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Aid-augmented reality for reinforced concrete class: students' perception

Realidad Aumentada en la enseñanza de hormigón reforzado: percepción de los alumnos

Dra. Gláucia Nolasco de Almeida Mello is a professor and researcher at Pontificia Universidad Católica de Minas Gerais (Brasil) (gnamello@pucminas.br) (gnamello@pucminas.br) (https://orcid.org/0000-0002-2865-8782)

Dr. Julio Cabero Almenara is a professor and researcher at Universidad de Sevilla (España) (cabero@us.es) (https://orcid.org/0000-0002-1133-6031)

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Abstract

For the structural engineer, spatial visualization ability is especially important for understanding the correct positioning of structural elements in a design. In order to improve the student's spatial visualization ability, in this investigation the development of activities was proposed using an application for mobile devices with the resources of Augmented Reality (AR). The activities were planned for the Reinforced Concrete subject in the eighth semester of the Civil Engineering course of the Pontifical Catholic University of Minas Gerais in Brazil. Eighteen students enrolled in that subject in the first semester of 2019 did the proposed activities. Four activities were developed using the RA resources for the Sketchfab application. The instrument chosen for the evaluation of student perception was a questionnaire based on the technology acceptance model (TAM), which was adapted in this study. By the students' answers about the usefulness and ease and intention of using the resources, it was concluded that the RA is an important resource to improve their spatial visualization ability because they facilitate the visualization of the details of the structures and make the learning more fun.

Keywords: Civil engineering, structural design, reinforced concrete, spatial visualization, augmented reality, computer assisted instruction.

Resumen

Para el ingeniero de estructuras, la habilidad de visualización espacial es especialmente importante para la comprensión del posicionamiento correcto de los elementos estructurales en un diseño. Así, para mejorar la habilidad de visualización espacial del alumno, en esa investigación fue propuesto el desarrollo de actividades utilizándose una aplicación para dispositivos móviles con los recursos de la Realidad Aumentada (RA). Las actividades fueron planeadas para la asignatura Hormigón Reforzado en el octavo semestre del curso de Ingeniería Civil de la Pontificia Universidad Católica de Minas Gerais en Brasil. Dieciocho alumnos matriculados en esa asignatura en el primero semestre de 2019 hicieron las actividades propuestas. Fueron elaboradas cuatro actividades utilizándose los recursos de RA para la aplicación Sketchfab. El instrumento elegido para la evaluación de la percepción del estudiante fue un cuestionario basado en el modelo de aceptación de tecnología TAM (*Technology Acceptation Model*), que fue adaptado en este estudio. Observándose las respuestas de los alumnos sobre la utilidad y facilidad e intención de uso de los recursos, concluyese que la RA es un recurso importante para mejorar la habilidad de visualización espacial de ellos pues facilitan la visualización de los detalles de las estructuras y hacen el aprendizaje más divertido.

Descriptores: Ingeniería civil, diseño estructural, hormigón reforzado, visualización espacial, Realidad Aumentada, informática educativa.

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1. Introduction

Buildings of concrete, steel, wood or other material structures with their complex arrangements of structuring elements are commonly represented in a set of two-dimensional drawings. These indicate the quantity, length and diameter of the steels, and also their positions within the structural elements. In universities, static, two-dimensional (2D) or three-dimensional (3D) drawings and images have been used to convey the complexity of steel arrangements and their modes of interaction. According to Fogarty, Mccormick and El-Tawil (2018), 2D rendering requires students to build an image of the structural element or set of various elements with limited information and experience. On the other hand, the emphasis on two-dimensional drawings of three-dimensional structures in civil engineering courses often hampers students' ability to spatially visualize arrangements. Visualizing spatial and complex arrays can be a challenge for some people when there is the deformation of these arrays in various load scenarios or other external stimuli. Maier (1994 *apud* Sorby, 2001) has indicated that activities involving 3D visualization are especially important for technological professions such as engineering, where spatial visualization ability (SVA) and mental rotation become completely necessary. A review of the tests used for the evaluation of SVA can be seen in Lin's work (2016). In that set of tests is the Purdue University tests - Purdue Spatial Visualization Test (PSVT), which was used by Sorby and Veurink (2012) to assess the spatial visualization ability of American students and that of other countries of the world. In the research, the authors conclude that cultural differences in pre-university education among students who studied the same career but belonged to other countries are probably an important factor that characterize underdeveloped visualization abilities. For their part, Segil, Sullivan, Tsai, Reamon and Forbes (2017) investigated the spatial visualization ability of students from various countries who were studying in the US., proposing the authors a workshop for students who would not have obtained the necessary grade on the PSVT test to improve their grades, a fact that happened but that was not enough.

In order to improve SVA in students, Mello, Maia and Calixto (2016) propose and develop a website for teaching reinforced concrete projects. Among other activities, the site has a web application to calculate structural elements (beams and columns) of reinforced concrete. Through the application, students can interact with the computer program and determine the rotation of the structure; that application was produced in Java programming language, with Java 3D resources. For its part, Fogarty *et al.* (2018) have investigated the use of virtual reality tools to help students understand the complex concept of "buckling" in structures. This study, conducted using the combination of mixed methods, analyzes pre and post exams covering topics that require spatial visualization abilities, as well as surveys and interviews with students who used the virtual reality tools. Quantitative results indicate that students can more accurately identify and visualize "buckling" modes after the virtual reality experience. The results found show that students show a better understanding, greater enthusiasm for the topic, and greater desire for other topics to be presented using virtual reality tools.

Although researchers have highlighted the main factors that compromise the teaching and learning process in engineering (Molyneaux, Setunge, Gravina & Xie, 2007; Mello, 2016), and especially the difficulty that its students have in spatial visualization (Sorby, 2001; Katsio-Loudis & Jones, 2015; Mello *et al.,* 2016, Fogarty *et al.,* 2018), other educational strategies should be explored to improve students' SVA in structural engineering teaching. In this scenario, the overall objective of this research was to plan and develop activities using mobile application with augmented reality (AR) resources, for reinforced concrete disciplines in the civil engineering course.

To achieve the objectives of the research the phases followed were: (1) choice of tools for the development of the application; (2) planning of reinforced concrete discipline activities carried out in RA application; (3) development of 3D models for RA; (4) class use of the application for the performance of planned activities; (5) evaluation of the proposed activities with regard to didactic, technical and aesthetic quality, and their use and acceptance through a questionnaire answered by students.

1.1. Augmented reality

Azuma (1997) points out that augmented reality is any system that has the following three features: it combines the real and virtual world, it is interactive in real time and it is recorded in three dimensions. Augmented Reality (AR) is a field of computer science research that combines reality and digital data, i.e., it employs computer vision, image processing and graphic techniques to merge digital content in the real world. Cabero and Barroso (2016) when presenting the possibilities of using RA in education showed some advantages of using this resource: (1) they help in the acquisition of knowledge that becomes essential to relate and understand the concepts learned through interaction with RA resources with the real environment; (2) promote more personalized learning so that each student can progress at the pace set by their own abilities and interests and; (3) encourage students to have a higher level of interaction and exploration on both information and objects.

Akçayir, Akçayir, Pektas and Ocak (2016) investigated the effects of the use of RA technologies in science laboratories and involved 76 first-year university students, all students from 18 to 20 years old. Each was assigned to an experimental group and another control group. While the experimental group used a RA-assisted laboratory manual, the control group used a traditional laboratory manual. The 5-week experience revealed that RA technology significantly improved the lab skills development of college students. In addition, it helped them develop positive attitudes towards physics labs, increasing student´s motivation.

On the other hand, Ayer, Messner and Anumba (2016) asked the students to carry out an activity in which they had to design, visualize and evaluate the exterior wall project to adapt it to an existing facility and improve its sustainable performance. The research was performed by 34 students of architectural engineering, 47 of architecture and 27 of civil engineering. They all received the same design activity using an augmented reality-based educational game called ecoCampus. The authors compared students using ecoCampus with the 65 students who completed a similar design activity using only blank spaces with sheets of paper, and another group of 23 students who used a paper approximation of the computerized ecoCampus. Based on the results, they concluded that students from all disciplines that used ecoCampus were able to break the trend towards design fixation. Students also used the app to evaluate their designs and generate additional concepts with better overall performance across all disciplines compared to students who used paper formats.

Meža, Turk and Dolenc (2015) created a prototype that was tested in a real building, and conducted an investigation aimed at evaluating the potential use of RA in the area of civil engineering designs. The authors interviewed a group of potential users who were asked to compare the prototype with conventional design presentation methods; they concluded that the use of RA provides the ability to move from two-dimensional to photorealistic designs in three-dimensional projections. The barriers to the use of RA, explained by the authors (Meža *et al.*, 2015) were the perceived conservatism in the construction business sector and the size of the three-dimensional models generally required for that sector. Li, Nee and Ong (2017) investigated the application of RA resources in some areas of engineering and published a review of the literature on the subject. According to Li *et al.* (2017), the selected studies used different visual-

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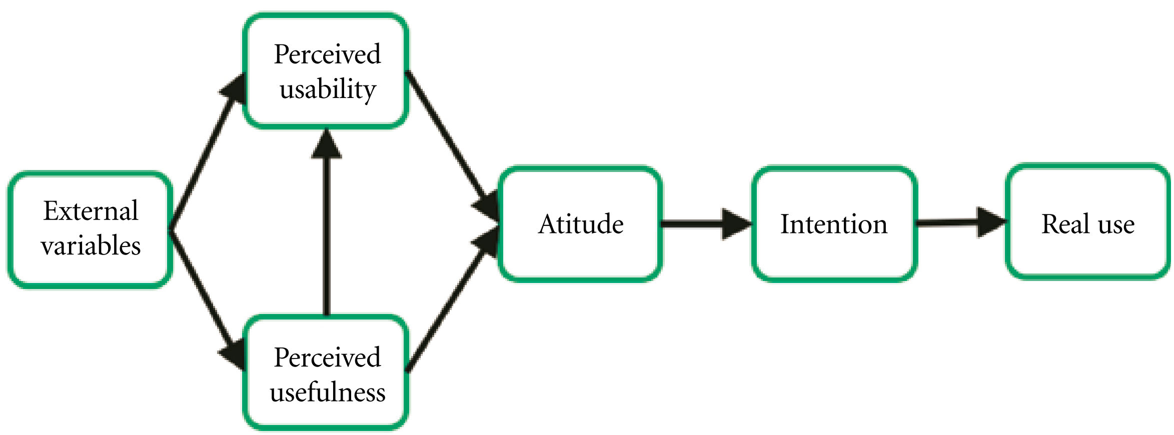
ization methods, such as image overlay, OpenGL programming, and a special software kit for displaying volumetric data and numerical simulation results. However, most studies use RA as a visualization tool and the possibility of interaction is neglected. Overall, Barroso, Gutiérrez, Llorente and Valencia (2019) have pointed out a number of difficulties that teachers have had for the incorporation of RA into teaching, ranging from the novelty of technology to the lack of research on its in action.

1.2. Student perception through the TAM

Technology Acceptation Model (TAM) was adapted from Davis' 1986 Reasoned Action-TRA (1986) theory of action to explain a person's behavior for the use of technology (Davis, 1989). In the TAM model, some external variables are proposed to outline the impact of external factors on the two main perceptions of the user in relation to the use of technology: (1) perceived usability and (2) perceived usefulness. According to Davis (1989), the former directly influences the latter and both directly influence the positive or negative attitudes of users regarding the use of technology. The attitude towards the use of technology influences the behavioral intent of using the technology, and the intention of using the technology determines the current use (Davis, 1989; Abdullah & Ward, 2016). Figure 1 shows the diagram of the TAM model, according to Davis (1989).

Figure 1. TAM Model



Source: Adapted from Al-Emran, Mezhuyev and Kamaludin (2018)

Various researchers have applied the TAM model to explain the user´s acceptance of different educational technological tools and resources (Chow, Herold, Choo & Chan, 2012; Cheung & Vogel, 2013; Schoonenboom, 2014; Wu & Chen, 2017; Cabero & Pérez, 2018). Schoonenboom (2014), used a TAM questionnaire adapted to measure the importance of the task, the performance of the task, the usefulness of learning management systems (LMS), its ease of use and the intention to use it, for 18 different educational tasks among 180 instructors of a Dutch university. According to the author, the results showed that the TAM model is more widely applicable for the tool/task combination. Cheung and Vogel (2013) adapted the TAM model to explain the factors that influence the acceptance of Google applications for the collaborative learning. The custom model was empirically evaluated using data collected from 136 students enrolled in a full-time undergraduate program who used Google apps to support the activities.

The TAM model proposes that the different external variables that may affect the usefulness and ease of use perceived by technology users be identified. According to Cabero and Pérez (2018), although different studies have suggested new proposals and the model has evolved over time, it remains essentially composed of a simple set of identified variables, as in the original formulation, which are presented as robust and reliable.

2. Methodology

This project is a descriptive and quantitative approach to validate the methodology and tools chosen for the planned activities, with the aim of establishing whether the use of RA motivates and helps the student's learning in reinforced concrete subjects.

2.1. The subject and the students

The research was developed in the subject of "Graphic Expression" of the eighth semester of the Civil Engineering course. This subject is part of the mandatory content of the Civil Engineering course of the Pontifical Catholic University of Minas Gerais in Brazil. In this subject students must not only interpret the drawings of designs of the structures but must also represent in 2D drawings, the entire reinforced concrete structure already calculated. In the first semester of 2019, eighteen students enrolled in the subject were invited to participate in the research and all agreed to participate. All students enrolled in the subject answered a questionnaire after using the proposed RA resources for some course activities.

2.2. Computational resources

Detailed projects for the theme of "two-dimensional slabs and beams" were represented using AutoCAD (https://www.autodesk.com.br/products) graphic design software. For the development of the 3D model, the software for three-dimensional modeling, Sketchup (https://www.sketchup.com) was used. The reasons for choising it were: its ease of use and its ability to integrate with AutoCAD. To render the 3D model, the Sketchfab platform was chosen (https:(https://sketchfab.com/feed). There are two ways to access the 3D models available on it: through the web environment or through the mobile app. The Sketchfab app for mobile devices allows to observe models in both augmented reality and virtual reality. For the production of the activities applied in this research, two ways were chosen for the 3D visualization of the structural elements: (1) access through the Sketchfab web environment and (2) through the Sketchfab mobile application with access to the RA function. In addition, in the web environment there is the possibility to insert resources such as text and audio in 3D models.

2.3. Activities

The subject "Graphic Expression" is divided into two parts: theoretical classes and practical classes in computer lab. During the theoretical classes, the contents related to the calculation of reinforced concrete are presented and discussed with students. In these classes, RA models were used to facilitate three-dimensional visualization of proposed structures and facilitate the observation of details. For example, in activity 1, students were presented with the 2D drawing for the detail of a reinforced concrete beam (Figure 2) with appropriate explanations on the distribution of the steel reinforcement of the beam. Students were then asked to access the Sketchfab app on their smartphones or tablets for three-dimensional viewing of the beam (Figure 3), using the RA functions.

In the practical classes held in the computer lab, the three-dimensional models available on the Sketchfab web platform were used. There were additional instructions in that model to perform the requested tasks, for example, to relate the reinforcement represented in the

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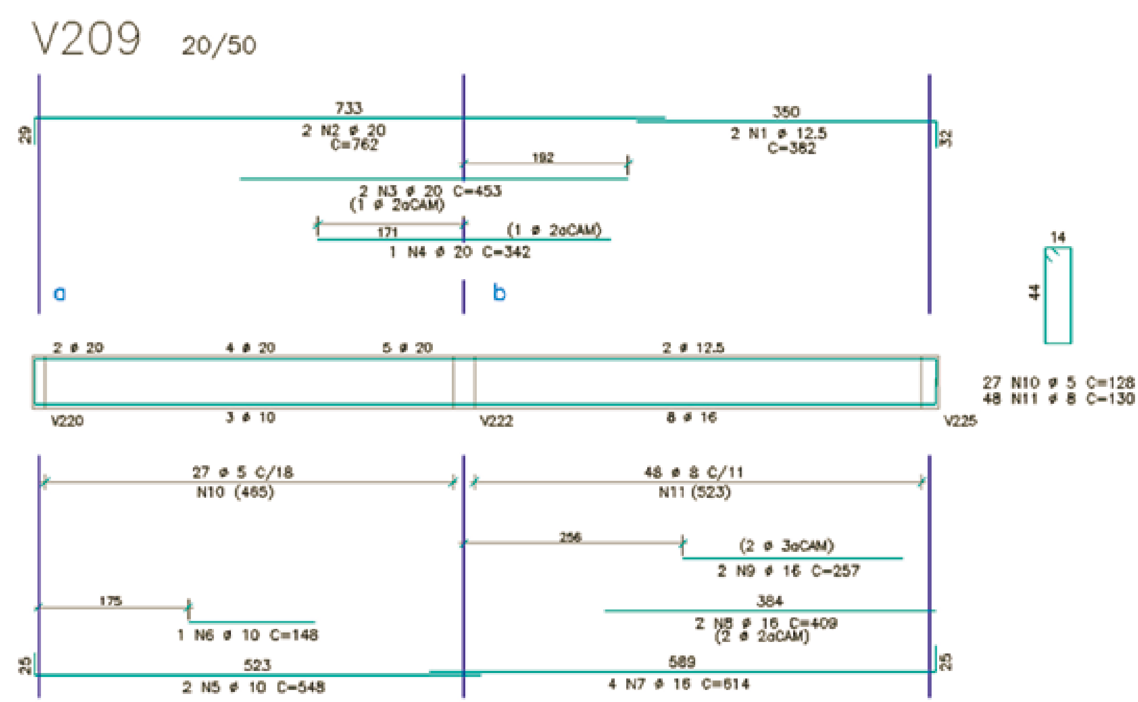
2D project to the corresponding one in the 3D model. These activities were carried out in the laboratory by accessing the Sketchfab web platform. The themes covered with the RA content are drawings of reinforced concrete slabs and beams, with a focus on the details of drawings for the steel bars that are used for the reinforcement of the concrete. For the first half of 2019, four three-dimensional models were developed: two slab models and two beam models. Figure 2 presents the 2D design model for the detail of a reinforced concrete beam. Figures 3 and 4 present the 3D model for the beam detailed in Figure 2. The model depicted in Figure 3 is accessed via mobile phone. The model in Figure 4 is accessed through the web platform.

Figure 2. Beam Detail



Source: Own elaboration

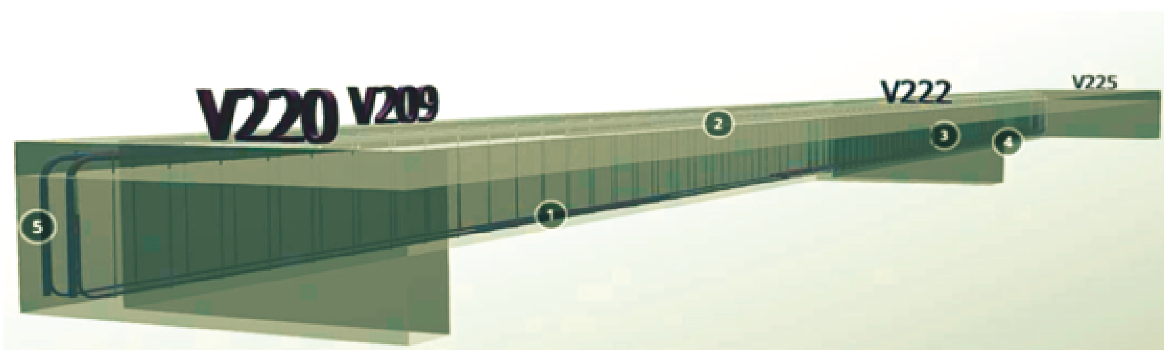
Using the Sketchfab platform has allowed to add some additional features to 3D models, such as text and audio. When clicking the numbered circles in Figure 4, the platform displays a text box. This resource was used to provide information to students about what they should observe at each of the points of the structure. However, this feature is only available for having access to models through the web environment.

For the specific case of reinforced concrete structures, the models are too dense due to the number of steel bars available. Thus, for the proposed activities, models were produced for the visualization of parts of a real structure. No model containing the entire structure of the building is presented.

Figure 3. 3D model in the Sketchfab app for mobile phones

Source: own elaboration

Figure 4. 3D model on Sketchfab web platform



Source: Own elaboration

2.4. The evaluation instrument

The instrument used to know the degree of acceptance of RA in students was a questionnaire answered by all students enrolled in the discipline. The questionnaire has three questions for the student characterization and twenty-three Likert scale issues with 5 options. Following Likert scale, the student should choose option 5 if he/she would totally agree with the statement and 1 if he or she would strongly disagree with it. The twenty-three Likert-scale issues were adapted from Cabero and Pérez›s research (2018) for the analysis by the TAM model of technology acceptance assessment by one person. Thus, the topics were grouped into the following categories: level of student knowledge about topics (2); student experience with visual applications and resources for structural engineering learning (3); usefulness of the resources and tools perceived by the student (6); ease of use of resources and tools perceived by the student (6) and; perceived enjoyment and intent to use resources and tools again (6).

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Table 1. Presents the Likert scale topics and the classification of each.

Categories	Identification	Affirmation
Student knowledge of topics	A1	I have difficulty visualizing the arrangement of the rebar within the concrete structures.
	A2	Before the discipline I did not have enough knowledge of design detail in reinforced concrete structures.
Student experience with applications and visual resources	A3	I've never used 3D visual resources for learning structure design.
	A4	During the Civil Engineering course, I have never used RA resources for learning.
	A5	During the Civil Engineering course, I have not used applications for learning.
Utility of resources and tools perceived	A6	3D models help in visualizing the details of the rebar of reinforced concrete structures.
	A7	I think the use of 3D visual resources for learning structure designs is very relevant.
	A8	The use of RA favors the visualization of the rebar of the concrete structural elements.
	A9	I think it is very relevant to use applications for teaching designs of concrete structures.
	A10	Using the RA tool positively influenced my learning.
	A11	3D models are suitable for the content presentation of the subject.
Ease of use	A12	I had no problem seeing the 3D model on my cell phone.
	A13	I had no difficulty using the RA Sketchfab app.
	A14	Using the RA Sketchfab tool does not require any special experience or skill.
	A15	All the information provided for the use of Sketchfab was sufficient.
	A16	I had no problems accessing the texts available in the model.
	A17	The texts presented in the tool are organized appropriately.
Enjoy perceived and intended to use	A18	It is fun to use the RA tool.
	A19	I was more motivated with RA activities.
	A20	Using the RA tool makes learning more interesting.
	A21	I didn't get bored using the tool.
	A22	I would like to use the tool in the future.
	A23	RA tools could be used in other subjects.

3. Results

Out of the eighteen students participating in the research, 11 (61.9%) were men and 7 (38.9%) women; 15 students (83.3%) were from 21 to 25 years old and 3 (16.7%) were over 25 years old. Most of them (77.8%) have already had contact with structure drawing activities through apprenticeship or building technician work.

Table 2 shows the response percentages for the 5 options of the 23 Linkert scale questions. A6-A11 statements are related to the usefulness of the resources and tools perceived by the student as well as the options selected (Table 2). More than eighty percent of the students totally agreed with all the statements of that category, indicating a great perceived usefulness by them.

Although most students were successful in using the application and viewing 3D models through the RA resource, it is considered the importance of presenting them with a more complete tutorial for installing and using resources, as that, for some, only the oral explanation was not enough. This result is perceived in the responses of the A12 to A17 statements that can be seen in Table 2, especially the responses of the A12 and A13 statements, where the difficulty of viewing RA structures on the mobile phone is observed. That difficulty occurred because not everyone had a device suitable for the app. In those cases, students worked together with their peers.

All students not only liked the activities, but also were motivated by the use of RA to learn the contents of that subject. It can be seen in the responses of A18 and A19, where one hundred percent chose options 5 or 4. In addition, all students would like to use the tool again (A22). They all also recommended the use of RA in other course subjects (A23), which confirms the relevance of 3D models to motivate the learning of civil engineering and technology here employed.

Table 2. Results of Likert's Scale questions

Linkert Scale Questions					
Identification	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)
A1	11,1	11,1	16,7	27,8	33,3
A2	22,2	5,6	33,3	11,1	27,8
A3	61,1	11,1	11,1	5,6	11,1
A4	88,9	5,6	5,6	0,0	0,0
A5	22,2	11,1	22,2	16,7	27,8
A6	88,9	5,6	0,0	0,0	5,6
A7	94,4	0,0	5,6	0,0	0,0
A8	88,9	5,6	5,6	0,0	0,0
A9	100,0	0,0	0,0	0,0	0,0
A10	88,9	0,0	11,1	0,0	0,0
A11	100,0	0,0	0,0	0,0	0,0
A12	50,0	27,8	16,7	0,0	5,6
A13	50,0	27,8	16,7	0,0	5,6
A14	61,1	22,2	16,7	0,0	0,0
A15	77,8	11,1	11,1	0,0	0,0
A16	83,3	11,1	5,6	0,0	0,0
A17	77,8	11,1	11,1	0,0	0,0
A18	77,8	22,2	0,0	0,0	0,0
A19	66,7	33,3	0,0	0,0	0,0
A20	88,9	11,1	0,0	0,0	0,0

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Likert scale issues					
Identification	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)
A21	88,9	5,6	5,6	0,0	0,0
A22	100,0	0,0	0,0	0,0	0,0
A23	94,4	5,6	0,0	0,0	0,0

Conclusions

Based on the student responses, the use of 3D resources through RA is believed to be positive and relevant to improve spatial visualization ability (SVA) and consequently the student´s performance, but that was a preliminary study to test the use of RA in concrete structure subjects. The proposal was to plan four activities with RA resources and assess the student's perception on the usefulness of resources and tools, the ease of their use and the enjoyment and intention of using the resources again. The results will allow the necessary adaptations for the use of the resource in other classes and subjects. The study showed that with the use of the platform Sketchfab, it takes a long time to process models with a large number of objects when using the mobile phone. Although the statement of Meža *et al.* (2015 has been confirmed on one of the main limitations to the use of RA for educational purposes: The size of the 3D models, the chosen application is suitable for simpler models like those that were presented to students and that are sufficient for understanding the chosen content.

It was also obtained the right device to carry out the project. However, not all students had the mobile with the necessary configuration, as can be seen in the analysis of the results, but the use of RA for three-dimensional visualization is motivating for students, since it facilitates the understanding of the reinforcement distribution within the structural elements, allowing the realization of activities in a funnier way.

This research agrees with the results obtained by other authors (Barroso, Cabero & Moreno, 2016; Marín, 2017; Barroso, Cabero & Gutiérrez, 2018; Martínez & Fernández, 2018; Cabero & Roig, 2019), where it was used with university students from different disciplines, from Medicine to Fine Arts and Educational Sciences. Therefore, the degree of acceptance of this technology by students is quite significant; thus, it is recommended for the training of students.

As future lines of research, different topics are proposed, ranging from linking the use degree of RA technology, and different variables that can be predictors of students' self-perceptions: age, gender or knowledge, that students showed the contents of the subject involved in the experience; at the same time it may be interesting to relate the degree of acceptance of RA technology to the degree of acceptance of mobile devices by students (Seifert, Hervás-Gómez & Toledo-Morales, 2019).

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