
ORIGINAL RESEARCH ARTICLE

Mobile augmented reality: A pedagogical strategy in the university setting

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ABSTRACT

The mobile augmented reality (M-AR) besides being a booming computer technology is an innovative tool that can support the pedagogical process in university classrooms, that is why the present research aims to show a methodological proposal for its implementation, in order to facilitate the learning of spatial reasoning of students, through the visualization and manipulation of three-dimensional virtual objects, promoting the motivation of learning knowledge and topics of the course of industrial design and technical drawing for the career of industrial engineering. A collection of geometric figures has been elaborated with the help of technological tools such as 2D and 3D modeling software, computer-aided design software and augmented reality application software. An updated methodology is proposed, available to any teacher, oriented to the stimulation of mental processes related to spatial reasoning of students, which integrates technological tools in the didactics of the dihedral system and the different graphic projections.

Keywords: pedagogical innovation; technical drawing; mobile augmented reality; university education

1. Introduction

The constant search for new tools to facilitate and enhance the acquisition of knowledge in different areas of knowledge is an activity that will always be linked to the evolution of information and communication technologies (ICT), especially those commonly used in human life. It is there where intelligent mobile devices or Smartphones stand out from the rest due to their increasing massification and their undeniable presence in university classrooms, which opens the window of opportunity for the implementation of new teaching strategies.

According to Paredes^[1], cell phones in the classroom are mainly used to search for information on the

Internet, communication, file sharing, note taking, information storage, use of web platforms, use of applications (apps), being currently the use of mobile devices in association with other technologies the most used aspect, since it transforms these mobile devices into powerful pedagogical tools, a fact that is beginning to be recognized by educators worldwide. Among these partnering technologies, AR stands out from the rest, first for being highly innovative and then for having potentially unlimited fields of application.

ARTICLE INFO

Received: April 9, 2020 | Accepted: June 21, 2020 | Available online: July 7, 2020

CITATION

Laurens Arredondo LA. Mobile augmented reality: A pedagogical strategy in the university setting. *Metaverse* 2020; 1(2): 9 pages.

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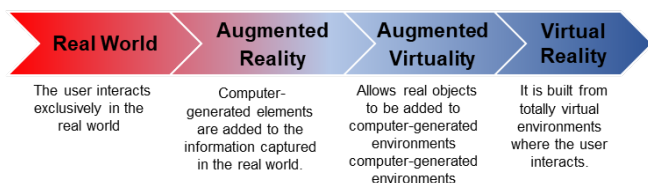


Figure 1. Taxonomy of Mixed Reality^[2].

Font^[2] defines AR as a technology that allows digital content or virtual information to be added to elements of the real world, i.e. a mixed reality is created that comes into contact with the real environment and the virtual environment simultaneously, as represented in **Figure 1**. The architecture of this technology comprises three fundamental elements: visualization devices, which are the peripheral hardware responsible for capturing images of the real world, such as webcams, tablets or smartphones. The AR when using this last type of device takes the name of AR-m. Another essential element is the software used, which is divided into integration, visualization and modeling software, all of which can work in isolation or integrated and are responsible for generating virtual objects and combining all the elements of the scene, both real and virtual, displaying them on screen to the user. Finally, the triggers are the ones that trigger the appearance of virtual information, they can be QR codes, objects, geolocation or markers and determine the exact position and orientation of real and virtual objects in the real world^[3].

The mixture of realities presented by AR makes the perception of the environment a more enriching experience, which provides the current teacher with an innovative tool that can be used to improve the learning process of any topic where it is implemented. In addition to the above, there is the undeniable universalization of mobile devices that enables the interaction between the reality captured by students to be complemented with digital data superimposed in a simple way without detracting from the focus of the main topic where it is implemented, this makes educational content more attractive^[4]. In the first experiences of AR as a support tool in the teaching/learning process in university education, Moreno and Perez^[5] indicate that they have been implemented in strategies such as educational games with AR, modeling of objects with AR, books with AR, didactic materials

with AR, all mainly aimed at the development of professional skills of students.

This has led to the study of the impact of these strategies in the pedagogical process, in areas such as biology, physics, language, languages, mathematics, religion, arts, etc.^[6] On the other hand, in the area of industrial design and technical drawing, the following researches stand out: in 2017, Ayala, Blázquez and Montes-Tubio^[7] evidence the good response of students in a university course of engineering graphic expression to the introduction of 3D augmented reality models, this through an experimental study based on the ARCS method. Then in 2018, Cerqueira, Clero, Moura and Sylla^[8] measured the level of enjoyment of university students with the use of a pilot virtual reality application for visualization, construction, deconstruction and manipulation of 3D polyhedral or solids with and without animation. Recently in 2019, Garzón and Acevedo^[9] conducted a meta-analysis of 64 quantitative research represent in the main scientific databases (Web of Science, Scopus and Google Scholar) conducted between 2010–2018 to analyze the impact of augmented reality on student learning. All these pedagogical investigations reinforce what has been said by Herpich, Martins, Fratin&Rockenbach^[10], which affirm that the implementation of innovative strategies is of high relevance for the cognitive development of students, and more so if these activities are supported by tools that help develop spatial reasoning through the demonstration of abstract concepts with the interaction of multimedia resources. This is combined with the need for universities to adapt and update themselves in the use of new tools and technologies in the field of education, offering a promising present and future as a line of applied research associated with disruptive pedagogical innovation^[11]. In the above mentioned lies the importance of the successful use of these innovative technologies in the classroom, which according to Ferguson^[12] not only have a positive impact on students achieving cognitive changes, but also affective and behavioral changes in them, becoming more confident, motivated and realistic.

The implementation of a technology such as AR in the academic environment has no future viability if

it is not framed in an educational approach adapted to the curriculum, which in turn will depend on the characteristics and context of the instance where it is applied. Bower, Howe, McCredie, Robinson and Grover^[6] indicate that AR can be associated with different pedagogical approaches, inferring that the optimal solution may not lie in a specific educational paradigm but rather in a combination of pedagogical approaches.

This paper presents an alternative pedagogical proposal, where AR is used, in a less complex way, as a didactic resource to support the teaching process implemented in university classrooms, exposing its most relevant advantages and limitations. This described methodology is supported by constructivist pedagogy, since it involves the use of diverse active strategies focused on achieving an education based on the construction, by the student, of his own learning, and taking into account that the selection of activities that motivate the participation and reaction of the student is a crucial aspect in the pedagogical process, since the degree of commitment and openness to internalize the concepts, ideas and topics that are facilitated in the classroom will depend on it, which is why the implementation of well-selected activities can lead the student to deep reflections and insights^[13].

2. Methodology

The present work is an applied research conducted under the action research approach^[14], since it allowed educational innovation from planning, action, observation and reflection, leading to improvements in the educational process in order to improve the teaching practice and the pedagogical process with the support of ICT^[15]. The context for the design of this educational proposal is the Industrial Design and Technical Drawing course of the School of Industrial Engineering of the Faculty of Engineering Sciences of the Catholic University of Maule, which was taught by the author of this work. The total number of participants was 82 students (68.3% men and 31.7% women) aged between 19–25 years. This course has special importance due to its link with the development of spatial reasoning of students, and its close re-

lationship with the internalization of abstract concepts of engineering drawing such as sections, auxiliary views, intersections, interpretations of engineering drawings, where its lack of development may be the origin of the poor performance of students in the course^[16]. The latter authors define spatial reasoning or spatial ability as a component of intelligence, which is linked to the ability to form a mental representation of the world, but what is generally known as spatial ability is a part of spatial ability. There are three main components that define spatial ability, two of them: dexterity and aptitude, which are of genetic origin and cannot be trained, while the last one, spatial ability, can be trained through the development of a study methodology, pedagogical tools and independent study.

The current study is based on the interest of the professors of the school of industrial engineering in facilitating the teaching and learning processes of the students of industrial design and technical drawing, especially to help them develop the mental processes related to spatial reasoning. It is a constant concern for the faculty academics that one of the consequences of the constant updating of the university curriculum plans is the reduction of courses related to graphic expression in engineering, a phenomenon that already happens in other universities^[16], which in turn generates the constant need for academics to ensure strategies that are sufficiently effective for implementation in 16 weeks of study, is perhaps the solution to this problem, the change of teaching strategies used.

For the design of the proposed pedagogical strategy, the basic principles proposed by Cuendet, Bonnard, Do-Lehn & Dillenbourg^[17] were followed. These principles require that AR systems should be flexible enough for the teacher to adapt to the needs of the student, that the content should be taken from the curriculum and delivered in short periods like the rest of the lessons, and that the application of the AR system should take into account the contextual constraints.

The methodology developed in this research is

focused on the expected learning outcome in the curricular activity in which it was implemented, which requires students to be able to apply ISO and NCh standards to the visualization of a geometric object using new technologies for the elaboration of industrial design productions. To achieve this objective, it is intended that, with the support of AR, students not only know the dihedral system but also the different graphic projections not as an abstract science, but as the representation of objects in the environment^[18], as well as their relationship with industrial design. A work structure was planned for 32 sessions as detailed in the syllabus of the branch, which establishes the evaluation techniques, criteria and indicators to measure the learning results. These work sessions were divided into theoretical classes and laboratory classes.

Theoretical classes. They were held in a classic classroom for 90 people, with a projector, blackboard and desks.

Laboratory classes. Rooms equipped with a computer with software from the Aumentaty[®] community, such as Creator[®] 2019 (integrator software) and AutoCAD[®] 2019 (modeling software) from Autodesk[®] that were installed, all in their free or academic versions. Additionally, for these classes the students must have a cell phone with the AumentatyScope[®] application installed (visualization software).

The development of the pedagogical proposal described in this report seeks to update the procedures used in the implementation of innovative tools in university teaching, in order to contribute to the retention, appropriation and understanding of highly abstract technical content and the promotion of spatial cognitive skills in students^[19].

3. Results and discussion

The proposed methodology is described below in a sequence of weekly activities distributed

throughout the working sessions of the chair; they can be seen in a summarized form in **Table 1**.

Week 1: In this instance the general content of the course was presented, the methodology, planning, evaluations and bibliography were delivered. The general framework of technical drawing and its application in engineering was discussed, trying to unify the previous knowledge of the group of students.

Week 2: The different projection systems (orthogonal, conical, axonometric), the different projection planes (vertical, horizontal, profile) and the different views that are generated of a part were briefly explained, all this with the support of slides and the AR application installed on the cell phone, as proposed by Sanchez^[20].

The students were provided, in printed form, with an AR exercise book called AR- Book UCM, shown in **Figure 2**, which included a series of exercises intended to put into practice the spatial reasoning and abstraction level of the students, in those exercises they had to complete the isometric view of each of the figures, having lateral, profile and plan views. These drawings of figures were used as markers (**Figure 2a**), so that the students could use their cell phones to visualize these markers through the Scope[®] visualization application. This session was intended to familiarize the students with the application and with the way of visualizing 3D solids and the relationship with their 2D representation, as can be seen in **Figure 2b**.

Week 3: General characteristics of drawings, types (assembly, fabrication, assembly, etc.), standard sizes and dimensions, labeling, types of lines, data box, technical standards by discipline were explained.

Week 4: This class provided information on the different types of scales, dimensioning, the standardization of the latter, as well as how to fold plan according to NCh 2370 regulations.

Table 1. Industrial design and technical drawing course program

Week	Description of activities	Resources	Evaluation instrument
1	Presentation of the course. Definition, uses and applications in engineering.		
2	Theory of projections and views		
3	Normalization of planes, formats		
4	Scales, dimensioning and folding of drawings		
5	CAD Control No.1		
6	ISO and NCh Standards		
7	Cabellera and Isometric Perspectives	Syllabus, Master Class, Slides, Slideshows, Mobile Phone, Auto-CAD 2019, AumentatyCreator	Written test, guideline, rubric, workshops, summative test, PRA, etc.
8	CAD Control No.2	2019, AumentatyScope 2019	
9	Blueprint Reading in Engineering		
10	Design of Industrial Drawings		
11	Cuts and Sections		
12	Development Final Project 1		
13	CAD Control No.3		
14	Development of Final Project 1		
15	CAD Practical Exam		
16	Presentation of the Final Project		

Week 5: The introduction to the graphic environment of AutoCAD® 2019 software was explained, covering the basic instructions for two-dimensional drawing, working tools, drawing editor, help commands, format, layers and lines configuration. Learning the basic drawing commands (line, circle, copy, move, delete, rotate, symmetry) were evaluated.

Week 6: This week's work sessions detailed the ISO and Chilean drawing standards, their comparison with DIN, UNE, ANSI standards, as well as their implementation in engineering projects.

Week 7: The topics covered were the dihedral system, the cavalier and isometric perspective, teaching the procedure to make freehand drawings in both perspectives with the help of squares.

Week 8: Students were introduced to the additional editing commands of AutoCAD® 2019 software. The learning of the basic editing commands (rotate, scale, symmetry, offset, fillet, chamfer, extend) was measured.

Week 9: Discussed reading and interpreting engineering drawings. Basic layout of the working area of a drawing, the different symbology used in the main disciplines according to the type of drawing.

Week 10: The concept of industrial drawing design and its integration with current CAD software was introduced. The solid drawing environment in AutoCAD® 2019, visualization commands and 3D solid generation are explained.

Week 11: The topics covered were the main types of cuts and sections of solids, cutting planes, cutting projection planes (views). Criteria and rules to consider when cutting a 3D object. Parallel plane cuts. The concept of Boolean operations in AutoCAD® 2019 as a tool for the creation of complex 3D solids was explained.

Week 12: The characteristics of the final project were explained, which was of individual character, both the evaluation rubric and the guidelines of the project were provided, which consisted of modeling in 3D a set of industrial elements, to then translate it

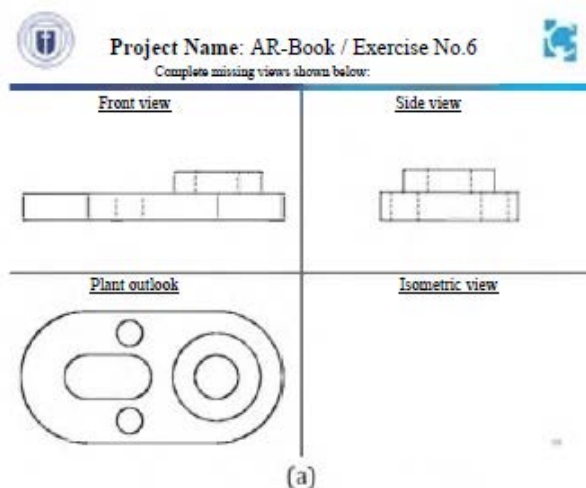


Figure 2. a) Workbook marker. b) Visualization of the marker using the APP Scope.

into an engineering plan that has a front, side and isometric view of the same, all this replicating the physical plans provided by the teacher (assembly plan of a metal structure). Then, this plan drawn by the students served as a marker for the integration with the 3D AR model, as can be seen in **Figure 3**.

The students were formally introduced to the Aumentaty® community, the basic procedure for AR integration with two-dimensional markers using the AumentatyCreator® software was explained, through the procedure described in **Figure 4**.

Week 13: 3D solids editing tools, dimensioning and dimension styles in AutoCAD® 2019 were explained.

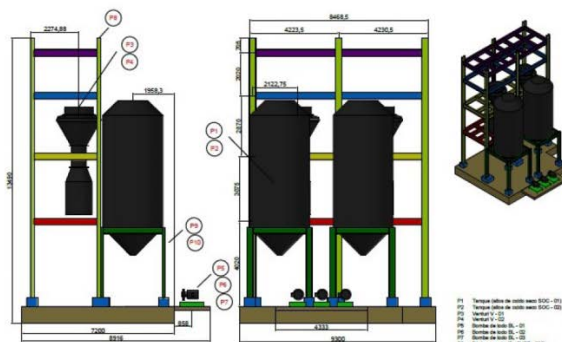


Figure 3. a) Mechanical structure plan that serves as a marker. b) AR visualization through the APP Scope.

Week 14: Test integrations practices were performed with basic 3D models generated in AutoCAD® 2019 (DWG format), exporting them in lithography graphic applications format (STL format), and then importing it into the integration software with RA AumentatyCreator®. The markers used were the two-dimensional drawings generated (without texture) of the 3D models previously generated by the students. The idea is that students can visualize in the AumentatyScope® software installed in their cell phones these 2D markers and have the possibility to visualize in 3D the object created with the help of AR through their cell phones. Difficulties were encountered in generating content in the AumentatyCreator®, as well as importing and exporting content. The visualization of the contents was uneven in a percentage of students due to the difference in performance between the available cell phones.

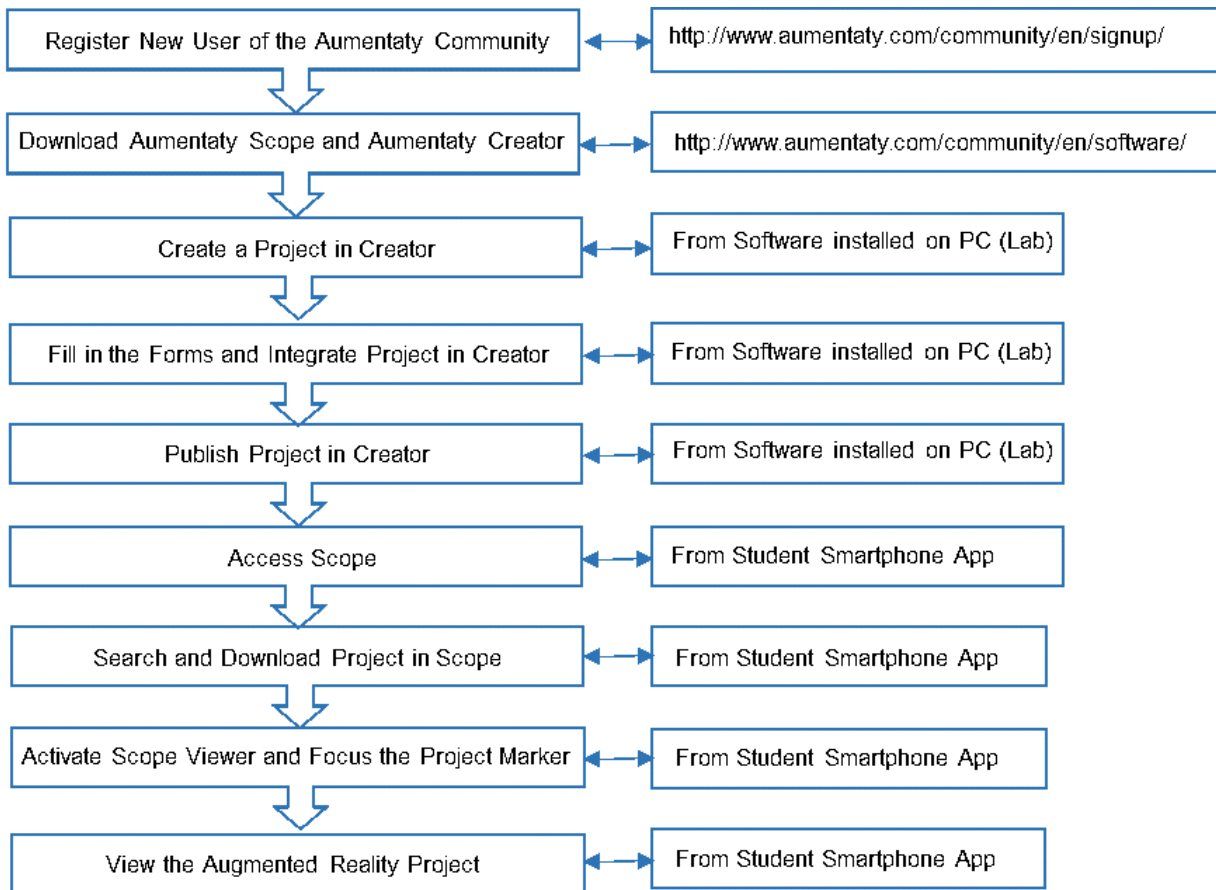


Figure 4. Procedure for visualization of virtual objects using AR^[21].

Week 15: An integrative exam (50% theoretical - 50% practical) aimed at measuring the learning of the contents covered throughout the course was performed.

Week 16: The presentation and delivery of the final project in public exhibition was carried out.

With the development of this methodology implemented for the pedagogy of the concepts of technical drawing and industrial design, it was possible to create virtual learning objects, which use the advantage provided by AR technology to capture the attention of students, stimulating their motivation, thus positively impacting the learning process^[22], through the implementation of innovative educational strategies, which, as has already been demonstrated, favor the learning of transversal competencies, such as leadership, teamwork, communication^[23].

4. Conclusions

A procedure for the didactics of the dihedral system and the different graphic projections through the inclusion of AR technology in the development of educational content has been carried out, which was oriented to the stimulation of mental processes related to spatial reasoning of students, where the creation and integration of virtual models moved away from the great procedural complexities and the need for deep knowledge in the computer area, relying on the increased presence of smartphones in university classrooms by the student population. The development of this research allowed knowing the existence of free software that serve as pedagogical tools for easy and quick learning of the management of this technology, such as AumentatyCreator[®] 2019 and AumentatyScope[®] 2019, which seeks to guide the university community in the adoption and implementation of this type of technology as a pedagogical strategy, as well as its strengthening as a line of research due to its high potential as a teaching tool, wide field of im-

plementation and the positive stimulation of performance and willingness to learn by students^[24].

The developed methodology proves to be a valid strategy to improve the pedagogical process in the area of technical drawing due to the impact on the motivation of students through the use of innovative technology, giving the possibility of an immersive experience in the industrial environment to students without the need to leave the classroom or expose themselves to physical risks^[25]. However, difficulties were encountered in its implementation due to the characteristics of the hardware (poor performance of older cell phones) and software (slowness of the AumentatyCreator[®] platform due to its dependence on an internet connection with high bandwidth).

It was determined that, in order to effectively design AR-based pedagogical activities, it was necessary to form multidisciplinary teams, including IT, pedagogical and industrial areas. The quantification of the motivation stimulated by the implementation of this methodology is proposed for future work.

Conflict of interest

The author declares no conflict of interest.

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