Received: 11 September 2023 | Revised: 15 February 2024 | Accepted: 18 February 2024

DOI: 10.1002/cae.22739

RESEARCH ARTICLE

WILEY

CAMPUS: A mobile app for construction processes learning and teaching in higher education

Carolina Valbuena-Bermúdez[1] | Natalia E. Lozano-Ramírez[1] | Alejandro Serrano-Sierra[1] | César Granados-León[2]

[1]Department of Architecture, Pontificia Universidad Javeriana, Bogotá, Colombia

[2]Department of Industrial Design, Pontificia Universidad Javeriana, Bogotá, Colombia

Correspondence
Carolina Valbuena-Bermúdez, Department of Architecture, Pontificia Universidad Javeriana, Bogotá, Colombia.
Email: valbuenas@javeriana.edu.co

Funding information
Pontificia Universidad Javeriana, Research Vice-Rectory, Grant/Award Number: 20297

Abstract

This article presents a descriptive, correlational, and quantitative study investigating the learning processes of undergraduate construction engineering and architecture students. The study aims to analyze the effectiveness of an alternative learning method compared to traditional approaches in engineering, architecture and construction education. The study focuses on the use of a mobile application (CAMPUS Javeriana) as a tool for experiential learning by using digital technologies, such as construction videos and photos, infographic images, building information modeling (BIM) models, virtual and augmented reality, among others, within the app. Forty-six architecture students participated in the study, divided into control and experimental groups within each of three undergraduate courses. Pretest and posttest questionnaires were administered to assess the students' learning outcomes, preferences, and perception of the importance of learning technologies. The test results were analyzed using scatter plots, and statistical analysis was conducted using the Jamovi package in R Studio. The students' perceived importance of the mobile app and their preference to use it in the future were also evaluated. Contextual factors such as student characteristics, available resources, and instructors' teaching style were taken into consideration. The study implemented rubrics based on the Expected Learning Results for each course to measure the overall academic performance. Furthermore, the study explores the concept of learning gain and its relationship with the obtained results, shedding light on experiences, perceptions, and academic performance in the specific context of construction education. Findings suggest a positive impact on learning outcomes and perception as a result of using a series of multi-media technologies in the mobile application.

KEYWORDS

alternative learning methods, construction education, digital technologies, experiential learning, mobile application

1 | INTRODUCTION

In recent years, the field of architecture and construction engineering education has undergone major changes with the rapid development of digital technologies. Education, worldwide, has been influenced by constant technological advances that continually alter academic processes [31]. Currently, the variety of technological means available for educational purposes is quite wide and different ways of using them are increasingly explored with the aim of improving teaching methods and generating greater impact on students [9]. Traditional teaching methods based solely on knowledge transfer have been found to be limited in providing students with an understanding of the complex processes and operations of the construction industry. As Hajirasouli and Banihashemi state, with traditional methods, knowledge occurs to be transferred with the use of manuals and from standard procedures with an explicit approach. Whereas the implicit knowledge that occurs from being on a construction site and living the experience of the place is neglected [17]. To solve this problem, the integration of new digital technologies with tools related to education has emerged to improve the processes of institutions linked to education [33]. This is an effective way to enhance learning, facilitate teaching, and provide new experiences, and especially mobile apps have demonstrated to be successful tools to comply with these goals [5, 6].

This study aims to investigate the effectiveness of alternative teaching methods and the integration of technology into building and construction. By exploring the benefits of this process, this study aims to fill an important gap in knowledge and provide insight for teachers, academics, universities and students in the field by creating a mobile app named CAMPUS Javeriana. This research has the potential to change the way architectural, engineering, and educational development is presented. Using alternative methods, such as a mobile application, downloadable in IOS [7] and Android [8], students can participate in the construction process, explore dimensions, and gain a deeper understanding of materials while using it. This academic program prepares students to solve real business problems, allowing them to bridge the gap between knowledge and practical experience. Digital technologies are ubiquitous in the day to day of the new generations and are increasingly integrated into various aspects in higher education related to the promotion of culture and the dissemination of information [24].

Specifically, in the field of architecture and construction engineering, the technologies that have been used in recent years, such as three-dimensional models and virtual reality, have allowed the development of skills such as learning motivations, self-learning capacity, attitude, and effect of teamwork. Furthermore, immersive experiences have shown improvements in spatial understanding and in the final three-dimensional models presented by students [38]. Arthur Firipis, Siva Chandrasekaran, and Matthew Joordens suggest that engineering employers are requiring recent graduates with skills that are not always acquired in traditional engineering courses, including professional and technical skills, and that this requires curricula to transform and foster learning environments based on innovative practices. This puts us in a position to re-evaluate the way in which we teach architecture and engineering [14]. The target market of the mobile application is the entire academic field, the students and the university community being the main users of the technological platform. However, the main consumers of the new technology will be those related to teaching and learning in the field of construction. Similarly, CAMPUS Javeriana is potentially designed not only to serve the educational sector but also for construction engineering companies and the public sector. CAMPUS Javeriana aims to encourage the academic, interactive, creative, and immersive material creation for teaching and learning construction processes. Since the app is at an early stage of development, it is expected to strengthen the innovation, market opportunity, and traction. In addition, the app is forecast to gain entrepreneurial and commercial skills to develop all the app possibilities in a near future.

The study corresponds to quasi-experimental research with an exploratory descriptive design. The results of the control groups, which received traditional training, were compared with the results obtained by the experimental groups, who had access to a self-directed learning application. The research process included pretest and posttest phases, as well as questionnaires used to measure the level of knowledge and the perception of usefulness of various technologies in the participants' learning process [11].

The needs of this research are many. First, it aims to improve knowledge in the field of architecture and construction engineering education by providing evidence of the effectiveness of alternative teaching methods and technology. This research provides new insights for teachers, books, and schools, making a significant difference in understanding how these lessons improve learning and help develop cognitive skills.

Second, this study provides practical implications. By demonstrating the value of integrating digital technologies and other teaching methods, teachers can receive guidance on how to design better courses and make good impact. Research findings can inform curriculum development, instructional design, and the use of new instructional strategies that meet changing business conditions. Also, directly addresses the need for digital skills in the work, building, and construction engineering industry. By equipping students with the necessary digital skills, this research helps to bridge the gap between education and business and makes students more employable and resourceful to contribute to real-world projects.

In conclusion, we proposed two research questions:

RQ1. *Does the combination of alternative teaching methods and technology improve architecture and construction engineering students understanding and application of concepts in the fields of construction and architecture?*

RQ2. *What are the perceptions of architecture and construction engineering students considering technology mediating their learning experience and how these can impact their learning outcomes? This study aims to improve architecture and educational design by investigating the effectiveness of alternative teaching methods and digital technologies.*

2 | LITERATURE REVIEW

> "Let's not use outdated methods to solve problems that are now solved with modern methods" —*Sugata Mitra*

Education, in the context of construction, has tended toward more traditional methods of learning and teaching. Readings, memorization, and notes are the basis of traditional methods, where the instructor and teacher are the focus of attention in the teaching environment before an audience, where the recipients passively receive the information [17]. In this sense, traditional pedagogical processes start from the simple teaching theory, where information is transferred to the student to shape him, from repetition, with predictable learning results [23]. In the traditional teaching of architecture and construction, students usually learn through theoretical classes, practical exercises, and design projects. Learning is based on the transmission of knowledge and skills from instructors to students.

According to Sanjar Khudoykulovich Mardov and Zilolaxon Xikmat Kizi Farxatova, in traditional teaching processes, the instructors organize the lessons in such a way as to accommodate low-performing students, because they take as a premise the lack of interest of the students. The basis of teaching is the transmission of information, but not the development of intellectual potential. In this sense, memory comes to play a fundamental role and only some of the information infused in class will manage to be a conscious element of the student [21]. The commonly used tools for these traditional methods are readings and demonstrations of experiments, the first focuses on the transfer of information, while the second, on shaping the student from the continuous repetition of activities, previously carried out by the teacher [23].

In the traditional teachings in architecture, some of the basic principles of design are taught, such as proportion, form, volume, balance symmetry and geometry, among others, and in the teaching of construction engineering, techniques, structure, finishing and the electrical, hydraulic and sanitary system. This comes from the use of manuals and traditional literature focusing on the explicit transfer of information. Explicit knowledge is of great importance in teaching and learning, however, tacit knowledge that is generated only through experience should be encouraged [17]. In this sense, in the fields of architecture and construction engineering, where teaching largely resides in image and drawing, it is possible to promote experience by relying on graphic education that stimulates interest and knowledge [21]. With the support of graphic practices derived from nontraditional education methods, it is possible for the student to live the work, the space, and the materiality in a timeless and almost immediate way, from their devices. Thus, in a world of constant change and speed, the student may be exposed to the experience and knowledge that can only be acquired from the construction site [17].

With the support of graphic practices and digital technologies derived from nontraditional education methods, it is possible for the student to live the construction experience, the space and the materiality in a timeless and almost immediate way from their devices. Thus, in a world of constant change and speed, the student may be exposed to the experience and knowledge that can only be acquired from the construction site [17].

Since the beginning of the twenty-first century, construction education (CE) research has gained a growing interest. This trend coincides with an emerging requirement of the construction industry for new labor requirements and confirms the role of education in sustaining this development [41]. A series of bibliometric analysis have been performed in CE in the last years, confirming the use of new technologies and methodologies (building information modeling [BIM], industry 4.0, sustainability, virtual reality [VR], project management [PM]) is gaining traction along with new pedagogical methods (student-centered learning [SCL], active learning [AL], among others), to align with the technologies accompanying the latest wave of digitalization [2, 39, 41].

2.1 | Digital technologies in the teaching of CE

Many experiences in the application of digital technologies in higher education and specifically in CE have shown that the introduction of digital skills is currently mandatory and the question of whether to be digital is no longer an option [12]. Tools such as VR, BIM, augmented reality (AR), generative design, CAVE system, among others, have contributed to the ability to simulate designs and identify problems early to teaching and evaluation processes. In addition, according to the work of Professor Sara Eloy and the Lisbon University Institute/ISTAR-IUL, these technologies have complemented the skills of students who are increasingly digital and have the need to progressively adopt these skills in their study and design processes of historical, contemporary, and future environments [4, 12]. In recent years, VR and AR have been highly explored in construction education and training [3, 17, 28, 29].

Local applications such as the work of the Faculty of Architecture and Design at *Universidad de los Andes* about the production of digital content carried out by Professor Rafael Villazón and its project "*Procesos Constructivos*" and Knowledge Objects of Construction KOC, capture lessons learned to contribute to pedagogy and the monitoring and registration of construction processes [3], or the development of professor Carolina Rodríguez Bernal entitled *"Plataforma interactiva sobre procesos de construcción de elementos arquitectónicos"* ("Interactive platform on processes of construction of architectural elements") proposes strategies aimed at promoting autonomous learning in the student through case studies, problem-based learning, and collaborative learning with peers [28, 29].

Other local examples, such as work in virtual reality and Building Information Modeling applied to CE that has been carried out in recent years at the *EAFIT* University and its research group in Construction Management [30–32, 36] and prototypes, such as the Virtual Model for the management of the campus of *Universidad Católica de Pereira* by Professor Tatiana Sánchez and the *Grupo de Investigación Arquitectura y Diseño UCP*, realize the imminent need for the use of technologies in the teaching of architecture and civil engineering. These studies have identified a wide acceptance of utility and ease in the use of these technologies, various benefits in the teaching-learning process for both students and teachers, and a positive impact on the response to the dynamic and increasingly demanding market of the construction.

The research process included pretest–posttest control group designs, which are well suited to investigating the effects of educational innovations and are common in educational research [11]. In the case of this article, the results were analyzed using a change scores analysis, or, in other words, a repeated measure to test the interaction between treatment and occasion. As indicated, this article tests on posttest scores, with pretest scores as a covariate, to provide a more appropriate and informative analysis.

2.2 | Mobile applications in CE

Several mobile applications have been implemented in the field of engineering, architecture, and urban planning, focused on the educational field [13, 26, 34]. Some experiences with the development of applications in the field of architecture have shown that they manage to train users to obtain a better knowledge about the physical space in which they are, thanks to the use of augmented reality that complements the physical environment by increasing information available during cities tours [13]. Other experiences in the field of engineering suggest that learning through mobile technologies ("m-learning") has a giant didactic potential and motivates "digital natives" to learn in a way that is natural for them [34].

Recent research on the perception of the effectiveness of education in mobile solutions suggest that when the educational content is found in a mobile application, very good results and a positive attitude are obtained regarding the use of this tool for learning [37]. Some studies recommend the use of innovative and disruptive technological strategies that are already available in learning applications, with the aim of promoting the use of said application, pointing to the capacity for intervention and communication on digital content [1, 19, 42].

2.3 | M-learning

The fields of knowledge, learning, and teaching today have had multiple advances in the last decade, and we find the need for a profound reform of the current educational systems [35]. The fields of knowledge, learning, and teaching today have had multiple advances in the last decade, and we find the need for a profound reform of the current educational systems [35]. The fields of knowledge, learning, and teaching have had multiple advances in the last decade, finding the need for a profound reform of the current educational systems [35]. Today, we find multiple methodological approaches such as computing (robotics, computational thinking, and artificial intelligence), extended reality (augmented reality and virtual reality), games (video games, serious games), and pedagogical tools (EVEA, apps) in education. [27].

Within all these methods, an increase in the use of modern telephone communication devices with their multiplicity of functions has been demonstrated and seems to have implications for student achievement [10]. A wide range of m-learning definitions can be found in the literature [20, 25], yet they all have the same idea in common: mobile devices play an important role in learning activities, irrespective of where such activities are carried out.

Learning with mobile devices, mobile learning, or m-learning, is based on the use of small portable equipment, mainly in the activity with advanced cell phones, smartphones, and tablets or tablet computers. These devices allow computerized data management and wireless connectivity for telematic interaction in the teaching-learning process [15].

3 | METHODS

3.1 | CAMPUS Javeriana mobile app

The construction and engineering processes and in general the subjects related to the construction techniques of the architecture and civil engineering degree are still being taught in the same way after several years without taking advantage of the new technologies already available. The research-creation process addressed by this project conceives the university campus as a learning laboratory in constant construction, through the creation of educational content supported by innovative means of transmission and immersion, the technological development of a tool (App), downloadable in IOS [7] and Android [8], that contains two-way interaction content with the platform's users. The application resulting from this process understands and presents the university campus as a space in constant physical transformation susceptible to the establishment of creative learning material through agile formats designed for the new generations and related to construction topics linked to the physical evolution of the university. Some of the contents included are: 360° videos of micro activities of construction processes, augmented reality models that allow the user to interact with the buildings, interactions with virtual reality, infographics, and detailed photographs, all of the above with bibliographic (Figure 1).

This mobile application, despite being under construction, has features that allow an ubiquitous, interactive, and collaborative platform, through personalized navigation [40]. In that sense, it allows an exploration of the campus construction sites, so that the student and the teacher achieve immersion and experience in the place. Hence, it is possible to generate knowledge from the implicit one, overcoming the barriers of explicit

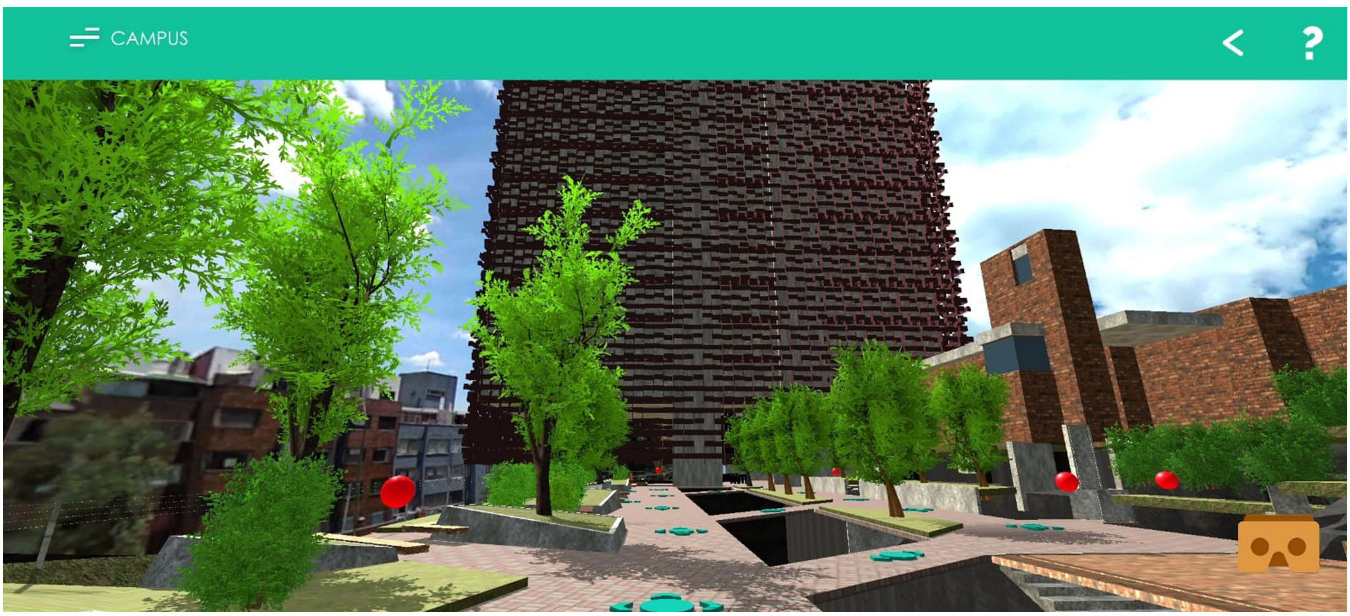


FIGURE 1 Virtual reality (VR) from building information modeling (BIM) model of the public space around the Sciences Faculty building.

knowledge transfer described above. The application supports the cognitive and motivational development of students and promotes diverse learning sources, from the campus and from home, encouraging the use of the app in a convenient way by the user [22]. The technologies present in the app are Site Videos, Augmented Reality, Site Photographs, Audio Capsule, Virtual Reality, Interactive Images, and Infographic images. Depending on the architectural and construction processes carried out, each of the buildings has different visual and auditory resources. In this sense, it is possible to demonstrate augmented reality by means of markers located in situ that allow 3D recognition (Figure 2).

Each construction phase is made up of a consecutive list of activities that allow the different engineering processes to be carried out on site, for example a 360° image that allows to identify the way in which the steel elements for reinforced concrete are contained and stored on site. Detailed videos taken from construction sites were also used to identify the importance of the concrete polishing process or one used to study the behavior of steel fibers in reinforced concrete in direct traction, bending, compression, and modulus, as well as for the study of seismic rehabilitation of reinforced concrete of two levels. Other examples are the rehabilitation of two-storey earth (heritage) buildings, by identifying the way in which a structural reinforcement of a masonry wall is carried out from the anchoring of electro-welded mesh and brickwork. The app presents different construction activities (Table A1) categorized by building's name, modality, construction phase, micro activity, type of content, and media used in the content. Buildings are featured in multiple entries emphasizing construction micro activities including concrete vibrating, concrete polishing, top-down system, façade staking, lifting of beams, steel figured, structural reinforcement and demolition, electrical and sanitary networks, among others.

3.2 | Experiment design

This study employs an exploratory descriptive design focused on quantitative data. Its quasi-experimental design consists of three phases: pretest, training phase, and posttest [11]. After obtaining informed consent from all participants, the pretest phase begins by administering a questionnaire to assess their initial level of knowledge and preferences regarding the use of learning technologies. Next, the control group receives traditional

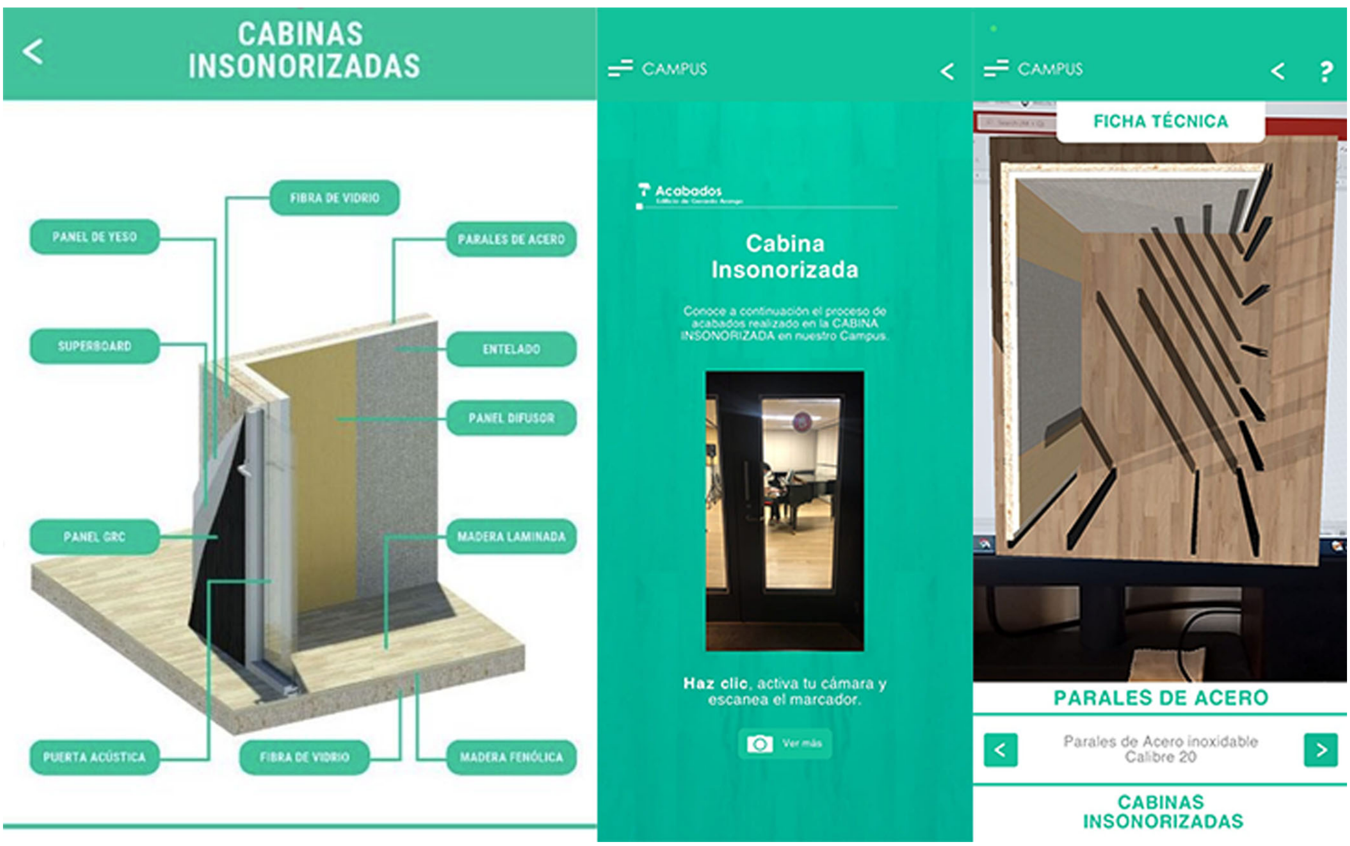


FIGURE 2 Augmented reality (AR) from in situ localized marker.

training, while the experimental group is provided access to a study app. Finally, in the posttest phase, the questionnaire is administered again to both groups to evaluate the acquired knowledge and perceptions regarding the use of learning technologies. The group allocation involved a random assignment of students to control and experimental groups conducted within each course. A total of 46 university students majoring in architecture were recruited for the study ($N = 46$). Participants come from three different courses, with specific distributions for each course and group. The distribution of participants in each course and group is as follows: course 1: 18 participants, control group: 9 participants, experimental group: 9 participants; course 2: 16 participants, control group: 8 participants, experimental group: 8 participants; course 3: 12 participants, control group: 6 participants, experimental group: 6 participants.

The instruments used in this study included a pretest questionnaire, designed with questions related to the specific learning objectives of each course (Expected Learning Results), and a posttest questionnaire, similar to the pretest questionnaire used to assess the knowledge acquired after the training phase. Additionally, both the pretest and posttest questionnaires included questions about the preference and importance of learning technologies.

The data analysis involved a comparative analysis conducted between the pretest and posttest results for the control and experimental groups within each course using scatter plots. This analysis was performed using the Jamovi package in R Studio. The evaluation of academic performance indicators was carried out by collecting information through targeted questions posed to students. This process included assessing their experiences with the alternative learning method, its benefits in their learning process, and their perception of effectiveness compared to traditional methods. The learning gain (LG) is originally defined as the percentage difference between post-assessment and pre-assessment results, normalized regarding the complement of the pre-assessment percentag, expressed by the formula LG = (% postscore − % prescore)/(100 − % prescore) [18]. To adapt this measure to the comparative analysis between a control group following a traditional teaching method and an experimental group using a mobile application, specific adjustments were made. Instead of considering direct percentages, the decision was to work with the means of prescore and post-score results for each group [5].

Thus, the adapted formula is expressed as $LG = (\bar{x}\ post - \bar{x}\ pre)/\bar{x}\ pre$, where $\bar{x}\ post$ is the mean of all post-assessment results and $\bar{x}\ pre$ is the mean of all pre-assessment results. This adaptation allows for the evaluation of the mean growth in learning within each group based on initial and final assessments, providing a comparative measure of the traditional method versus the relative impact of the mobile application.

This adjusted methodology aims to quantify the relative effectiveness of the mobile application compared to the traditional method more precisely, considering averages to mitigate potential individual variations and emphasizing the average percentage change in learning over time.

In addition to assessing effectiveness, student perception about the importance of the alternative method was measured. Students were asked about their overall level of importance and whether they would prefer to continue using this method in the future. A comparison with traditional methods was conducted to determine the effectiveness of the alternative method in improving academic performance. The results obtained with this method were compared to those of traditional methods, allowing for an evaluation of whether the alternative approach had a positive impact on students' academic performance.

To ensure the validity of the evaluation, the context in which the alternative method was implemented was considered. Factors such as students, available resources, and the instructor's teaching style were considered, as they can influence the evaluation results and provide a comprehensive understanding of the effects of the alternative approach. A review of common methodological points was conducted to determine academic performance indicators in the field of architecture and building construction. This involved a literature review, curriculum analysis, identification of key terms, examination of case studies, and expert interviews.

Expected Learning Results (ELR) of each lesson were used as a reference for data analysis. The ELRs were crossed with the information collected during the teaching evaluation, employing rubrics to objectively measure students' overall academic performance. Different types of evaluations, including multiple-choice questions, open-ended questions, and categorization tests, were used to assess various aspects of academic performance and students' preferences regarding new technologies.

3.3 | Courses of application

Figure A1 shows the complete architecture curricula and the location of the three application courses. Construction processes and Design of finishes are courses from the *Technical* emphasis area, while Technology component XXI Century Habitat Project is a component in the *Project* emphasis area.

3.3.1 | Construction processes (CON)

The construction process by which a work is done contemplates a regulation in the plans and specifications of the work. In the planned program, it has a beginning and an end, it consumes resources, it is tangible, and therefore it can be quantified or measured.

The subject "Construction processes" (CON) description is based on the above definitions. The optimal use of materials, the correct use of labor according to the degree of complexity of the activity, the necessary equipment to carry out the construction processes, and the management of the construction projects are considered.

1. Based on a single-family housing project or a low complexity architectural project, the list of work is made sorting the activities in chapters according to their function or affinity with their respective unit and quantity of work.
2. The work specifications are elaborated considering *the description*, which answers the question "What is the activity about?" *the methodology*, which answers the question "How is it built?" *the materials*, "What is it built with?" *the labor*, "Who builds it?" *the equipment*, "What do you help to build it with?" and finally, *the unit of measurement*, "How is the activity measured and quantified?".
3. It concludes with the study (unit of measurement, quantity, and performance) of the resources that make up an activity.

3.3.1.1 | *Sample and test description*

We perform the tests to two groups with the characteristics shown in Table A2.

3.3.1.2 | *Expected Learning Results (ELR)*

At the end of the semester, the student will be able to:

1. Apply the knowledge to make a list of work with the supporting tables of the bill of quantities of each of the activities organized by chapter.
2. Interpret topographic, architectural, and structural plans.
3. Identify integrally the work specifications.
4. Distinguish the resources an activity consumes, to control and quantify the necessary materials in the construction and its processes.

3.3.1.3 | *Questions*

1. The vibrating stage is among the most important micro-activities of the concrete construction process. Explain the differences between external vibrating and immersion vibrating.
2. What are the benefits of using the flexible shaft internal vibrator in a concrete mix?
3. If the image describes the activity of lifting beams, explain the activity in your own words using technical vocabulary, proper names of materials and equipment, so that an official or construction worker can understand the activity you are referring to.
4. Imagine what is to initiate the hoisting of a steel building structure. Describe the main elements necessary for the procedure and the personnel you would need for the lifting of a structural steel beam.
5. Explain what is figured steel.
6. Name what elements/components constitute a steel reinforcement for an object constructed in reinforced concrete.
7. According to the wall reinforcement activity, place in the proper order each of the steps to perform this construction process. Position in first place the process by which you would start and then proceed in its order of execution.
8. What is the main intention of reinforcing an existing masonry wall with electro welded mesh?
9. According to the activity of applying polyurea and primer, place in the proper order each of the steps to perform this construction process. At the beginning, drag the first process and then proceed in its order of execution.
10. Explain the construction process performed for the casting of steel fiber reinforced concrete elements.
11. For a steel fiber concrete casting process, should an immersion vibrator be used? Choose which of the options is the most correct.

3.3.2 | Design of Finishes in interior Design and spaces, social, commercial, and services (FIN)

The Design of Finishes in Interior Design and spaces, social, commercial, and services is a course exclusively aimed at fourth-semester architecture and civil engineering students at Pontificia Universidad Javeriana in Bogotá, Colombia. The course focuses on teaching architectural finishes to transmit materiality as an integral part of the architectural element.

In developing the work contents, the following topics are proposed for both individual and teamwork:

- Historical and trend review.
- Customer case study analysis.
- The individual and his interaction with his very close context.

- Research on materials.
- Technical specifications - Measurement units - Obtaining in commerce.
- Globality in the finishing industry—Application—The benchmark.
- Interior, exterior, special construction processes.
- Costs unitary budget.
- Work in specific spaces of the study object such as kitchens, bathrooms, or spaces with special finishing characteristics.
- Technical coordination of finishes.
- The details as the focal point of the finish.
- Presentation, application, results of the challenge posed with the use of state-of-the-art technologies.
- Finishes in the design of public spaces.

3.3.2.1 | *Sample and test description*

The tests were conducted on two groups, as outlined in Table A3.

This course was tested by multiple choice exams. The study was developed in the early stages of knowledge development, and the answers of true and false were important to understand both principles and concepts. The test has low literacy skills for an easier understanding.

In this exam, five questions were asked with the objective of measuring and comparing the influence of the use of the application in the student outcomes. In this sense, the experimental group had the possibility to develop the posttest evaluation.

3.3.2.2 | *Expected Learning Results (ELR)*

At the end of the semester, the student will be able to:

1. Foster approaches to determine the stages for the concrete polishing process, the importance of this activity, and the tools used for its realization.
2. Evidence the benefits of finishing concrete polishing in terms of its maintenance and economic viability.
3. Analyze the construction process, materials, and finishes of the soundproof booths on site.
4. Relate and distinguish the construction processes, as well as protective implements and equipment for the application of polyuria and waterproofing. Relate these aspects with sustainability, chemistry, and material mechanics.

3.3.2.3 | *Pretest and posttest*

The pretest and posttest for "The Design of Finishes in Interior Design and spaces, social, commercial and services" course was based first on the general expected learning results (ELR). For each individual content in the CAMPUS Javeriana mobile app, we analyzed the relevance of this specific content. At the end, we selected three contents:

- Concrete polishing
- Soundproof booth
- Square waterproofing

Additionally, due to the level of the course in the architecture program, all answers are multiple choice.

3.3.2.4 | *Questions*

1. What are the most important reasons to perform the concrete polishing process?
2. Which of the following tools is the most efficient for the concrete polishing process?
3. What are the main benefits of the behavior of polished concrete in spaces such as building parking lots?
4. Which of the following processes should be done immediately before applying a polyurea waterproofing?
5. What are the main characteristics of waterproofing with polyurea?

3.3.3 | Technology component XXI Century Habitat Project (TEC)

This course is part of the architecture project "XXI Century Habitat" which aims to analyze and compare different types of city construction and to understand the complexity of habitat issues in the twenty-first century from an integral approach of different components comprising a project (urban planning, environment, technical infrastructure, management processes, and socio-cultural and aesthetic frameworks).

In XXI Century Habitat, students are able to propose comprehensive design solutions based on the principles of sustainability, to conceive complex urban-architectural designs with technological and environmental responses consistent with the context in which they are inserted and to develop an ethical position to the asymmetries generated by the high differences in the habitat conditions of the city, from an equiality perspective.

The course is part of a group of three projects with an architectural detailing focus, taught in the 6th semester (out of 10 semesters in total) in the architecture program.

3.3.3.1 | *Expected Learning Results*

In the technological infrastructure area, we aim to:

- Compare traditional types of structures with non-conventional types of structural systems identifying advantages and disadvantages.

- Analyze the on-site implications of the selection of a structural system.
- Relate the decision to use certain types of internal partitions to their construction process according to their location in space.
- Connect the context and environment of the architectural proposal with the environmental and technological solution.
- Argue the selection of a structure and structural material related to the final finish it provides to a building.

3.3.3.2 | *Sample and test description*

The tests were conducted on two groups, as outlined in Table A4.

3.3.3.3 | *Pretest and posttest*

The pretest and posttest for "Technology area—XXI Century Habitat Project" course was based first on the general expected learning results (ELR) of the XXI Century Habitat project. For each individual content in the CAMPUS Javeriana mobile app, we analyzed the relevance finally selecting the following three contents:

- Concrete polishing
- Beam lifting
- Wall and plaster reinforcement

Additionally, due to the level of the course in the architecture program, all answers are open-ended in line with higher order verbs according to Bloom's taxonomy [16].

3.3.3.4 | *Questions*

1. Explain why you would select a concrete structure with "exposed concrete" as final finishing.
2. Analyze the possible relationships between the architectural concept and the decision to leave the concrete exposed as finishing.
3. When implementing a structural steel system, what implications should you consider on the construction site? Name two implications.
4. Compare and describe three substantial differences of using steel versus concrete on a project.
5. Compare the construction process of a masonry wall located in a kitchen with built-in furniture and one located in a circulation hall, highlighting their differences.
6. Evaluate whether you would need to reinforce any walls in your project and explain the reasons why you would need to do so.

3.4 | Technology questionary

Additional to all three courses test, a supplementary questionary was implemented to better understand the learning experience through different means and technologies. The questions were designed to measure the student's perception on the influence of technology in the usefulness and improvement of their learning experience.

3.4.1 | Questions

A. Organize the following technologies from most useful to least useful as they allow you to learn about construction processes in general:
- Construction site videos
- Construction site photos
- White board explanation
- BIM model: virtual reality
- BIM model: augmented reality
- Power Point presentation
- Interactive image
- Infographic image
- Book
- Podcast

B. Do you agree with the statement "a mobile application is a useful tool to learn about construction related topics"?

C. Based on the answer to the previous question, please answer: why?

4 | RESULTS

4.1 | Construction processes (CON)

Table 1 shows the CON course descriptives. The results of the questions are described in the following section.

1. *Among the most important micro-activities of the concrete construction process is the vibrating stage. Explain the differences between external vibrating and immersion vibrating.*

   The distribution shows a very similar grouping of students in the rating, especially in the control group. The experimental group presents a noticeable improvement (1.50/5.00), so we can conclude a greater influence of the mobile application in improving learning.
2. *What are the benefits of using the flexible shaft internal vibrator in a concrete mix?*

TABLE 1 CON course descriptives.

	Group	Test	1	2	3	4	5	6	7	8	9	10	11
Mean	Control	Pre	1.63	0.00	0.00	1.88	2.00	2.38	2.63	2.50	3.13	0.625	0.500
		Pos	2.00	0.00	0.00	2.13	1.75	2.88	2.13	3.00	3.13	2.00	0.125
	Experimental	Pre	1.63	0.00	0.00	2.25	1.50	3.00	1.63	2.50	3.13	1.75	0.125
		Pos	3.13	4.38	4.25	4.50	4.25	4.88	4.00	3.88	3.50	3.00	3.13
Median	Control	Pre	2.00	0.00	0.00	1.50	2.00	2.00	3.00	4.00	5.00	0.500	0.00
		Pos	2.50	0.00	0.00	2.00	1.50	2.50	2.00	4.00	5.00	2.50	0.00
	Experimental	Pre	1.50	0.00	0.00	2.00	1.50	3.00	2.00	4.00	5.00	1.50	0.00
		Pos	3.50	5.00	4.50	5.00	4.50	5.00	4.50	4.00	4.00	3.00	5.00

For this question, in the control group, the sample is maintained in answers that do not meet the expected learning results for the subject. However, once the students in the experimental group made use of the application, there was a notable improvement in the posttest, going from an insufficient evaluation to an evaluation of 4.38 on average.

3. *If the image describes the activity of lifting beams, explain the activity in your own words, using technical vocabulary, proper names of materials and equipment, so that an official or construction worker can understand the activity you are referring to.*

   The distribution shows a very low and similar grouping of students in the rating, especially in the control group. However, the experimental group presents a notorious improvement (4.30/5.00), so we can conclude a greater influence of the mobile application in the improvement of learning. The figure shows that in the control group, the sample is maintained in answers that do not meet the Expected Learning Results for the subject.
4. *Imagine what is to initiate the hoisting of a steel building structure. Describe the main elements necessary for the procedure and the personnel you would need for the lifting of a structural steel beam.*

   The control group maintains a positive trend of the results in the posttest, even though it is a difference of 0.3 points above on average, while for the experimental group it is evident that the results of the students are 2.3 points higher on average than the pretest.
5. *Explain what is figured steel.*

   The control group shows a slight negative trend in the posttest results, with a decrease of 0.25 lower than the pretest results. On the other hand, for the experimental group, there is an evident improvement in the results of the students, even surpassing the posttest results by 2.8 points above the pretest average.
6. *Name what elements/components constitute a steel reinforcement for an object constructed in reinforced concrete.*

   In the case of question 6, the control group remained very homogeneous, with an almost imperceptible difference between the pretest and the posttest. The tendency is maintained indicating that, for the experimental group, the results of the posttest evaluations reach outstanding grades, almost approaching the maximum grade (4.87/5.00).
7. *According to the wall reinforcement activity, place in the proper order each of the steps to perform this construction process. Position in first place the process by which you would start and then proceed in its order of execution.*

   The control group maintains a very similar average, although it is slightly reduced by 0.5 points in the posttest results. It is worth noting that once again the experimental group rises 1.88 points higher after the use of the mobile app.
8. *What is the main intention of reinforcing an existing masonry wall with electrowelded mesh?*

   Both groups failed the pretest, but for both the control and experimental groups, favorable results are obtained with points above in the posttest. In the experimental group we notice a remarkable improvement of students who fail the pretest but upgrade after using the application, obtaining grades with an average of 3.87 as a result.
9. *According to the activity of applying polyurea and primer, place in the proper order each of the steps to perform this construction process. At the beginning, drag the first process and then proceed in its order of execution.*

   An average of 3.1 is obtained in the pretest for both the control group and the experimental group, an average very close to the minimum grade. No major changes are obtained in the application of the posttest in both cases. In fact, in the control group, average remains at the same value and for the experimental group it rises only 0.4 above the pretest.

10. *Explain the construction process performed for the casting of steel fiber reinforced concrete elements.*

    As an observation of question 10, the results in general are very poor in both the pretest and the posttest. In fact, in most of the variables, the results do not obtain a passing average with respect to the question. For the control group, there is a baseline of 0.62 and it rises to 2 once the posttest is performed. Although in the experimental group a positive improvement of 1.25 points above the average is observed.

11. *For a steel fiber concrete casting process, should an immersion vibrator be used? Choose which of the options is the most correct.*

In the case of the previous question and this one, the results obtained in both groups are very poor. In the case of the control group, the average even decreases by a few points before and after the test, but in any case, average grading does not reach the expected results of this question. On the other hand, in the case of the experimental group, there was a notable improvement in the test once the application was used. In fact, questions 2, 3, and 11 are the ones where an improvement of more than 3 points is shown in comparison to the result obtained in the pretest.

Table 2 shows that both questions had a higher learning gain, followed by questions 4, 5, 7, and 11, where the percentage is a little lower, however, an increase is evident. Finally, questions 1, 6, 8, 9, and 10 had the lowest percentages of learning gains. Nevertheless, for all the questions, learning gains are mostly positive and evident in different proportions.

4.2 | Design of finishes in interior design and spaces, social, commercial, and services (FIN)

Table 3 shows the FIN course descriptives. The results of the questions are described in the following section.

1. *What are the most important reasons to perform the concrete polishing process?*

   In the pretest, the control and experimental groups had conceptual gaps regarding the importance of the process to achieve finishes such as concrete polishing. When performing the posttest, while the control

TABLE 2 Learning Gain Index per question contrast control and experimental groups (CON).

	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7	Question 8	Question 9	Question 10	Question 11	Summary
Control	0.0%	0.0%	0.0%	0.4%	−0.5%	0.6%	−1.2%	0.0%	0.0%	1.1%	−0.4%	
Experimental	1.5%	4.4%	4.3%	2.3%	2.8%	1.9%	2.4%	1.4%	0.4%	1.3%	3.0%	

TABLE 3 FIN course descriptives.

Descriptive	Group	Test	1	2	3	4	5
Mean	Control	Pre	4.33	1.00	2.33	1.00	2.33
		Pos	3.00	5.00	4.33	1.00	3.00
	Experimental	Pre	3.29	1.57	3.86	1.00	3.86
		Pos	5.00	5.00	5.00	2.14	2.71
Median	Control	Pre	5.00	1.00	1.00	1.00	1.00
		Pos	3.00	5.00	1.00	1.00	3.00
	Experimental	Pre	5.00	1.00	5.00	1.00	5.00
		Pos	5.00	5.00	5.00	1.00	1.00

TABLE 4 Learning Gain Index per question contrast control and experimental groups (FIN).

	Question 1	Question 2	Question 3	Question 4	Question 5	Summary
Control	−1.4%	4.0%	2.0%	0.0%	0.7%	
Experimental	1.8%	3.5%	1.2%	1.2%	−1.2%	

group continues and even worsened the results, the experimental group fully improved their understanding of the construction process by studying it from the CAMPUS Javeriana application, answering that the most important reason to perform the concrete polishing process was to Leveling floors for installation of finishes/Leave the concrete exposed. In the posttest, the experimental group had 100% accuracy in their answer.

2. *Which of the following tools is the most efficient for the concrete polishing process?*

   In both the control and experimental groups, the basic concepts in terms of construction, which include basic tools present in a work, are scarce. In this sense, both groups in the posttest achieve a significant improvement in their response, since they are instructed on the tools to achieve finishes such as polished concrete. Hence, it is evident that the use of the CAMPUS Javeriana mobile application achieves the objective of teaching basic concepts of work from the virtual and alternative experience, providing students with the answer to the question.

3. *What are the main benefits of the behavior of polished concrete in spaces such as building parking lots?*

   It is evident that the experimental group achieves an improvement in terms of the posttest. In this sense, the group as a whole advances from the control group, evidencing 100% of the group in the highest grade (5). The control group, trained by traditional teaching, also achieves an evident improvement but shows that some members of the group remain behind and below average.

4. *Which of the following processes should be done immediately before applying a polyurea waterproofing?*

   We can notice a small improvement in terms of the processes of the polyurea waterproofing finish in the experimental group. Even though the results show a small variation especially in the experimental posttest with some correct answers, it is important that in constructive teaching, which must involve experience and a more visual tools, the application manages to generate said cognitive practices from virtuality. In this sense, it is evident that memorization of instructional processes is limited and produces results that do not necessarily lead to better student understanding and learning.

5. *What are the main characteristics of waterproofing with polyurea?*

For this question it is not possible to show an improvement in the results when comparing the pretest and the posttest for both the control and the experimental groups. In this case, both the traditional teaching and alternative teaching from the app, show there are still conceptual gaps regarding simple characterizations in the construction processes of polished concrete and waterproofing with polyurea. In this sense, an opportunity is presented to demonstrate, from the mobile application, the benefits in the behavior of the finish, since the traditional methods, as evidenced in the graph,

Descriptive	Group	Test	1	2	3	4	5	6
Mean	Control	Pre	3.91	4.10	4.10	3.84	3.50	3.60
		Pos	4.37	4.19	4.09	3.84	3.73	2.87
	Experimental	Pre	4.27	4.03	3.98	3.74	2.36	2.67
		Pos	4.38	3.59	3.79	3.64	3.49	3.82
Median	Control	Pre	4.00	4.20	4.50	3.90	3.80	3.50
		Pos	4.40	4.10	4.50	3.90	3.80	2.70
	Experimental	Pre	4.20	4.10	3.90	4.00	3.60	2.90
		Pos	4.40	4.00	3.80	4.00	3.50	3.90

TABLE 5 TEC course descriptives.

leave these gaps.From the M-learning point-of-view, it is possible to impart said processes experientially.

Table 4 shows that there was a learning gain referred to the use of the mobile application, evident in the learning gain percentages of the experimental group. In detail, the table shows that question 2 obtains the highest percentage learning gain, followed by questions 1, 3, and 4, where a moderate learning gain is observed, while question 5 shows a loss in the learning index. In pretest, the control and experimental groups had conceptual gaps in terms of the importance of the process to achieve finishes such as concrete polishing. In the posttest, while the control group continued and even worsened their results, the experimental group completely improved their understanding of the construction process by studying it from the CAMPUS Javeriana application.

4.3 | Technology component XXI Century Habitat project (TEC)

Table 5 shows the TEC course descriptives. The results of the questions are described in the following section:

1. *Explain why you would select a concrete structure with "exposed concrete" as final finishing.*

   The distribution shows a higher grouping of students toward an improvement in grading, especially in the control group (0.46 higher in the posttest). The experimental group shows a very low improvement (0.11/5.00), therefore we cannot conclude that the mobile application has a major impact on the improvement of learning.
2. *Analyze the possible relationships between the architectural concept and the decision to leave the concrete exposed as finishing.*

   In terms of average, there was a minor improvement in the control group, and a downgrading of 0.44 in the experimental group. Once again, the results do not indicate a significant improvement attributable to the use of the mobile app.
3. *When implementing a structural steel system, what implications should you consider on the construction site? Name two implications.*

   Finally, the control group's grades were distributed more evenly across different scales, while the experimental group had a major grouping at about 4,00. However, once again, the average grades decreased in the experimental group, and the impact of the mobile app could not be demonstrated.
4. *Compare and describe three substantial differences of using steel versus concrete on a project.*

   Results of the posttest show a higher distribution of data; however, the average grading is stable. Results do not show an improvement in learning after the mobile app training.
5. *Compare the construction process of a masonry wall located in a kitchen with built-in furniture and one located in a circulation hall, highlighting their differences.*

   These results show an interesting phenomenon, while data is more distributed in the experimental pretest group, this distribution is similar in the posttest, however in this case, the average grading improves in the control group and the experimental group. While the control group presents an improvement of 0.23, the experimental group presents a higher improvement of 1.13, which can be considered as a major influence of the app in the students learning this specific topic.
6. *Evaluate whether you would need to reinforce any walls in your project and explain the reasons why you would need to do so.*

Finally, we can notice a major improvement in gradings after the training with the mobile app. The posttest control group has a relatively lower grading

TABLE 6 Learning Gain Index per question contrast control and experimental groups (TEC).

Test	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Summary
Control	0.5%	0.1%	0.0%	0.0%	0.2%	−0.8%	
Experimental	0.1%	−0.5%	−0.2%	−0.1%	1.2%	1.2%	

(0.73) while the experimental group has a high improvement (1.15). In the final case, the mobile app influences the students learning in this specific topic.

Table 6 shows learning gains in questions 1, 5, and 6, while in questions 2, 3, and 4 there is a loss for the experimental group. In this sense, in questions 2, 3, and 4 it is not possible to demonstrate a learning gain due to the use of the mobile application for the experimental group. In this case, it is important to reevaluate the contents and questionnaires of the mobile application when used by students in more advanced stages of their Architecture program and recognize the limitations of the app for such students.

5 | TECHNOLOGIES IN APP

A. *Organize the following technologies from most useful to least useful as they allow to learn about construction processes in general.*

Figure 3 shows the results of these questions. On average, all courses have the best ranking assigned to construction site videos, resulting in a greater average reliability in this technology compared to others. However, in the FIN course, the percentage of students responding "construction site videos" decreases from pre to posttest, particularly in the experimental group. This suggest that after the training, students began to recognize other more useful technologies. For both the CON and TEC courses, this percentage goes up in both control and experimental groups. This can be explained since the FIN course training included the use of "augmented reality," the second technology with the best ranking for this course, compared to the CON and TEC courses, that did not use it.

In general, students from the three courses believe "podcasts", "books", and "infographic images" are the least useful means to learn about construction processes, in all three courses.

Specific to the CON course, the higher reliability of the students was assigned to "construction site videos", "construction site photos", and "whiteboard explanation". For the FIN course, the best ranked technologies were "construction site videos", "BIM model: augmented reality" and "BIM model: virtual reality". For the TEC course, "construction site videos", "whiteboard explanation", and "BIM model: virtual reality" have the best rankings. After the noticeable trend of construction site videos, we can see "whiteboard explanation" has a great ranking in two courses, considering the students are subjected to all kinds of media, which demonstrates a powerful validity of this traditional mean.

B. *Do you agree with the statement "a mobile application is a useful tool to learn about construction related topics"?*

In Figure 4, we can see if students agree with the usefulness of mobile apps for learning about construction-related topics. The percentage of students agreeing with the questions is stable for both control and experimental groups, with a low increment in the experimental group. This is the highest percentage for both groups. However, the percentage of "partially agree" lowers from the pretest to the posttest, and the percentage of "disagree" increments.

C. *Based on the answer to the previous question, please answer: why?*

In Figure 5, we can see the concepts that both control and experimental group have in common. In general, students agree with the statement of the usefulness of mobile app for construction learning relating to: more, tool, better, information, application, process, topic, site, easy, form, and video. On the other side, the control group further mentions: finishing, knowledge, reality, app, access, explanation, among others with lower frequency. Finally, the experimental group additionally mentions: useful, force (as in labor force), useful, construction, method, among others with lower frequency.

Based on the gathered opinions, students expressed diverse perspectives regarding the use of mobile applications to learn about construction and architectural finishes. Some consider these applications useful due to their ability to display videos, images, and 3D models, which facilitate understanding and perception of space. They also highlight the convenience of having quick access to information anytime, anywhere, as well as the possibility of having a wide variety of interactive resources such as PowerPoint presentations and virtual

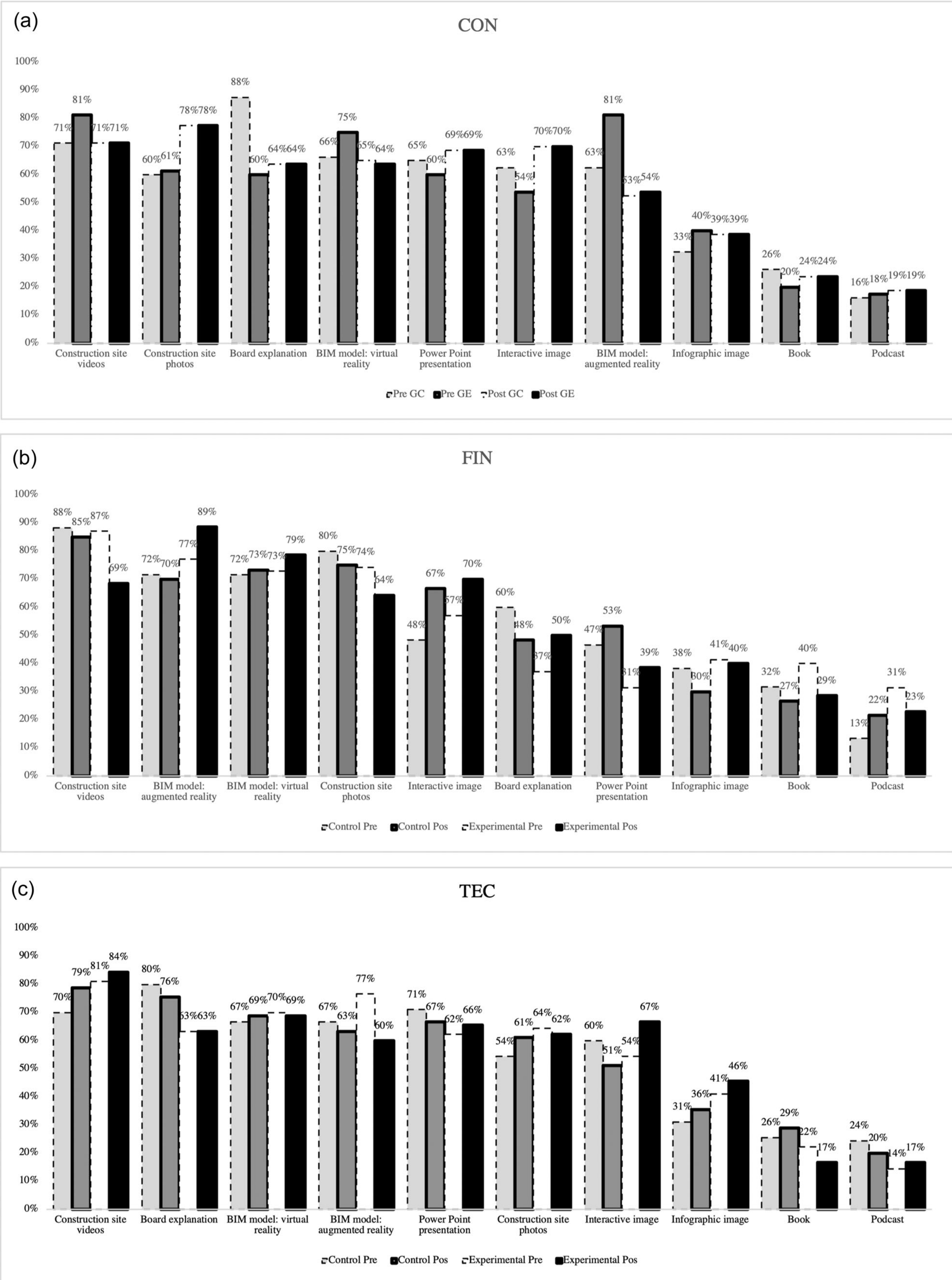


FIGURE 3 Technologies in app Question A (a) CON course, (b) FIN course, (c) TEC course.

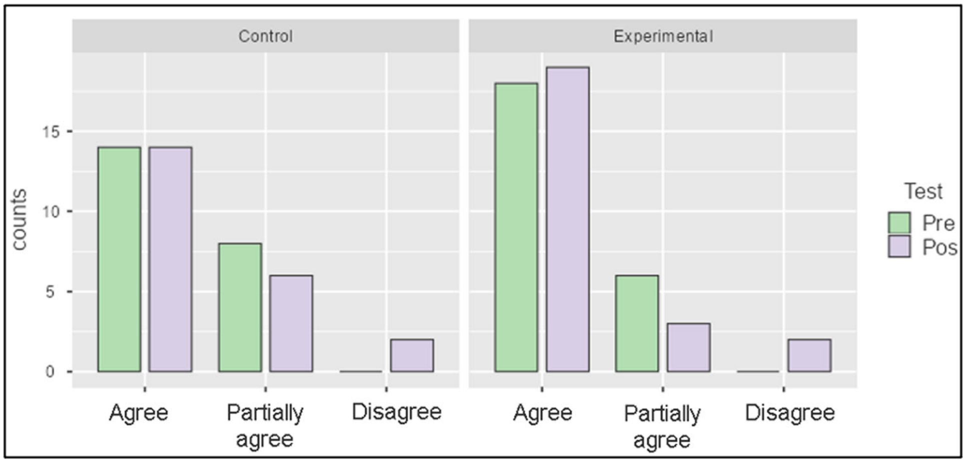


FIGURE 4 Technologies question B results.

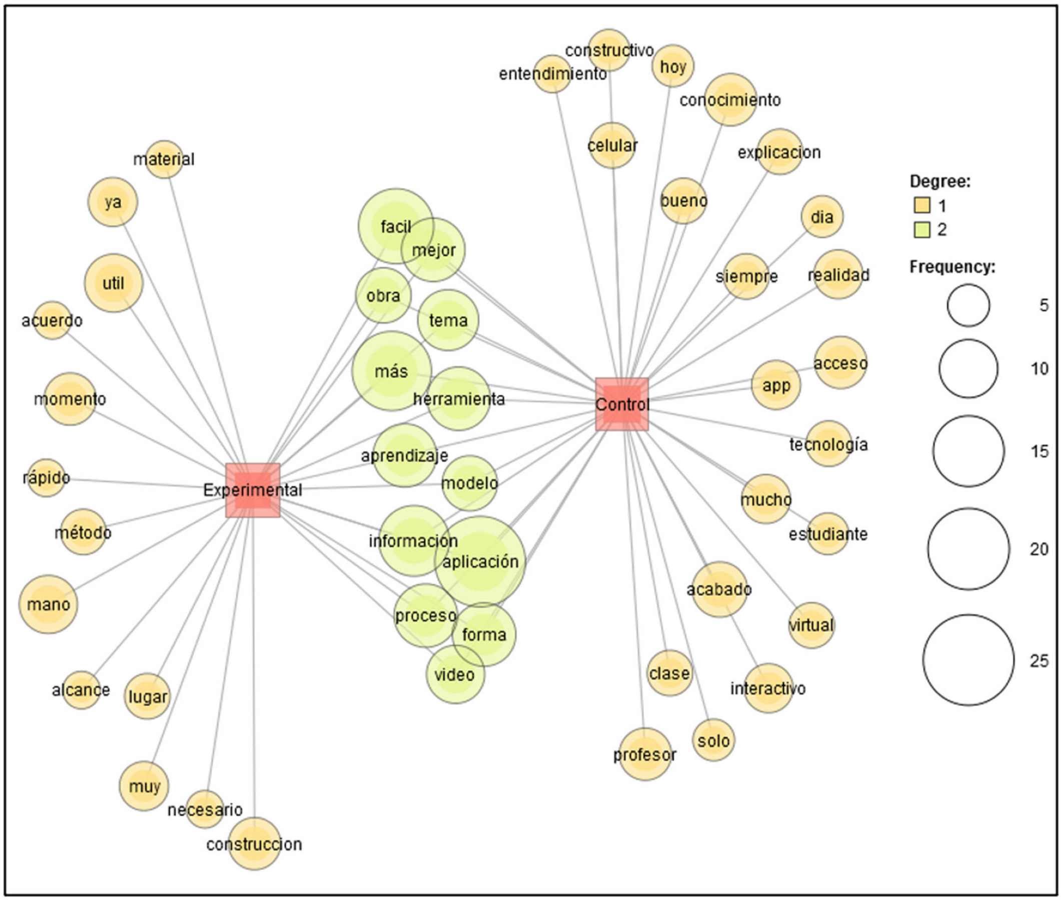


FIGURE 5 Technologies Question C results. The color scheme represents the closely associated parts of the network. The square represents the control and experimental groups. The circles indicate nodes of the most frequently mentioned words by the participants, with green circles representing words that co-occur in both control and experimental groups. The network consists of 49 nodes, 60 edges, and a network density of 0.051. A Jaccard filter was used. The units of analysis were the words.

reality. However, the importance of having the guidance and explanation of the teacher for better understanding is also mentioned, along with the need to combine the use of applications with practical experiences on-site. While some students believe that applications can replace the presence on construction sites, others point out that these tools should be complementary and supported by up-to-date and quality content. Additionally, the importance of an intuitive interface and interactive features to maintain interest and learning is emphasized. In general, the potential of mobile applications as learning tools is recognized, but there is an emphasis on the need for appropriate integration into the educational methodology and the support and knowledge of professionals in the field of construction.

6 | CONCLUSION

This article analyzes the results obtained from the performance evaluations of architecture students from different terms and various construction-related subjects, based on the quantitative and qualitative analysis of pretest posttest control and experimental groups using an app that showcases construction micro activities processes through different technologies.

Following the concept of transforming classrooms into playful and dynamic environments for students has been a recent trend in many academic institutions worldwide. The use of new teaching methodologies and the application of technologies such as BIM, virtual and augmented reality, and even immersive 360° models pose a challenge. Teaching construction and structures in general within architecture and engineering faculties require a consolidation of theoretical knowledge that can be applied in subsequent exercises within a project, thereby acquiring the necessary skills and practical experience.

This study addresses the implementation of a mobile application and the design of a virtual platform with construction-related content using various technologies such as videos, 360° photos, BIM models, virtual and augmented reality, and infographics linked to books that deepen knowledge within the university library. In this app, students are responsible for their own trajectory within the proposed content and can control each of the construction micro processes narrated through different digital and immersive media from their mobile devices. The main objective of CAMPUS Javeriana is to enable students, professors, and researchers to explore building construction processes within the university campus that are susceptible to understanding and are also an integration of technology with processes carried out in a real construction environment. The app allows for the integration of stakeholders within the university setting, bringing construction projects closer to the classroom and implementing innovative solutions with an aesthetic appearance aligned with the expected learning results of different construction subjects.

This research also presented quantitative evaluations of the benefits of technologies in various construction-related contents and the effectiveness of each technology on students before and after implementing a knowledge assessment, especially through learning gain index. The findings of these tests were collected through students' responses to online forms (Microsoft Forms) and were administered to students from three different academic semesters of the architecture program (second, fourth, and sixth-eighth terms) during the second semester of 2022, which coincided with the implementation and launch date of the application.

Based on the tests conducted to answer the research question RQ1: "How can the combination of alternative teaching methods and technology improve architecture and construction students' understanding and application of concepts in the fields of construction and architecture?", the following conclusions can be drawn:

Since the students of the CON subject are in the second semester of the architecture course and traditional teaching methods were used for the control group, and only for the experimental group the mobile application was used as a learning tool, it is concluded that for the whole questionnaire there is a marked difference of improvement in the experimental group. Out of the 11 questions, 100% of the answers were improved, on average 2.3 points higher than the results obtained in the pretest. This is evidenced also in the learning gain, where results for the pretest group are positive for some questions and negative for others, while for the posttest group all learning gain indexes are positive. This may be because the students are starting their professional career and in their first year they still have a lot of knowledge to learn in the area of construction and technologies. In general, they were inclined toward the use of construction site videos in the teaching of a construction subject with several benefits that could be translated into an improvement in the performance of the students. The contents asked in this questionnaire allude to construction site micro-activities that are generally taught in the classroom through power point presentations as the student very rarely attends the construction site. CAMPUS Javeriana becomes the experiential learning tool, since by watching the videos and going through the content, students can virtually experience the construction processes, even if they do not have the opportunity to do it physically. The last two questions of the questionnaire had a higher level of difficulty as these dealt with contents not yet deepened within the subject as first-year students, but having them as contents within the App, it was decided to include them within the evaluation. Although they are asked about the usefulness of the audio capsules for learning construction, a minimum percentage agrees with the usefulness these can have in learning. In conclusion, the application proves the effectiveness of using new technologies in learning construction processes in a subject such as CON and the micro-activities that make up these processes on a worksite.

Regarding the FIN course, the integration of alternative teaching methods, specifically through the use of the CAMPUS Javeriana mobile application, has demonstrated significant improvements in the understanding of the concrete polishing process among students. The experimental group, which utilized the application, achieved 100% accuracy in comprehending the reasons for performing concrete polishing, while the control group showed limited improvement. Additionally, the control and experimental groups initially lacked knowledge regarding the most efficient tools for achieving polished concrete finishes. However, after utilizing the CAMPUS Javeriana application, both groups significantly improved their understanding of the necessary tools. Furthermore, the experimental group displayed notable advancements in comprehending the benefits of polished concrete in spaces like building parking lots. The posttest results indicated that the experimental group as a whole achieved a higher level of understanding compared to the control group, which received traditional teaching methods. This result is evident in the learning gain index, where 80% of questions had a positive outcome. However, it is important to note that some control group members still lagged behind, highlighting the limitations of traditional teaching approaches. The experimental group showed a slight improvement regarding the knowledge of processes preceding the application of polyurea waterproofing. Although the results were not as significant as in other areas, the CAMPUS Javeriana application facilitated a more visual and experiential learning experience, which is crucial for understanding construction processes. The control and experimental groups exhibited conceptual gaps in their understanding of the main characteristics of waterproofing with polyurea. This suggests that there is room for improvement in teaching this specific aspect of construction. However, using the CAMPUS Javeriana application presents an opportunity to address these gaps and provide a more comprehensive understanding of the benefits and behavior of polyurea waterproofing. In conclusion, the combination of alternative teaching methods, specifically by using the CAMPUS Javeriana mobile application, has shown promising results in enhancing architecture and construction students' understanding and application of concepts in the fields of construction and architecture. The application has proven effective in improving knowledge of concrete polishing, construction tools, polished concrete benefits, and certain aspects of waterproofing. However, further research and refinement of teaching methods are necessary to address remaining gaps and ensure a comprehensive understanding of architectural finishes and construction processes.

In terms of the TEC course, the results are not conclusive. Four of the six questions have results with no evidence about a major influence of the mobile app on the students learning. Only two answers present a high improvement in the experimental group, that is, after the training with the CAMPUS Javeriana app. This phenomenon can be explained as the students in this course have greater learning in construction processes and are already in a stage in their architecture undergraduate programs where theoretical contents are already covered, and their focus is on the project's proposal, a greater level in the Bloom's taxonomy of learning objectives. On the other hand, the app does not cover any creative or proactive content or activity, identifying this aspect as a limitation of the CAMPUS Javeriana mobile app. Future studies are encouraged to address this issue.

Finally, to answer RQ2: "What are the perceptions of architecture and construction engineering students considering technology mediating their learning experience and how these can impact their learning outcomes?", in terms of the questions related to technology use, students' perceptions are better for "construction site videos," and worst for "podcasts", "books", and "infographic images", to learn about construction processes, in all three courses. Multimedia means have a greater ranking compared to the static, mono-media means, demonstrating a stronger perception in multi-media means in mobile apps for better learning outcomes. However, in two out of the three courses, "whiteboard explanation" was ranked among the first three more useful technologies, preserving the powerful validity of this traditional mean. On the other hand, a great percentage of students agree with the statement "a mobile application is a useful tool to learn about construction-related topics," linking this answer to the terms "more", "tool", "better", "information", "application," "process", among others, highlighting the importance of the mobile apps as complementary tools to up-to-date and quality content.

Going back to the tests results, the use of the mobile application for learning constructive processes resulted in a significant increase in the Learning Gain Index of students, not only from the first academic semesters but also from courses with more advanced students. Students who used the mobile application showed an average improvement in their knowledge and skills related to constructive processes compared to those who did not use the application. A positive correlation was observed between the frequency of app use and an increase in the Learning Gain Index, suggesting that greater exposure to the app was associated with greater learning gains. This is linked to the fact that the app is currently in the development of its second phase and will be associated with more academic content relevant to learning constructive processes where the results of the students in terms of satisfaction with the mobile application will be considered, highlighting its ease of use, interactivity, and relevance to their learning.

The mobile application proved to be an effective tool to enhance the learning of construction processes among students by providing an accessible and engaging medium for the acquisition of knowledge and practical skills, and the implementation of the mobile application could contribute to reducing the knowledge gap among students in educational settings where access to traditional learning resources is limited. The increase in the Learning Gain index suggests that the mobile application can potentially improve academic outcomes and student performance in courses related to construction, architecture, and engineering.

As future lines of research, our objective is to incorporate more immersive content within the mobile application that directly relates to theoretical subjects in the technical and construction areas, reaching both civil engineering and architecture students. We suggest to explore the integration of emerging interface technologies, such as immersive AR models, real-time monitoring with digital twins, and procedure tracking with robots on construction sites, to better understand the impact of digital technologies in construction education exploring other trending technologies as they continue to develop.

ACKNOWLEDGMENTS

This research was funded by the Pontificia Universidad Javeriana Research Vice-Rectory under grant #20297—for research-creation projects. The authors would like to thank Professor Juan Cuberos for the conception and original idea of the project, the Center for Teaching, Learning, and Evaluation (CAE + E) of the Pontificia Universidad Javeriana, Colombia, for their assessment and support of this study, Julián Buriticá and Leonardo Saavedra for the collection and organization of the construction processes data under the architecture practice program, the Facilities Direction of the Pontificia Universidad Javeriana for their constant support and construction information delivery, and all the students and professors participating on the study.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data supporting the findings of this study are available upon request.

ORCID

Carolina Valbuena-Bermúdez http://orcid.org/0000-0003-1592-1008
Natalia E. Lozano-Ramírez http://orcid.org/0000-0003-4932-675X
Alejandro Serrano-Sierra http://orcid.org/0009-0005-5848-2561
César Granados-León http://orcid.org/0000-0002-1696-1311

REFERENCES

1. J. M. Aguado, I. J. Martínez, and L. Cañete-Sanz, *Tendencias evolutivas del contenido digital en aplicaciones móviles*, El Profes. Inform. **24** (2015), 787–796. https://doi.org/10.3145/EPI.2015.NOV.10
2. J. Aliu and C. Aigbavboa, *Reviewing the trends of construction education research in the last decade: A bibliometric analysis*, Internat. J. Construct. Manage. **23** (2021), 1571–1580. https://doi.org/10.1080/15623599.2021.1985777
3. G. Bravo, D. Cifuentes, and R. Villazón, Authoring tools for KOC—A knowledge repository to teach building construction. Proc. 4th ICSOFT, DBLP, Sofia, 2009.
4. G. Campagnol, S. Caffey, M. J. Clayton, K. Glowacki, N. Klein, J. Kang, and G. Booth, *Unreal projects: Using immersive visualization to learn about distant and historical locales*. Digital Cities, 2020, pp. 279–298. https://doi.org/10.1093/OSO/9780190498900.003.0014
5. E. Corral Abad, M. J. Gómez García, E. Diez-Jimenez, P. M. Moreno-Marcos, and C. Castejón Sisamon, *Improving the learning of engineering students with interactive teaching applications*, Comput. Appl. Eng. Educ. **29** (2021), 1665–1674. https://doi.org/10.1002/cae.22415
6. E. Corral Abad, M. J. Gómez García, R. Ruiz Blázquez, C. Castejon, and J. C. García-Prada, *Effects of an android app on mechanical engineering students*, Comput. Appl. Eng. Educ. **26** (2018), 1050–1057. https://doi.org/10.1002/cae.21955
7. J. Cuberos, C. Valbuena-Bermúdez, and N. E. Lozano-Ramírez, CAMPUS Javeriana IOS App. https://apps.apple.com/co/app/campus-javeriana/id1591306355?l=en (accessed 29 June 2023).
8. J. Cuberos, C. Valbuena-Bermúdez, and N. E. Lozano-Ramírez, CAMPUS Javeriana Android App. https://play.google.com/store/apps/details?id=com.Javeriana.Campusjaveriana&hl=es_CO&gl=US (accessed 29 June 2023).
9. S. Deb, D. W. Carruth, R. Sween, L. Strawderman, and T. M. Garrison, *Efficacy of virtual reality in pedestrian safety research*, Appl. Ergon. **65** (2017), 449–460. https://doi.org/10.1016/J.APERGO.2017.03.007
10. L. De-Marcos, J. R. Hilera, R. Barchino, L. Jiménez, J. J. Martínez, J. A. Gutiérrez, J. M. Gutiérrez, and S. Otón, *An experiment for improving students performance in secondary and tertiary education by means of M-learning auto-assessment*, Computer. Educ. **55** (2010), 1069–1079. https://doi.org/10.1016/j.compedu.2010.05.003
11. P. Dugard and J. Todman, *Analysis of pre-test-post-test control group designs in educational research*, Educ. Psychol. **15** (1995), 181–198. https://doi.org/10.1080/0144341950150207
12. S. Eloy, M. S. Dias, P. F. Lopes, and E. Vilar *Digital technologies in architecture and engineering: exploring an engaged interaction within curricula*. Architecture and Design: Breakthroughs in Research and Practice, IGI Global, 2019, pp. 390–426. https://doi.org/10.4018/978-1-5225-7314-2.CH014.
13. S. Eloy, P. F. Lopes, T. M. Pedro, L. Ourique, and L. S. Dias Mobile Apps for Acting on the Physical Space. In *Mobile Applications and Solutions for Social Inclusion*; IGI Global, 2018, pp. 48–82. ISBN 9781522552703.

14. A. Firipis, S. Chandrasekaran, and M. Joordens, *Influence of critical thinking on creativity when using mobile devices for learning*, Asian Education Studies **3** (2018), 40. https://doi.org/10.20849/aes.v3i2.366
15. J. Fombona-Cadavieco and M.Á. Pascual-Sevillano, *Beneficios del M-learning en la educación superior benefits of m-learning in higher education*, Educatio Siglo XXI **31** (2013), 211–234.
16. M. Forehand, *Bloom's Taxonomy: Original and Revised*, *Emerging perspectives on learning, teaching, and technology* (M. Orey, ed.) 2005.
17. A. Hajirasouli and S. Banihashemi, *Augmented reality in architecture and construction education: state of the field and opportunities*, Internat. J. Educ. Technol. Higher Educ. **19** (2022), 39. https://doi.org/10.1186/S41239-022-00343-9/FIGURES/9
18. R. R. Hake, *Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses*, Am. J. Phys. **66** (1998), 64–74. https://doi.org/10.1119/1.18809
19. Y. C. Hsu, K. Rice, and L. Dawley, *Empowering educators with google's android app inventor: an online workshop in mobile app design*, Br. J. Educ. Technol. **43** (2012), E1–E5. https://doi.org/10.1111/J.1467-8535.2011.01241.X
20. G. J. Hwang and C. C. Tsai, *Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010*, Br. J. Educ. Technol. **42** (2011), E65. https://doi.org/10.1111/j.1467-8535.2011.01183.x
21. M. S. Khudoykulovich and F. Z. X. kizi, *Content of the science of architecture construction and its current status of teaching*, Internat J. Innov. Anal. Emerg. Technol. **1** (2021), 106–114.
22. M. Lebedeva, M. Taranova, and V. Beketov, *Assessment of academic achievements in M-learning*, Educ. Inform. Technol. **28** (2022), 5945–5965. https://doi.org/10.1007/s10639-022-11423-8
23. M. Y. Leung, Y. Wang, and D. K. K. Chan, *Structural surface-achieving model in the teaching and learning process for construction engineering students*, J. Profession. Issue Eng. Educ. Pract. **133** (2007), 327–339. https://doi.org/10.1061/(ASCE)1052-3928(2007)133:4(327)
24. E. Pacheco, M. Lips, and P. Yoong, *Transition 2.0: digital technologies, higher education, and vision impairment*, The Internet Higher Educ. **37** (2018), 1–10. https://doi.org/10.1016/j.iheduc.2017.11.001
25. S. Y. Park, M. W. Nam, and S. B. Cha, *University students' behavioral intention to use mobile learning: evaluating the technology acceptance model*, Proc. Br. J Educ. Technol. **43** (2012), 592–605.
26. G. Penello Temporão and A. M. Beltran Pavani, *Tailoring Apps and podcasts for Mobile learning in engineering education*, INTED Proc., vol. 1, IATED, March 24, 2020, pp. 5203–5208.
27. P. Prendes Espinosa and F. Cerdán Cartagena, *Tecnologías avanzadas para afrontar el reto de la innovación educativa*, RIED **24** (2020), 35–53. https://doi.org/10.5944/ried.24.1.28415
28. C. M. Rodriguez Bernal, *Student-centred strategies to integrate theoretical knowledge into project development within architectural technology lecture-based modules*, Arch. Eng. Design Manage. **13** (2016), 223–242. https://doi.org/10.1080/17452007.2016.1230535
29. C. M. Rodríguez-Bernal, *Plataforma Interactiva Sobre Procesos de Construcción de Elementos Arquitectónicos.* In *Innovate 330 Investigando la innovación con TIC en Educación*, A. H. Galvis Panqueva, O. Mariño Drews, and L. A. Osorio Gómez (eds.), 2016; pp. 60–65.
30. T. Sánchez Botero *Aplicación de La Realidad Virtual En La Enseñanza de La Ingeniería de Construcción*, Universidad EAFIT, Medellín, 2014.
31. T. Sánchez-Botero, and L. F. Botero-Botero, La realidad virtual inmersa como herramienta de aprendizaje en la arquitectura, la ingeniería civil y la ingeniería de la construcción, Arquitek, 2017, pp. 9–19.
32. T. Sánchez-Botero, E. D'paola-Puche, and L. F. Botero-Botero, Building information modeling como nueva tecnología en la enseñanza de la ingeniería civil, la arquitectura y la construcción, Arquetipo, 2015, pp. 87–110.
33. J. R. Sarmiento Guede and A. Barceló Hernando, *El uso de las tecnologías en la innovación docente*, Dykinson, Madrid, 2020.
34. I. Simonova and P. Poulova, *Mobile Devices and Applications Enhancing Engineering Education in ESP*, Proc. 2016 13th Int. Conf. Remote Eng. Virtual Instrument., REV 2016, Institute of Electrical and Electronics Engineers Inc., March 30 2016, pp. 163–167.
35. J. Valverde-Berrocoso, M. R. Fernández-Sánchez, and M. C. Garrido-Arroyo, *El pensamiento computacional y las nuevas ecologías del aprendizaje*, Revista de Educación a Distancia (RED), 2015. https://doi.org/10.6018/red/46/3
36. A. Villegas-Hortal, Realidad virtual en el sector de la construcción, Universidad EAFIT, Medellín, 2012.
37. I. S. H. Wai, S. S. Y. Ng, D. K. W. Chiu, K. K. W. Ho, and P. Lo, *Exploring undergraduate students' usage pattern of mobile apps for education*, J. Librarianship Inform. Sci. **50** (2016), 34–47. https://doi.org/10.1177/0961000616662699
38. Y. C. Wu and J. C. Yang, The effects of the social media-based activities and gaming-based learning in construction education, Proc. 2015 IIAI 4th Int. Congress Adv. Appl. Inform., IIAI-AAI 2015, Institute of Electrical and Electronics Engineers Inc., January 6, 2016, pp. 323–328.
39. N. S. Zabidin, S. Belayutham, and C. K. I. Che Ibrahim, *A bibliometric analysis of industrial revolution (IR) 4.0 in construction engineering education*, MATEC Web of Conf. **266** (2019), 05006. https://doi.org/10.1051/MATECCONF/201926605006
40. S. Zhang, *Mobile English learning: an empirical study on an APP, English fun dubbing*, Int. Emerg. Technol. Learn. (iJET) **11** (2016), 4–8. https://doi.org/10.3991/ijet.v11i12.6314
41. L. Zheng, K. Chen, and W. Lu, *Bibliometric analysis of construction education research from 1982 to 2017*, J. Profession. Issue Eng. Educ. Pract. **145** (2019), 04019005. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000412
42. J. M. Zydney and Z. Warner, *Mobile apps for science learning: review of research*, Comput. Educ. **94** (2016), 1–17. https://doi.org/10.1016/J.COMPEDU.2015.11.001

How to cite this article: C. Valbuena-Bermúdez, N. E. Lozano-Ramírez, A. Serrano-Sierra, and C. Granados-León, *CAMPUS: A mobile app for construction processes learning and teaching in higher education*, Comput. Appl. Eng. Educ. (2024); e22739. https://doi.org/10.1002/cae.22739

APPENDIX

See Tables A1, Figure A1, Table A2–A4.

TABLE A1 Microactivities included in app and its means.

#	Building	Category places	Modality	Construction phase	Microactivity	Type of content	Media used in the content
1	Ed. 125	Buildings	New construction site	Foundations and structure	Concrete vibrating	Constructive	Infographics
2	Ciencias	Buildings	New construction site	Foundations and structure	Lifting of beams	Constructive	Infographics
3	Ed. 125	Buildings	New construction site	Foundations and structure	Concrete polishing	Constructive	360°
4	Ciencias	Buildings	New construction site	Foundations and structure	Steel Figured	Constructive	360°
5	Ed. 125	Buildings	New construction site	Foundations and structure	Top Down System	Constructive	Model
6	Maldonado	Buildings	structural reinforcement	Architectural finishes	Reinforcement of wall and plaster	Constructive	360°
7	Giraldo	Public squares	work adaptations	Architectural finishes	Waterproofing of small square	Constructive	interactive image
8	Ingenieria	Laboratories	Laboratories and testing	N/A	Shear walling	test	Infographics
9	Ingenieria	Laboratories	Laboratories and testing	N/A	Fiber-reinforced concrete casting	test	Infographics
10	Plazoleta Ed. Ciencias	Public squares	Historical	N/A	N/A	Model	Virtual Reality (VR)
11	Facultad Arquidiseño	Public squares	Historical	N/A	N/A	Interview	360° + Audio capsules
12	Artes	Buildings	Historical	Architectural finishes	Soundproof booth	Model	Augmented reality
13	Artes	Buildings	Historical	Architectural finishes	Skylights	Model	Augmented reality
14	HUSI	Buildings	work adaptations	Networks and installations	Installation of sanitary networks	Constructive	Infographics
15	Maldonado	Buildings	Demolition	Preparatory phase	Demolition of mortar layer	Constructive	Infographics
16	Ed. Central	Buildings	work adaptations	Foundations and structure	Reinforcement of mezzanine plate	Constructive	Infographics
17	Ed. Ciencias	Buildings	New construction site	Architectural finishes	Light walls	Constructive	Augmented reality
18	Ed. Ciencias	Buildings	New construction site	Networks and installations	Electrical networks (EMT)	Constructive	Infographics
19	Ed. Ciencias	Buildings	New construction site	Architectural finishes	Wall plastering	Constructive	Interactive image
20	Ed. 125	Buildings	New construction site	Architectural finishes	Façade staking	Constructive	360°

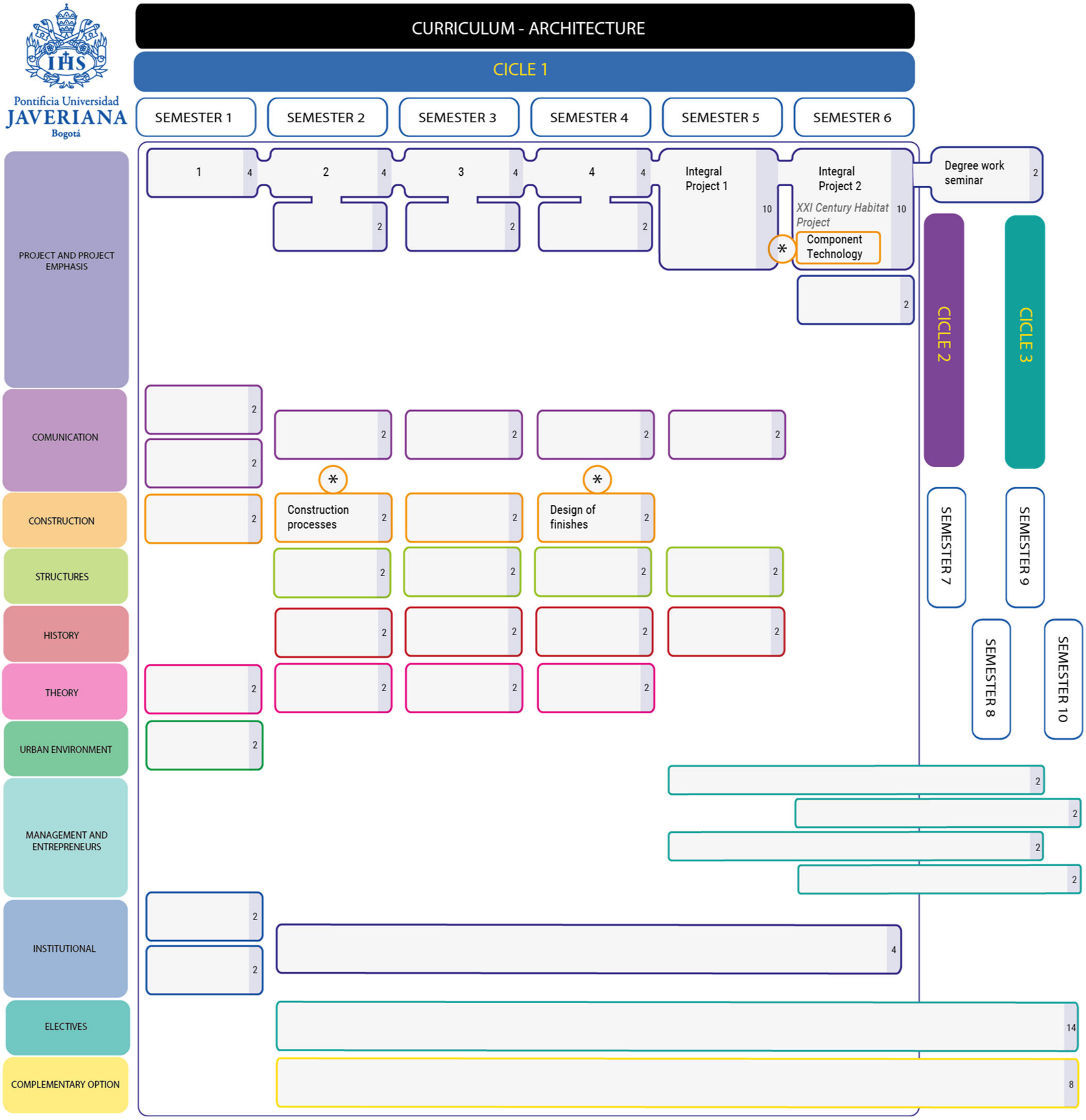


FIGURE A1 Architecture curricula.

TABLE A2 CON tests characteristics.

CON control group Sample size: 12 students (2nd to 3rd semester)	
Pretest application 15th October, 2022	No previous lecture on the topic Previous explanation ** 60 min to respond
Posttest application 16th October 2022	Previous project activity with traditional supporting tools (books, lecture presentations, whiteboard notes) 60 min to respond
**Classroom explanation of construction processes involving tools, materials, processes, and resources of a specific activity at the construction site.	
CON experimental group Sample size: 8 students (2nd to 3rd semester)	
Pretest application 15th October, 2022	No previous lecture on the topic 60 minutes to respond
Posttest application 16th October 2022	Previous project activity with innovative supporting tools (CAMPUS mobile app) 60 minutes to respond

CON test (Answer type: Open-ended)

Construction activity contentTechnology **General ELR**	***Subject***	***Specific ELR***	***Hypothesis***	***Question***
Concrete vibrated content *infographic* ELR: Distinguish the resources that an activity consumes, so that in the professional exercise can control and quantify the necessary materials in the construction and its processes.	Construction processes	Identify integrally the work specifications.	In the concrete polishing content, the student will be able to explain the differences between external vibrating and immersion vibrating.	Among the most important micro-activities of the concrete construction process is the vibrating stage. Explain the differences between external vibrating and immersion vibrating.
	Construction processes	Distinguish the resources that an activity consumes, so that in the professional exercise can control and quantify the necessary materials in the construction and its processes.	In the concrete polishing content, the student will be able to are the benefits of using the flexible shaft internal vibrator within a concrete mix.	What are the benefits of using the flexible shaft internal vibrator within a concrete mix?

TABLE A2 (Continued)

CON test (Answer type: Open-ended)				
Construction activity contentTechnology **General ELR**	***Subject***	***Specific ELR***	***Hypothesis***	***Question***
Beam lifting *Infographic* ELR: To develop an ethical position to the asymmetries generated by the high differences in the habitat conditions of the city, from an equity perspective	Steel structures—construction processes	Distinguish the resources that an activity consumes, so that in the professional exercise can control and quantify the necessary materials in the construction and its processes.	In the beam lifting content, the student will be able to analyze the on-site implications of the selection of a structural steel system, and explain in their own words the activity, using technical vocabulary, proper names of materials and equipment	If the image describes the activity of lifting beams, explain in your own words the activity, using technical vocabulary, proper names of materials and equipment, so that an official or construction worker can understand the activity you are referring to.
	Steel structures —construction processes	Apply the knowledge to make a list of work with the supporting tables of the quantities of work of each of the activities by chapter.	In the beam lifting content, the student will be able to Describe the main elements necessary for the procedure and the personnel you would need for the lifting of a structural steel beam., through the initial video and a complementary infographic.	Imagine what is to initiate the hoisting of a building structure. Describe the main elements necessary for the procedure and the personnel you would need for the lifting of a structural steel beam.
Steel figured *360° view* ELR: To understand the complexity of habitat issues in the 21st century based on an integral approach from the different components of the project, urban planning, environment, technical infrastructure, management processes and socio-cultural and aesthetic framework.	Interior partitions—construction process, reinforcement and its influence on finishes	Identify integrally the work specifications.	In the content of wall and plaster reinforcement, the student will be able to explain what is figured steel., through the initial video and a complementary 360° view.	Explain what is figured steel.
	Architectural finishes - construction process	Distinguish the resources that an activity consumes, so that in the professional exercise can control and quantify the necessary materials in the construction and its processes.	In the content of wall and plaster reinforcement, the student will be able to evaluate the need for wall reinforcement according to the finishes to be implemented and to name which elements constitute a steel reinforcement, through the initial video and a complementary 360° view.	Name what elements/components constitute a steel reinforcement for an object constructed in reinforced concrete.

(Continues)

TABLE A2 (Continued)

CON test (Answer type: Open-ended)				
Construction activity contentTechnology General ELR	***Subject***	***Specific ELR***	***Hypothesis***	***Question***
Wall reinforcement *360° view*	construction process	Identify integrally the work specifications.	In the content of wall and plaster reinforcement, the student will be able to place in the proper order each of the steps to perform this construction process., through the initial video and a complementary 360° view.	According to the wall reinforcement activity, place in the proper order each of the steps to perform this construction process. Place in first place the process by which you would start and then proceed in its order of execution.
	construction process,	Apply the knowledge to make a list of work with the supporting tables of the quantities of work of each of the activities by chapter.	In the content of wall and plaster reinforcement, the student will be able to evaluate the need for wall reinforcement according to the finishes to be implemented, through the initial video and a complementary 360° view.	What is the main intention of reinforcing an existing masonry wall with electrowelded mesh?
Waterproofing of small squares *Interactive image*	construction process,	Apply the knowledge to make a list of work with the supporting tables of the quantities of work of each of the activities by chapter.	In the content of waterproofing of small squares, the student will be able to place in the proper order each of the steps to perform this construction process, through the initial interactive image.	According to the activity of applying polyurea and primer, place in the proper order each of the steps to perform this construction process. At the beginning drag the first process and then proceed in its order of execution.
Fiber reinforced concrete casting *Infographic*	construction process,	Distinguish the resources that an activity consumes, so that in the professional exercise can control and quantify the necessary materials in the construction and its processes.	In the Fiber reinforced concrete casting content, the student will be able to explain the constructive process performed for the casting of steel fiber reinforced concrete elements, through the initial video and a complementary infographic.	Explain the constructive process performed for the casting of steel fiber reinforced concrete elements.
	construction process,	Identify integrally the work specifications.	In the Fiber reinforced concrete casting content, the student will be able to explain the constructive process performed for the casting of steel fiber reinforced concrete elements, through the initial video and a complementary infographic.	For a steel fiber concrete casting process, should an immersion vibrator be used? Choose which of the options is the most correct.

TABLE A3 FIN tests characteristics.

FIN control group Sample size: 13 students (3rd to 4th semester)	
Pretest application 6th October, 2022	No previous lecture on the topic 20–30 min to respond
Posttest application 8th October, 2022	Previous project activity with traditional supporting tools (books, lecture presentations, whiteboard notes) 30–45 min to respond
FIN experimental group Sample size: 13 students (3rd to 4th semester)	
Pretest application 6th October, 2022	No previous lecture on the topic 20–30 min to respond
Posttest application 8th October, 2022	Previous project activity with innovative supporting tools (CAMPUS Javeriana mobile app) 30–45 min to respond

FIN test (Answer type: Multiple choice)

Construction activity content **General ELR**	***Subject***	***Specific ELR***	***Hypothesis***
Concrete polishing *360° view* and infographics ELR: Formulate approaches at the level of constructive detail in plan and elevation, in which students give an account of the understanding of the different systems and processes that are involved in the coating of an architectural project, without neglecting the economic feasibility and use of technologies appropriate to the proposal.	Foundation and structures	Foment approaches to determine which are the stages for the elaboration of the concrete polishing process, the importance of this activity and the tools used for its realization.	In the content of concrete polishing, the student will be able to determine the importance of concrete polishing within the construction stage of architectural finishes and identify the inputs associated with its execution through the initial video and a 360 photograph and explanatory infographics. **Questions**: **1**. What are the most important reasons to perform the concrete polishing process? **2**. Which of the following tools is the most efficient for the concrete polishing process?
	Architectural finishes	Evidence of what are the benefits of finishing concrete polishing in terms of its maintenance and economic viability.	The student will be able to identify the qualities of architectural finishes, in terms of durability, cost and benefits. This will incorporate the finish as part of the architectural project in an integral way. **Questions**: **1**. What are the main benefits of the behavior of polished concrete in spaces such as building parking lots?
Soundproof booth *Augmented reality (AR)* ELR: Differentiate the multiple possibilities in the use of	Structures and finishes—construction processes	Analyze the construction process, materials and finishes of the soundproof booths on site.	In the content of soundproofing of spaces, the student will be able to identify the parts, components and materials that

(Continues)

TABLE A3 (Continued)

FIN test (Answer type: Multiple choice) ***Construction activity content*** **General ELR**	***Subject***	***Specific ELR***	***Hypothesis***
materials and design a comprehensive architectural proposal that provides solutions to the particular problems of each object of study.			allow to acoustically isolate a space through augmented reality. **Question**: Draw below the section of a wall of a music booth, considering the following materials that are in a random order: -Freshhouse −20 caliber gauge stainless steel studs −5/8" gypsum sheet -Gypsum panel covered with textile -Wood panels -GRC panel -Superboard sheet 9 mm
Square waterproofing *Infographic* ELR: Distinguish the operation of architectural finishes from a historical and cultural journey, and the understanding of the physical, chemical, mechanical, technological, sensory and ecological characteristics of the materials. In the same way, it will be done from an assessment of use, place and appearance.	Structures and finishes—construction processes	Relate and distinguish the construction processes, as well as protective implements and equipment for the application of polyuria and waterproofing. Relate these aspects with sustainability, chemistry and material mechanics.	The student will identify the materials, equipment, tools, personal protection elements and labor that is needed for this construction process and will know which are the phases for the correct application of the primer and the polyuria on the mortar cake to be able to waterproof the square through an initial video and explanatory infographics. **Questions**: **1**. Which of the following processes should be done immediately before applying a polyuria waterproofing? **2**. What are the main characteristics of waterproofing with polyuria?

TABLE A4 TEC tests characteristics.

Control group Sample size: 14 students (5th to 8th semester)				
Pretest application 6th October, 2022			No previous lecture on the topic 20–30 min to respond	
Posttest application 13th October, 2022			Previous project activity with traditional supporting tools (books, lecture presentations, whiteboard notes) 30–45 min to respond	
Experimental group Sample size: 14 students (5th to 8th semester)				
Pretest application 6th October, 2022			No previous lecture on the topic 20–30 min to respond	
Posttest application 13th October, 2022			Previous project activity with innovative supporting tools (CAMPUS Javeriana mobile app) 30–45 min to respond	
TEC test (Answer type: Open-ended) ***Construction activity content Technology*** **General ELR**	***Subject***	***Specific ELR***	***Hypothesis***	***Question***
Concrete polishing *360° view* ELR: To develop an ethical position to the asymmetries generated by the high differences in the habitat conditions of the city, from an equity perspective	Concrete structures	Argue the selection of a structure and structural material related to the final finish it provides to a building	In the concrete polishing content, the student will be able to argue the selection of a structure and structural material related to the final finish it provides to a building, through the initial video and a complementary 360 view.	Explain why you would select a concrete structure whose final finish is "exposed concrete."
	Architectural finishes	Relate the selection of concrete as a structural material to the architectural concept.	In the concrete polishing content, the student will be able to relate the selection of concrete as a structural material with the architectural concept, through the initial video and a complementary 360 view.	Analyze the possible relationships between the architectural concept and the decision to leave the concrete exposed.
Beam lifting *Infographic* ELR: To develop an ethical position to the asymmetries generated by the high differences in the habitat	Steel structures—construction processes	Analyze the on-site implications of the selection of a structural steel system.	In the beam lifting content, the student will be able to analyze the on-site implications of the selection of a structural steel system, through the initial video and a complementary infographic.	When implementing a structural steel system, what implications should you consider on the construction site? Name two implications.

(Continues)

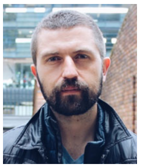
TABLE A4 (Continued)

TEC test (Answer type: Open-ended) ***Construction activity content Technology*** **General ELR**	***Subject***	***Specific ELR***	***Hypothesis***	***Question***
conditions of the city, from an equity perspective	Steel structures	Compare the work activity with respect to other activities related to the use of concrete as a structural material.	In the beam lifting content, the student will be able to compare the work activity with respect to others related to the use of concrete as a structural material, through the initial video and a complementary infographic.	Compare and describe three substantial differences of using steel versus concrete on a project.
Wall and plaster reinforcement *360° view* ELR: To understand the complexity of habitat issues in the 21st century based on an integral approach from the different components of the project, urban planning, environment, technical infrastructure, management processes and socio-cultural and aesthetic framework.	Interior partitions—construction process, reinforcement and its influence on finishes	Relate the decision to use certain types of internal partitions to their construction process according to their location in space.	In the content of wall and plaster reinforcement, the student will be able to relate the decision to use certain types of internal partitions with their construction process according to the location in space, through the initial video and a complementary 360° view.	Compare the construction process of a masonry wall located in a kitchen with built-in furniture and one located in a circulation hall, highlighting their differences.
	Architectural finishes	Evaluate the need for wall reinforcement according to the finishes to be implemented.	In the content of wall and plaster reinforcement, the student will be able to evaluate the need for wall reinforcement according to the finishes to be implemented, through the initial video and a complementary 360° view.	Evaluate whether you would need to reinforce any walls in your project and explain the reasons why you would need to do so.

AUTHOR BIOGRAPHIES

Carolina Valbuena-Bermúdez, Architect from Pontificia Universidad Javeriana PUJ, with a master's degree in Sustainable Project Development from Politecnico di Torino, Italy. Strong track record of over 8 years in leading sustainability strategies and promoting environmental conservation and adaptation projects. Has contributed to achieving the Sustainable Development Goals (SDGs) and establishing regulatory frameworks in Colombia and Latin America. She has a comprehensive approach that encompasses decarbonization of the built environment, leadership skills, agile project management, data analysis, and international development experience. Have reached management and leadership positions, developing a comprehensive profile in roles of sustainable and urban projects advisor, senior principal consultant for Sustainable Cities and Public Spaces, manager of innovation projects, leader of the sustainability fields, and she is currently (2024) a full-time professor in the Department of Architecture and the head of the Architecture Department at the Architecture and Design Faculty at PUJ.

Natalia E. Lozano-Ramírez, Architect and civil engineer from Pontificia Universidad Javeriana PUJ, with a master's degree in architecture, building, and planning from Politecnico di Torino. Professional experience in the development of interdisciplinary projects in the design sector, coordination, project management and BIM implementation, and academic experience in teaching, research, and consulting in the Departments of Architecture and Civil Engineering at PUJ. Leader in the development and appropriation of new technologies in construction participating in the BIM Academic Forum Colombia and working on research projects related to technology, construction, and structures, achieving publications in indexed journals, development of MOOCs, among others. She is currently (2024) a full-time professor in the Department of Architecture at PUJ, coordinator of the BIM certification at PUJ, and PhD student in Engineering at Universidad de los Andes.



Alejandro Serrano-Sierra, Architect from Pontificia Universidad Javeriana with a master's degree in Architecture and City Construction from the Politecnico di Torino, Italy. Currently, professor at Pontificia Universidad Javeriana. Experience in urban standard and design in popular habitat. As a contractor architect in the Caja de la Vivienda Popular, he participated in social projects such as the implementation of the Social Public Curator's Office and the District Terrazas Plan, as well as participation, through technical documents for the Land Management Plan (POT) 2022–2035, Bogotá Reverdece, in the chapter of Integral Improvement and habitability, through the document Typological Analysis for Architectural, Structural and Regulatory Guidelines District Terrazas Plan. Founder of the design studio Alejandro Serrano Studio and the collective Studio Hifa with emphasis on biomaterial developments, where organisms, architecture, art and design are integrated.

César Granados-León, PhD in Psychology with a focus on Consumer Behavior research, holds a master's in Strategic Marketing Management and brings over 10 years of experience in the industrial sector. He has collaborated with leading organizations such as Saint Gobain in Colombia, OSRAM Licht AG from SIEMENS, Bankinter, and Metalco Prolians in Spain. In addition, he has dedicated 11 years to teaching in professional and postgraduate programs in Marketing, Industrial Design, Economics, and Finance, both in face-to-face and virtual formats. Recognized as a speaker on topics related to Strategic Marketing Management, Integrated Marketing Communications, and Product Design, Experience, and Interface. His academic and professional expertise is reflected in two patents registered with the SIC, and he serves as the coordinator of the User Experience Laboratory at Universidad Javeriana.