that were proposed during the process.

Data Analysis

The authors conducted a content analysis of the students' responses about the experience. The goal was to find main ideas and to be able to form groups of ideas that many of the answers encompassed to analyze all the feedback received by the students, identifying the positive experiences, the skills gained during the development of the activities, and the challenges that the students encountered when working with unified courses of the two careers. Students also provided suggestions on possible improvements for the combined educational module.

The learning module characteristics

The students worked in multidisciplinary groups for four weeks, during which they learned definitions and identified centroids, moments of inertia, and internal forces in trusses. Typically, students met for two 1 hour and 20-minute sessions per week. The class schedule of the second session of the week was modified and moved to Fridays at 4:00 pm so students from all three courses had class together. After the Friday class, students had an assignment to work on in teams due Friday night. The teams were made up of three students, and each team had to have at least one student from the other major. The first week's topic was Centroid, and the practical team assignment was related to rotational equilibrium. The second week's topic was Moment of Inertia, and the practical team assignment was to apply the concepts to the practical team assignment was finding the moment of inertia of the structural floor plan, considering the disposition of the columns. The third- and fourth weeks' topic was to determine the internal forces of trusses by the nodes (concurrent forces equilibrium) and sections method (non-concurrent forces equilibrium), and the practical team assignment was to determine the internal forces on a truss from a known bridge near the university and from the roof of a famous structure.

Students worked in the same teams during the three practical assignments for four weeks. For the final activity, we rearranged the teams again, so students were in teams with different members from the ones they worked with before. The final activity was a practical assessment, where students were given instruction for three tasks. For the first one, students were assigned one of the topics studied in the previous four weeks and asked to craft slides for a 20-minute presentation about that topic. For the second topic, students were instructed to determine where the centroid of the columns of a building is and to determine the moment of inertia in both directions of such building. Students had to analyze the building to determine where the columns were and manually take measurements of the dimensions of the column and the distances. The third task consisted of determining the real internal forces of a small truss of the roof of the sports building at the university. For this, students had to determine the real weight of material, take measurements, and make assumptions to solve the task.

Results

Civil engineering and architecture students' answers about the experience of working with partners from the other major were collected. There were two main categories that were found to encompass students' perspectives on collaboration, namely: benefits reported by students from working with other construction majors and challenges reported by students from working with other construction majors.

Benefits reported by students from working with other construction majors

The benefits included (a) working with different perspectives, (b) development and application of soft skills, and (c) an early exposure to professional collaboration. The subcategories for benefit (a) were different approaches to problem solving, adopting new approaches for the same result, efficiency in results, and security and satisfaction. The subcategories for benefit (b) were communication, teamwork, and empathy. Finally, the subcategories for benefit (c) were networking, proximity to work life, and complementary careers. The following table shows a summary of the themes that emerged from students' answers.

Table 1 Themes that emerged from students' answers about benefits

Benefits reported by students from working with other construction majors	
a. Working with different perspectives	Different approaches to problem solving
	Adopting new approaches to achieve the same results
	Efficient results
	Security and satisfaction
b. Soft skills	Communication
	Teamwork
	Empathy
c. Early exposure to professional collaboration	Networking
	Proximity to work life
	Complementary careers

a. Working with different perspectives

The first benefit obtained from the student responses is that students had to deal with different teammates with different approaches to problem solving. Each member contributed feasible solutions from their perspective as, for example, was explained in the following quote: "...learn their way of interpreting problems or how they arrive at an answer in a different way [student A-3]," or as another student stated, "I feel that having different points of view is interesting, to see how each person understands things in a different way, but despite this, you can reach the same conclusion or result [student A-16]." These quotes show that they are struck by the fact that there are different methods, and they can learn to decide on which method to use and complement each other for more options for solving problems of this nature.

Another benefit derived from working with different perspectives was efficient results since students could learn different ways of reaching the same result and, therefore, choose how to solve the problem efficiently or, in other words, achieve a correct result in less time. This explanation is supported by the following student quotes: "There are several solutions or ways to solve an exercise, which allow me to save time [student A-17];" "Looking for the most efficient and effective way to solve that problem [student E-6];" and "Another view to physical problems helped to solve everything in a more efficient way [student E-20]." There may be cases where the methods can be mixed, and, in this manner, the most efficient method is not chosen but rather created.

Finally, some students were pleased to work in a group because they felt supported by a team that, by different methods than their own, could reaffirm that the proposed answer was correct. Students who were struck by this benefit of working with different perspectives expressed it as follows: "Group work always brings confidence in the subject when we were all sure that something is right then we feel satisfied with the work [student A-9]." On the other hand, when a classmate knew more about the subject and explained it to another classmate, some students saw it as an incentive to stand out and learn more about the subject. This was expressed as follows: "The activity being something real motivated me to stand out more, seeing my classmates who could contribute more made me also want to go further, a healthy competition, learning real things and not only from books is something that really fascinated me [student A-8]." In this way each one made the other go out of the comfort zone and dare to do more.

b. Soft skills

The second benefit students gain by working in multidisciplinary teams is enhancing soft skills. Students who are part of this process develop skills in communication, teamwork, problem solving and empathy. Such soft skills help students to analyze problems from different perspectives and at the same time look for efficient and functional solutions. The first soft skill students reported using during this activity was communication. At the time of presenting each of their varied perspectives, they had to reach a communication agreement to listen and be heard. The good thing about this exercise was that they allowed themselves to listen to another person and not be left thinking that their method of resolution was the only one that would work. These ideas were related by students. For example, "It forced us to agree, to give the floor to another person to express the reason for their opinion, and it also forced us to really understand the subject matter so that we could all agree [student E-11]."

The second soft skill students reported using during this activity was teamwork. Some of the responses included: "I liked the teamwork, besides the positive thing is that everyone sees their strengths to give one hundred percent in the work and help where needed [student A-5]" and "We were all looking for the same goal and united ideas to do it well [student E-8]." What the answers meant was that everyone contributed in different ways and in different percentages, but all with the objective of having a quality and complete result. They were able to learn to take advantage of each of the skills of each member so that the final result would be of good quality. Also, if any member of the team did not understand something, they had the support of their team to fill these gaps and not be left behind. This is how they learned to work as a team with students from the other major.

The third soft skill students reported using during this activity was empathy. Students may think that what they learn in their major is an irrefutable law, but by empathizing with the other major, they recognize their different strengths. Being able to admit and highlight the positive points of the other major showed that the students knew how to empathize with colleagues. Some of their comments about those of the other major included: "They (the architects) try to make the graphics in a very nice way, while I (engineer) made the calculations a little disorganized so with that it helped me to be a little more organized [student E-12];" "Architecture students are very detailed in every sense [student E-18];" and "Engineers are much more logical, much more direct [student A-17]."

c. Early exposure to professional collaboration

The third benefit obtained from the student responses was early exposure to professional collaboration. Students were able to start developing their professional network from early stages of their academic training. It is very common that the first time both careers relate with one another is in the labor field, but with this small approach, students will already graduate knowing people from the construction environment who in the future may be work colleagues. This thought was expressed by several students with the following words: "It helps to expand our knowledge in the field of construction and finally helps us to create job contacts that can help us in the future [student E-2];" "Relating to people from another career that in the future may be our co-workers and making friends [student A-9];" and "I met people from another career who in the future may be my co-workers [student A-10]."

Proximity to work life is the second benefit of having been exposed to early professional collaboration. "I liked interacting with people from another career because in the world of work we will have a similar experience and it is good to know how to handle such a situation [student E-16]." This student expressed that he gained knowledge of how to relate to the people who will be his colleagues in the future, this being an exercise that is closer to the professional reality in which work is carried out after graduation. The same sentiment was expressed by other students. For example, "The interaction with people that we will meet in the future and in the same field of work [student A-4]."

Complementary careers are the third benefit of having been exposed to early professional collaboration. It is well known that both careers, architecture and civil engineering, are different but complementary and workers usually realize this when they start working together. In this case, the students themselves realized this by combining their knowledge to obtain a quality result. The students expressed the following: "Since we share knowledge of our careers and we complement each other [student A-20]" and "What one did not know, the other knew [student A-12]." This interaction allowed students to realize that architecture and civil engineering can complement each other and, when working together, the team can propose more comprehensive solutions.

Challenges reported by students from working with other construction majors

As for the challenges, they included different approaches to problem solving and different communication styles. The challenge of different approaches was divided into two subcategories: a different points of view for solving problems, and the lack of tools due to different curricula. As for the different styles of communication, this was also divided into two subcategories: the difference in technical language, and the lack of time for agreement.

Table 2 Themes that emerged from students' answers about challenges

Challenges reported by students from working with other construction majors	
d. Different approaches to problem solving	Different points of view for solving problems
	Lack of tools due to different curricula
e. Different communication styles	Different technical language
	Lack of time for agreement

d. Different approaches to problem solving

The first challenge of having different approaches to problem solving was different points of view for solving problems. Previously, this was stated as a benefit, but at the beginning it proved to be a challenge. This is because by not having the same teaching methodology, it was difficult for both parties to learn in a different way what had already been learned in a certain way. This was expressed in comments such as the following: "The main barrier was that having different perspectives on how to solve a problem often made it difficult to reach an agreement [student E-1];" "Because they (the engineers) when directed to a more mathematical subject and we architects, based on understanding and functionality in some parts, had a hard time understanding each other clearly [student A-7];" and "Discrepancy of opinions but it always brought with it dialogue and learning [student E-3]." At first this was an uncomfortable challenge that students had to face, but over time they came to take it as a benefit as well.

The second challenge of having different approaches to problem solving was the lack of tools due to different curricula. The students reported that there were challenges in mastering the topics covered. This was due to the methodology they had used for their learning. In addition, being from different majors, they had different bases which opened certain gaps in the other major's fundamentals. This can be explained as a lack of deepening in the fundamentals behind the exercises that they solved. This phenomenon was expressed with the following quotes: "Architecture students sometimes did not have all the tools to solve a problem. For example, trigonometry, finding angles, relating concepts were more difficult than I would have expected [student E-13]," and "It's a disadvantage that the engineers don't stop to see how the results look in real projects [student A-12]."

e. Different communication styles

Now, the first challenge of having different communication styles was the different technical language. Again, this challenge was due to the different teaching methods used in both majors. For example, certain students stated that they had problems communicating with each other since having different lexicon about the exercises made it difficult for them to fully understand each other. For example, "Many times, engineers speak with more technical language, so they had to ask for explanations from the final [student A-19]".

To finish, the second challenge of having different communication styles was the lack of time for agreement. As expressed several times before, the students of each career speak with different language, and at the beginning it was quite a challenge to understand each other, but when they wanted to explain and share their knowledge, time was invested in it. The problem here was that while everyone checked the results obtained by different methods, taught each other the gaps that could exist, explained what was not clear, or reached an agreement, a lot of valuable time was lost that could have been used to solve problems. This was expressed as follows: "Work in groups takes much longer than usual because everyone's doubts have to be resolved and we all have to agree with the answers [student A-6]" and "Each one tried a different method, in the end for that reason we could lose time [student E-5]." In the end they realized that investing time helped them reach the benefits that they pointed out, but at the beginning it was an inconvenience.

Discussion

The positive contribution that this type of collaborative pedagogy had on students is noteworthy. The early connection between careers helped the participants to have a broader vision in terms of problem solving [18]. Sharing activities with students who were not classmates in most cases was an enriching experience that strengthened their working skills and expanded their knowledge, encouraging them to analyze different approaches to solve professional challenges [31]. Students reported this educational module as positive and stated that it helped them to analyze the strengths and weaknesses of their major and to appreciate the potential of complementing their knowledge with other majors [3], [27]. During the teams' interactions, students tested their ability to respond to different situations and adapt to an unfamiliar environment in order to find the most efficient solution to the task.

As presented in the results section, having different resolution methods was both a benefit and a challenge. At the beginning it was a challenge for both parties to work together because they were used to working with people from their same background. This difference in background relates to the knowledge each major has [3]. For instance, while second year engineering students may be more mathematically versed, architecture students may have a more developed spatial intelligence. As a result, engineers may want to work at a faster pace when solving problems on paper, while architecture students may take longer. At the same time, architecture students on field tasks may be able to work faster than engineers. However, working together over time, the teams seemed to reach a consensual pace. Once both parties allowed themselves to learn from each other, having different backgrounds became a benefit since in addition to learning new ways of problem resolution, their soft skills were developed [2].

Similarly, communication was difficult at the start. Despite using construction language on an everyday basis, both majors struggled to talk and listen to each other [2], [7]. In fact, many students reported "confusion" when trying to understand their counterparts. However, constant interaction allowed them to be able to explain to each other what was expected of them to complete each task [2].

In both examples presented above, the pattern of having conflict at the beginning was shown, and after talking, analyzing, and sharing knowledge, the tasks were completed and benefits were visible. The problem was that the time invested to turn the challenge into a benefit was extensive. On certain occasions the necessary days to fulfill the assigned activities were lengthened by the fact of having to reach a consensus among all [4], [39]. This was a challenge that had to be overcome, but it is important to mention that in general, it is a momentary challenge since the gains are lasting and enrich the person.

Additionally, we identified students practicing soft skills throughout the process. There is a need to close the gap between these complementary careers that are academically distant. As a result, the implementation of soft skills proved to be an effective tool for conflict resolution throughout all imposed tasks. Soft skills are highly valued in the industry [7], [39], and by creating spaces that encourage their development, undergraduate students may be more employable. In this case, the most outstanding soft skills were communication, teamwork, and empathy, which helped students to have a much broader vision regarding the different topics covered and to successfully collaborate with their counterparts.

As stated above, both careers are different but complementary. For this reason, those soft skills are highly relevant when working together. Often, workers will collaborate in a team, so knowing how to do this is a great plus in order to reduce conflicts and achieve quality results. In the same way, communication is key because this is the way that architects make their perspective known to civil engineers and vice versa. Finally, empathy is the key to maintaining an environment where problems are solved without the need for conflict. Acquiring these skills is a plus for the participants since, although these skills have not been treated in depth in the academic field, they add significantly to the work life of the students [39]. As professionals, soft skills are necessary personal traits to excel in the professional world [40].

Conclusions

With a globalized construction industry, architects and civil engineers are required to interact with professionals from different backgrounds and especially with each other. Starting such interdisciplinary interaction from early stages of the academic path may contribute to the training of future professionals' broad vision and capability of working with different points of view. However, academic curricula often limit the possibilities for interaction between students from these two majors. This in turn creates friction in the workplace. This study suggests that increasing the interaction between civil engineering and architecture students supports not only their development of technical skills but also that of soft skills. Soft skills such as problem solving, teamwork, communication, and empathy have proven to be necessary from employers' perspectives and are important tools for the success of collaboration.

This project conducts an exploratory study to start understanding the cognition process of students in civil engineering and architecture when putting to work together. This study does not intend to generalize propositions but rather to start the discussion about collaborative learning happens in the construction-related majors such as civil engineering and architecture. Future work includes collecting a larger sample of students and understanding the cognitive traits of working in interdisciplinary teams from early stages, the characteristics to design an educational module with both majors, and how to carry it out in different levels of the majors. Furthermore, future studies include to perform more quantitative analysis to further understand the collaboration between both majors. Additionally, the researchers will investigate the connection of this kind of educational intervention with the development of soft skills to advance students education for the professional challenges.

References

[1] C. T.W. Chan y W. Sher, "Exploring AEC education through collaborative learning", *Eng. Constr. Archit. Manag.*, vol. 21, no. 5, pp. 532-550, ene. 2014, doi: 10.1108/ECAM-04-2013-0036.

[2] A. K. Ali, "A case study in developing an interdisciplinary learning experiment between architecture, building construction, and construction engineering and management education", *Eng. Constr. Archit. Manag.*, vol. 26, no. 9, pp. 2040-2059, sep. 2019, doi: 10.1108/ECAM-07-2018-0306.

[3] J. Keenahan y D. McCrum, "Developing interdisciplinary understanding and dialogue between Engineering and Architectural students: design and evaluation of a problem-based learning module", *Eur. J. Eng. Educ.*, vol. 46, no. 4, pp. 575-603, jul. 2021, doi: 10.1080/03043797.2020.1826909.

[4] J. Mahasneh y W. Thabet, "*Rethinking construction curriculum: A descriptive cause analysis for the soft skills gap among construction graduates"*. 2015.

[5] M. Itani y I. Srour, "Engineering Students' Perceptions of Soft Skills, Industry Expectations, and Career Aspirations", *J. Prof. Issues Eng. Educ. Pract.*, vol. 142, no. 1, p. 04015005, ene. 2016, doi: 10.1061/(ASCE)EI.1943-5541.0000247.

[6] Y. H. Ahn, R. P. Annie, y H. Kwon, "Key Competencies for U.S. Construction Graduates: Industry Perspective", *J. Prof. Issues Eng. Educ. Pract.*, vol. 138, no. 2, pp. 123-130, abr. 2012, doi: 10.1061/(ASCE)EI.1943-5541.0000089.

[7] R. Salleh, M. A. M. Yusoff, H. Harun, y M. A. Memon, "Gauging Industry's Perspectives on Soft Skills of Graduate Architects: Importance vs Satisfaction", *Glob. Bus. Manag. Res.*, vol. 7, no. 2, 2015.

[8] D. M. Richter y M. C. Paretti, "Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom", *Eur. J. Eng. Educ.*, vol. 34, no. 1, pp. 29-45, mar. 2009, doi: 10.1080/03043790802710185.

[9] M. A. Guerra y Y. Abebe, "Pairwise Elicitation for a Decision Support Framework to Develop a Flood Risk Response Plan", *ASCE-ASMEJournalofRiskandUncertaintyinEngineeringSystems*, jul. 2018, doi: 10.1115/1.4040661.

[10] P. W. Holley y C. Ben Farrow, "Expanding collaboration in academia: case study of the development of construction products", *J. Prof. Issues Eng. Educ. Pract.*, vol. 139, n.º 2, pp. 139-147, 2013.

[11] R. E. Davis, S. Krishnan, T. L. Nilsson, y P. F. Rimland, "IDEAS: Interdisciplinary Design Engineering and Service", *Int. J. Serv. Learn. Eng. Humanit. Eng. Soc. Entrep.*, pp. 165-179, dic. 2014, doi: 10.24908/ijsle.v0i0.5546.

[12] A.-T. Järvenpää, A. Pavlik, y T. K. Gustavsson, "Contextual Communicative Competence in Multinational Infrastructure Projects", *Buildings*, vol. 11, no. 9, p. 403, sep. 2021, doi: 10.3390/buildings11090403.

[13] Y. Gamil y I. Abdul Rahman, "Identification of Causes and Effects of Poor Communication in Construction Industry: A Theoretical Review", *Emerg. Sci. J.*, vol. 1, no. 4, ene. 2018, doi: 10.28991/ijse-01121.

[14] H. Murzi *et al.*, "Cultural dimensions in academic disciplines, a comparison between Ecuador and the United States of America", 2021.

[15] M. Dickson, "Building for a small world-past parallels, future opportunities, Engineering Architecture, Eds", *McConnochie Al Glasg. UK*, 1999.
[16] M. Guerra y T. Shealy, "Teaching user-centered design for more sustainable infrastructure through role-play and experiential learning", *J. Prof. Issues Eng. Educ. Pract.*, vol. 144, no. 4, p. 05018016, 2018.
[17] D. P. McCrum, "Evaluation of creative problem-solving abilities in undergraduate structural engineers through interdisciplinary problem-based learning", *Eur. J. Eng. Educ.*, vol. 42, no. 6, pp. 684-700, nov. 2017, doi: 10.1080/03043797.2016.1216089.
[18] T. Ucol-Ganiron y A. S. Alaboodi, "Cultural Learning Environment in Structural Engineering Courses of Architecture and Civil Engineering Students in Qassim University", *Procedia - Soc. Behav. Sci.*, vol. 102, pp. 300-310, nov. 2013, doi: 10.1016/j.sbspro.2013.10.744.
[19] C. K. I. C. Ibrahim, S. B. Costello, y S. Wilkinson, "Making sense of team integration practice through the “lived experience” of alliance project teams", *Eng. Constr. Archit. Manag.*, 2018.
[20] Z. Vrcelj, M. Attard, G. Bell, y C. Longbottom, "Project X experiences of multidisciplinary Arch/COFA/ENG teaching", *Unpubl. Pap. Syd. Univ. NSW*, 2007.
[21] A. Živaljević, N. Vrcelj, y A. Tošović-Stevanović, "Is quality of higher educational institutions in Western Balkan real?", *Industrija*, vol. 43, no. 1, 2015.
[22] R. Jin *et al.*, "Project-based pedagogy in interdisciplinary building design adopting BIM", *Eng. Constr. Archit. Manag.*, vol. 25, no. 10, pp. 1376-1397, ene. 2018, doi: 10.1108/ECAM-07-2017-0119.
[23] W. Shen *et al.*, "Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review", *Adv. Eng. Inform.*, vol. 24, no. 2, pp. 196-207, abr. 2010, doi: 10.1016/j.aei.2009.09.001.
[24] M. A. Guerra y T. Shealy, "Theoretically comparing design thinking to design methods for large-scale infrastructure systems", *Fifth Int. Conf. Des. Creat.*, feb. 2018.
[25] D. P. McCrum, "Evaluation of creative problem-solving abilities in undergraduate structural engineers through interdisciplinary problem-based learning", *Eur. J. Eng. Educ.*, vol. 42, no. 6, pp. 684-700, nov. 2017, doi: 10.1080/03043797.2016.1216089.
[26] M. A. Guerra y C. Gopaul, "IEEE Region 9 Initiatives: Supporting Engineering Education During COVID-19 Times", *IEEE Potentials*, vol. 40, no. 2, pp. 19-24, mar. 2021, doi: 10.1109/MPOT.2020.3043738.
[27] M. Miranda, Á. Saiz-Linares, A. da Costa, y J. Castro, "Active, experiential and reflective training in civil engineering: evaluation of a project-based learning proposal", *Eur. J. Eng. Educ.*, vol. 45, no. 6, pp. 937-956, nov. 2020, doi: 10.1080/03043797.2020.1785400.
[28] A. Lee-Post, "Developing numeracy and problem-solving skills by overcoming learning bottlenecks", *J. Appl. Res. High. Educ.*, vol. 11, no. 3, pp. 398-414, jul. 2019, doi: 10.1108/JARHE-03-2018-0049.
[29] J. Zuo, X. Zhao, Q. B. M. Nguyen, T. Ma, y S. Gao, "Soft skills of construction project management professionals and project success factors: A structural equation model", *Eng. Constr. Archit. Manag.*, 2018.
[30] J. A. Botke, P. G. Jansen, S. N. Khapova, y M. Tims, "Work factors influencing the transfer stages of soft skills training: A literature review", *Educ. Res. Rev.*, vol. 24, pp. 130-147, 2018.

[31] G. Ruge y C. McCormack, "Building and construction students' skills development for employability – reframing assessment for learning in discipline-specific contexts", *Archit. Eng. Des. Manag.*, vol. 13, no. 5, pp. 365-383, sep. 2017, doi: 10.1080/17452007.2017.1328351.
[32] P.-H. Diao y N.-J. Shih, "Trends and Research Issues of Augmented Reality Studies in Architectural and Civil Engineering Education—A Review of Academic Journal Publications", *Appl. Sci.*, vol. 9, no. 9, p. 1840, May 2019, doi: 10.3390/app9091840.
[33] J. Zhang, H. Xie, y H. Li, "Improvement of students problem-solving skills through project execution planning in civil engineering and construction management education", *Eng. Constr. Archit. Manag.*, vol. 26, no. 7, pp. 1437-1454, ago. 2019, doi: 10.1108/ECAM-08-2018-0321.
[34] S. Alizadehsalehi, A. Hadavi, y J. C. Huang, "Virtual reality for design and construction education environment", en *AEI 2019: Integrated Building Solutions—The National Agenda*, American Society of Civil Engineers Reston, VA, 2019, pp. 193-203.
[35] N. S. Zabidin, S. Belayutham, y C. K. I. C. Ibrahim, "A bibliometric analysis of industrial revolution (IR) 4.0 in construction engineering education", en *MATEC Web of Conferences*, 2019, vol. 266, p. 05006.
[36] K. T. Simsarian, "Take it to the next stage: the roles of role playing in the design process", en *CHI'03 extended abstracts on Human factors in computing systems*, 2003, pp. 1012-1013. Accedido: 12 de febrero de 2017. [En línea]. Disponible en: http://dl.acm.org/citation.cfm?id=766123
[37] M. de Blois, B. Herazo-Cueto, I. Latunova, y G. Lizarralde, "Relationships between Construction Clients and Participants of the Building Industry: Structures and Mechanisms of Coordination and Communication", *Archit. Eng. Des. Manag.*, vol. 7, no. 1, pp. 3-22, ene. 2011, doi: 10.3763/aedm.2009.0110.
[38] M. A. Guerra, H. Murzi, J. Woods Jr, y A. Diaz-Strandberg, "Understanding Students' Perceptions of Dimensions of Engineering Culture in Ecuador", 2020.
[39] J. B. Noah y A. A. Aziz, "A Systematic review on soft skills development among university graduates", *Educ. J. Soc. Sci.*, vol. 6, no. 1, pp. 43-58, 2020.
[40] G. B. Cotet, B. A. Balgiu, y V. – C. Zaleschi (Negrea), "Assessment procedure for the soft skills requested by Industry 4.0", *MATEC Web Conf.*, vol. 121, p. 07005, 2017, doi: 10.1051/matecconf/201712107005.