Augmented Reality in a Smart Classroom—Case Study: SaCI

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***Abstract*— In this paper, we propose the utilization of augmented reality (AR) in a smart classroom (SaCI). The architecture of a SaCI has been proposed in a previous work, based on the paradigm of multi-agent systems. In this paper, we propose an agent that provides services of AR to display and design, among other things, augmented scenarios. In addition, we define an experimental real environment in SaCI to evaluate the utilization and impact of AR in it. The results are promising, since the criteria of motivation, learning curve, and memorization of the students are substantially improved in the experimental group.**

***Index Terms*— Augmented reality, smart classroom, education, learning, multi-agent systems, multimedia systems, technological innovation.**

I. Introduction

AUGMENTED REALITY (AR) provides information about anything, anytime, anywhere [1]. In particular, AR looks at the real world and increases it with additional information generated by a computer. AR mixes physical and virtual objects, integrating the two worlds, in order to improve the interaction between them, by moving additional information to the physical world in real time. The user stays in touch with its context, without taking it into a virtual world. An introductory book to AR is presented in [34], which is a book that exposes its conceptualization, its architectures and where it is used, among other aspects.

On the other hand, Virtual Reality (VR) is defined as environments generated by a computer to simulate real scenarios, with the aim of appearing real, in such a way that the user has the sensation of being in it. For interactivity, the computer keyboard and mouse can be used, but also more complex devices such as gloves and electronic glasses, among others, thus producing an “immersion effect” [2].

AR is a promising technology in education, because it allows conceptually enriching real educational scenarios, contributing to motivation in students. However, AR also provides challenges, for example, How should be the classes in the classroom? Or, What is the cognitive level that the use of this technology can bring in students?. A SaCI must study these aspects in order to adapt AR to the requirements of the pedagogical activities at a given time.

Manuscript received July 20, 2017; revised November 9, 2017; accepted November 13, 2017. Date of publication November 23, 2017; date of current version December 28, 2017. This work was supported by the UTPL Project: Medios de Gestión de Servicios (Middleware) Inteligentes para Entornos de Aprendizaje Virtual. The work of J. Aguilar was supported by the Prometeo Project of the Ministry of Higher Education, Science, Technology and Innovation of the Ecuador. *(Corresponding author: Luis Chamba-Eras.)*

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Digital Object Identifier 10.1109/RITA.2017.2776419

It is important to define the difference between VR and AR. In VR, the user is completely immersed in an artificial world, and there is no way to interact with real world objects. In contrast, in AR systems, the users interact with an environment that blends the real and virtual world in a natural way. The difference between VR and AR is in the treatment they make of the real world. VR immerses the user into a virtual world that replaces the real world, while AR extends the real world around it by overlapping or composing of virtual 3D objects [3], [4].

Ambient Intelligence (AmI) is a domain dedicated to define spaces composed of intelligent or non-intelligent objects, which interact with each other, in order to develop applications that support the users in their activities. The main characteristics for AmI are: ability to detect information from the environment; based on the autonomous interaction of devices with calculation capabilities; and to reason from the accumulated data, information and knowledge, in order to select the actions to be taken. There are many fields of application, among which are the smart houses (home automation), the educational environments, etc. In this work, the context of interest is the educational field, particularly SaCI. An AmI for education is a space where ubiquitous technology helps the learning process in a transparent way, incorporating new ideas and approaches in the educational process [5]–[7].

The main objective of this work is to use AR to reinforce the theoretical or practical knowledge of a course in a SaCI. In particular, it seeks to determine the impact of the use of AR on the learning dynamics in a SaCI, based on the assessment of the contribution of its use in the teaching processes of students in SaCI. This paper is organized as follows: Section II presents the state of the art information on the use of AR for educational purposes and in AmI. Section III describes the technical and philosophical bases for the use of AR in a SaCI, which has been proposed in [7]–[9]. Section IV describes how an agent of AR is added in a SaCI. In section V the methodological process is presented in order to demonstrate that AR can be applied in a SaCI. Section VI describes the results obtained, and analyzes the impact of AR on the learning dynamics in a SaCI. Finally, section VII presents the conclusions and future work.

II. State of the Art

In the literature, there are a variety of works around AR. This section briefly describes some of the work related to the educational context.

There are works that present the state of the art information on the use of AR for educational purposes, in particular, for the promotion of learning through AR [1], [4], [10]–[14]. In [4], it is studied how serious games and AR can be used in the teaching of the physic. They analyze a serious interactive game based on AR, for a physics class. Brown and Gabbard [12] describe how the combination of the personalized learning and of AR produces better learning processes, since it allows fulfilling the specific needs of each student in a more appropriate way. In [13], it is proposed a learning model based on AR. The learning process uses an AR scheme, called eco-discovery, which consists of an ecological learning process that discovers educational resources on the Internet, and takes them as AR to the educational environment, to stimulate students' positive emotions and experiences. Martín-Gutiérrez *et al.* [14] propose to combine during the learning process of a course of electrical machines, theoretical explanations with laboratory practices, using AR. The authors analyze the interactive and autonomous process that allows AR, in a collaborative environment by carrying out laboratory practices among students, without the help of the teacher.

In [15], it is proposed the development of a tool that facilitates the visualization and manipulation of virtual models for the study of some geometric concepts in courses of computer graphics. Carrecedo and Martínez [16] analyze the pedagogical possibilities offered by AR in the primary education. In addition, they present an application of AR in the arithmetic sum of two integers, to show its potential for learning traditional subjects. In [17], it is analyzed the advantages and disadvantages of AR in educational settings, and some experiences are presented. Also, the authors study the different modes of interaction that are developed through their interfaces. In [18] and [19] Magic Book is presented, an enlarged book, and the didactic value of this technology in educational contexts is analyzed. Ferrer-Torregrosa *et al.* [20] describe the experience of using AR to present the anatomy of the lower limbs of a human. The developed application is called ARBOOK, and was constructed using TC and MRN images, dissections and drawings.

In [21], it is proposed to several educational activities created using AR. In particular, they analyze marker-based and markerless AR applications and show how learning activities can be created to display augmented information, such as animations and 3D objects that help students understand the educational content. In [22], it is described how an Enhanced Immersive Reality (iAR) application, in combination with a book, can define an intelligent learning method based on the use of the greatest amount of user senses and human functions as possible. LearnAR "*eLearning with Augmented Reality*" is an interactive learning tool, composed of ten syllabuses that help to explore, by combining the real world with virtual contents, knowledge in the areas of mathematics, science, anatomy, physics, geometry, physical education and languages [23]. *Google SkyMap* is a free application to study astronomy, mainly for those who are usually interested in observing the space in the evenings [23]. Finally, in [24], it is proposed a system of AR for the study of the interior of the human body, and analyzes its acceptance, and how much it facilitates the learning of the different organs of the human body. The AR has been used in special education for visually impaired people, the hearing impaired, and people with intellectual disabilities [25].

On the other hand, at present there are several works related to the subject of AmI applied to educational environments. For example, in [5], it is proposed an AmI that considers the elements found in an educational environment, as well as student-centered learning processes. Some previous works have proposed the use of Multiagent Systems (SMA) to specify a SaCI, due to their intelligent and distributed characteristics [8], [9]. In particular, Sánchez *et al.* [9] develop an autonomous reflexive middleware based on SMA to support intelligent educational environments (called AmICL), which characterizes the different components that make up an environment of this type; a summary of the middleware is detailed in section III.

There are many works in AR area that show that AR is an emerging technology that complements the individuals' perception of the world around them, and embeds them in a real environment enhanced by a computer. It is considered that the application of AR in a SaCI brings a great meaning to the learning process, because it is possible developing didactic contents of another way, being intelligently incorporated in the learning dynamics managed in a SaCI. However, neither paper analyzes the impact of AR on a SaCI from an experimental context. In this sense, this paper analyzes these possibilities experimentally.

III. Bases for the Use of AR in a SaCI

In order to analyze the specification, implementation and use of AR in a smart classroom, we will use as a base the SaCI model proposed in [7], and as the middleware environment AmICL [9]. In this section, both components are described. In addition, several hypotheses are presented for the operation of AR in a SaCI, in order to analyze them in the experimentation process (section V).

A. Architecture of a SaCI

Classically, a smart classroom is a student-centered approach that supports the learning process through collaborative devices and applications that facilitate self-training. A smart classroom has different types of components, such as hardware (e.g., smart board, projectors, cameras, among others), and software (e.g., Intelligent Tutoring Systems (ITS), Computer Supported Collaborative Learning Systems (CSCL), Virtual Learning Environments (VLE), etc.). In [7], we propose a SaCI model that characterizes a smart classroom, using the SMA paradigm [35]. In addition, SaCI uses AmICL for the deployment of its agents, which is composed of several levels/layers. In particular, AmICL is an autonomous reflective middleware for learning environments (see [9] for more details).

B. Philosophical Bases for the Inclusion of an AR Agent in a SaCI

AR can be used in different ways in the educational contexts [11]:

- Learning based on discovery.
- Object modeling.
- Book.
- Skills training.
- Video game.

In this work, AR is considered as a tool in the service of the learning process in a SaCI, which should allow a didactic orientation to the students, enriching the educational dynamics with the information that adaptively is incorporated to the environment. In particular, an agent (called SRA) is proposed to compensate some of the deficiencies that may be present in a SaCI, such as [26]:

- There is no possibility of carrying out actual experiments or practices due to equipment costs, the relationship between the number of available equipment and students enrolled, and the unavailability of appropriate facilities, among other things.
- Difficulty performing complex and dangerous experiments.
- Complexity of experiments or phenomena that occur after a long period of time in seconds, as for example, the evolutionary process of the species.

In this way, AR is a complement to the learning process, but nevertheless, it requires a pedagogical accompaniment that indicates when and how to use it, provided that by the software agents of a SaCI, who are guiding the learning process (agents present in [7] and [9]). This is where the adaptive behavior of a SaCI as a whole is reflected. In this sense, the key factors in the implementation process of AR in a SaCI are [27], [28]:

- AR is inserted within a given context of learning dynamics, so that it is not perceived as an isolated entity, but as a useful complement that is used when it is required.
- AR appears invisible in the environment, the least intrusive as possible, so that the focus of attention is the pedagogical process.
- AR works in real time, avoiding frustrations by the lack of interactivity that slow down and disrupt the educational experience.
- The content where AR is used is relevant for a specific learning process, according to the pedagogical objective that is to be reached. In this way, AR is properly linked to users who are currently using a SaCI, and the student is not distracted from their learning objective defined by the class and the activities they are developing.
- AR is easy to handle and accessible; in that sense, usability is a crucial criterion.

Based on this, the possible uses of AR in a SaCI are [17]:

- Enlarged book.
- Educational games for the classroom.
- Virtual models of certain complex structures.
- Virtual models that reproduce sounds.
- Represent sounds.
- Magic mirrors.
- Windows and magic doors.
- Magic eyeglasses.
- Support for navigation.
- Collaborative space.

To evaluate the benefits of using the SRA agent in a SaCI, we will consider the following assumptions about the impact of AR on a SaCI. In this work, the impacts will be called *learning dynamics*, and are based on the criteria defined in [11]:

- *Dynamics linked to the student's mental state*:
  - ✓ Higher motivation.
  - ✓ Higher attention.
  - ✓ Higher concentration.
  - ✓ Higher satisfaction.
- *Dynamics linked to the teaching process*:
  - ✓ Higher learner-centered learning.
  - ✓ Improvement of the collaborative learning process.
  - ✓ Improvement of the learning curve.
  - ✓ Higher understanding of content.
  - ✓ Higher creativity.
- *Dynamics linked to the compromise of the student to the learning process*:
  - ✓ Higher attention to detail.
  - ✓ Higher interactivity.
- *Dynamics linked to improvements in the process of understanding contents*:
  - ✓ Improvement in spatial skills development.
  - ✓ Improvement in the memorization.
  - ✓ Improvement in the execution of physical tasks.

In addition, SRA agent should:

- Make multiple representations of information and knowledge, in time/space, appropriately.
- Present the contents in a novel form to the students.
- Focus the attention on relevant contents.
- Allow the interaction of the students with the objects presented by it.
- Allow a natural interaction and collaboration of the students through it

IV. AR IN A SACI

In this section, we specify how to add an AR agent (SRA) to a SaCI. Classically, a smart classroom is a learner-centered approach that supports the learning process. Figure 1 presents the general context of SRA in a SaCI. In particular, SRA is modeled through a device agent of the logical layer of the AmICL, which interacts with the following components of a SaCI:

- The human users of a SaCI.
- The types of augmented display devices in a SaCI (tablets, smartphones, smartboards, computers, among others).
- The learning process management software (characterized as agents) in SaCI (content repositories agents, agents representing the VLE, etc.).
- The specific services required by SRA in SaCI to perform its tasks (marking, geolocation, among others). Basically, it is the software that allows creating augmented scenarios of different types, to deploy them, etc.

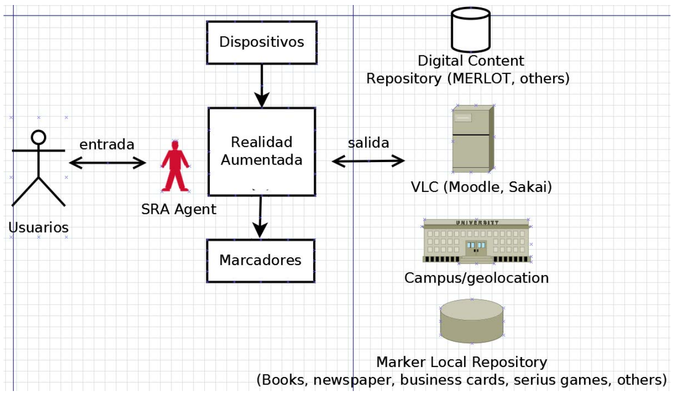

Fig. 1. General context of a SRA agent in SaCI [29].

The main objective of SRA agent is to provide AR services to other SaCI agents, in particular, to human agents (students and teachers). In general, SRA processes request for augmented information management, such as: visualization of augmented objects, design of augmented objects, among others, at the request of different agents of SaCI (for the detailed design of this agent, see [29]).

V. Experimental Methodology

This section describes the methodological process used in the experiments, in a real educational context. Specifically, the use of AR is analyzed to reinforce the theoretical or practical knowledge of a course taught in SaCI, studying the *dynamics of learning* present in it, as defined in section III.B. For this proof a course about "Simulation" is considered.[1]

A. Evaluation Criteria

In order to evaluate the benefits of the use of SRA agent in a SaCI, and specifically in our case study, three hypotheses are considered:

- H1: AR in a SaCI improves the compression of the contents of a course (memorization).
- H2: AR in a SaCI increases the learning curve of the students.
- H3: AR in a SaCI motivates students.

Based on these hypotheses, the aspects to be evaluated are selected from the four categories of *learning dynamics* defined in section III.B:

- Due to H1, and considering the criteria linked to *improvements in the content understanding process*, the next question is defined: *What is the students' opinion about the application of AR in learning processes?* (memorization)
- Due to H2, and considering the criteria linked to *the teaching process*, the next question is defined: *What is the initial and final knowledge of students about the use of AR in learning processes?* (learning curve)
- Due to H3, and considering the criteria related to *the student's mental state*, the next question is defined: *What is the level of student acceptance of AR applications used during the course?* (motivation)

These questions are based on papers that analyze the use of AR in educational contexts [1], [10], [11], [19], [22], [30]–[33].

B. Experimental Environment

Based on the specification of how to add an SRA in a SaCI proposed in section IV (see Fig. 1), in conjunction with the philosophical bases of section III.B, the experimental environment is defined. It is intended to demonstrate the importance of AR as an emerging technology, which enhances the teaching-learning process in smart educational environments (SaCI). During the academic periods A (2014-2015) and B (2015-2016), "Simulation" course was developed in the degree "Ingeniería en Sistemas" from "Universidad Nacional de Loja" in Ecuador. All the material about this "Simulation" course can be accessed at the URL: [https://sites.google.com/view/cis-simulation1617/p%C3%A1gina-principal], where the transparencies, projects and resources, among other things, can be located.

On the other hand, this course was taught to 100 students enrolled in the academic period C (2016-2017), but now in the SaCI environment. In particular, in SaCI there is a software agent VLE defined in [7] that can use the services of the agent SRA during the session of a course that is managing. "Simulation" course has the same academic contents of periods A and B, and will be the study group for experimentation. That group was divided into two sub-groups at random, 50 of the students interacted with SRA during the course (experimental group), while the other group of 50 students received the course in a traditional way (control group). During the course development, the three criteria defined in section V.A were evaluated. We used a survey agent for that. In addition, two case studies are defined for the experimental group:

- Case study A (see Fig. 3): students and teacher interacting with AR scenes within an AR resource repository (Web) in a SaCI. It is used to evaluate the criterion linked to the teaching process (hypothesis H2).
- Case study B (see Fig. 4): students and teacher interacting through a mural (auras and markers) of AR with digital resources (Web) in a SaCI. It is used to evaluate the criteria related to the student's mental state, and improvements in the process of understanding the contents (hypotheses H1 and H3).

In general, the experimental group interacts through the VLE software agent to create and manipulate AR scenes linked to "Simulation" course, using the next AR software (see Figure 2): Aurasma,[2] Layar,[3] Augment[4] and Aumentaty.[5] Specifically, students selected some course topics, and created AR scenes of them. In particular, they carried out 5 scenes of the theme of "Introduction", 15 scenes of the theme of

[1]https://goo.gl/K0HcrN

[2]https://www.aurasma.com/
[3]https://www.layar.com/
[4]http://www.augment.com/es/
[5]http://www.aumentaty.com/

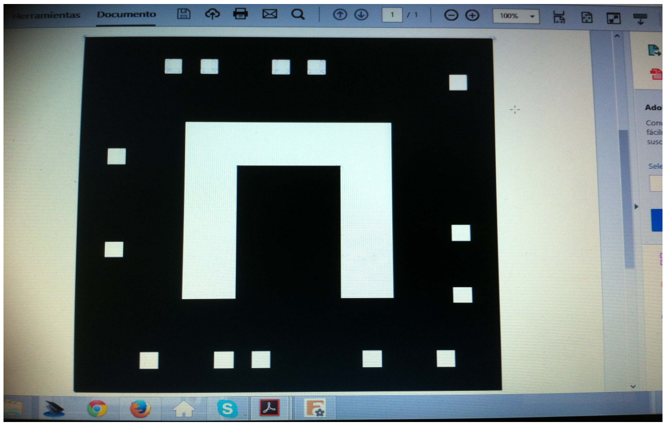

Fig. 2. Aumentaty: Author markers to recreate AR.

Fig. 3. Experimental group interacting in the case study A.

"Pseudo-random Algorithms" and 30 scenes of the theme "Simulation Software". All these scenes were shared, visualized and evaluated through a Forum in the VLE. Finally, the evaluation criteria (see section V.A) are evaluated for the two study groups, using questionnaires as instruments for collecting quantitative data. As mentioned before, these questionnaires are managed by the survey agent of SaCI.

C. Adequacy of SaCI for the Experiment

The components of the general architecture in SaCI, used by the experimental group, were:

- Users: fifty students and one teacher participated.
- Specific services in a SaCI used by SRA: the type of marker-based AR was used. To do this, we worked with the applications Aurasma, Layar, Augment, Aumentaty (author, viewer), and created a total of 50 AR scenes.
- Types of deployed devices: desktop and laptop computers, tablets and smart phones, cameras and printers.
- Involved SaCI agents: SRA agent, VLE agent based on Moodle,[6] and Survey agent based on LimeSurvey.[7]

The control group does not use the SRA agent during the course, since they do not create AR scenes, nor do they interact

[6]http://goo.gl/CvcSu8
[7]http://goo.gl/uT0Fx2

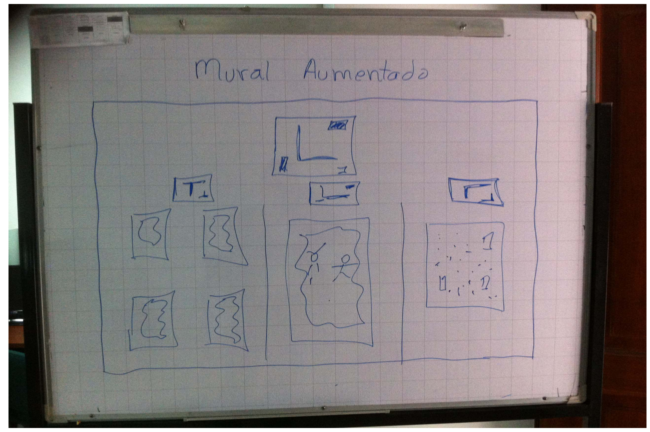

Fig. 4. Mural increased using Aurasma for case study B.

with AR scenarios. In this case, only the teacher interacts with AR scenes during the teaching process to explain the contents of the course (see Fig. 2). On the other hand, the activities in the course carried out by the students of the control group, as well as those of the experimental group, are the same as those performed by the students of the previous periods. The simulation topics studied are the same. Finally, the groups in each case have approximately an identical size, with the aim that the teacher (himself in all cases) has to do the same management of the group. The only difference between student groups is with respect to the utilization of not of AR.

Questionnaires are used as instruments for collecting quantitative data, and the answers to the questions defined in section V are based on the works proposed in [1], [10], [11], [19], [22], and [30]–[33]. Three questionnaires were constructed with the survey agent:

- Diagnostic questionnaire[8]: applied at the beginning and at the end of the course, and it consists of eight closed questions and one open question.
- Acceptance questionnaire[9]: applied ten weeks after the course has started, and it consists of four closed questions.
- Opinion questionnaire[10]: applied at the end of the course, and it is composed of ten closed questions.

The three questionnaires were applied to both the experimental and control groups.

VI. Results and Discussion

A. Questionnaire One: Diagnostics

Criterion: linked to the teaching process.

Sub-criterion: improvement of the learning curve.

Extended sub-criteria: higher learner-centered learning, improvement of the collaborative learning process, higher understanding of the contents, higher creativity.

In Table I, the context of the experimentation is made up of 61% of students ranging from 21 to 25 years old, corroborating that the ages of the study group actors are in the

[8]http://goo.gl/r4j5Af
[9]http://goo.gl/WVBNj2
[10]http://goo.gl/POYuER

TABLE I

DESCRIPTION OF THE STUDY GROUP (DEMOGRAPHIC DATA)

Descriptor	Value	Percentage
Age	21 to 25 years	61
Gender	Male	83
Level of instruction	Second year	78

TABLE II

DESCRIPTION OF QUESTIONNAIRE ONE, INITIAL KNOWLEDGE OF THE STUDY GROUPS

Question	Value	Percentage (%)
Knowledge of AR	No	56
Interaction with AR	Less than a year	70
Using AR applications	No	60
Factors not to use AR applications	I have not had the possibility	57
	I do not handle technology	14
Context of use of AR	Games	55
	Entertainment	33
	Education	33
Interest in creating AR applications	Yes	100
Preferences for applications to be created with AR	Games	86
	Education	60
	Entertainment	52
Devices of preference for AR	Smartphones with Android	73
	Personal computers (desktop / laptop)	73

TABLE III

AVERAGE GRADES IN THE STUDY GROUPS

	Period A	Period B	Period C	
	Simulation (10)	Simulation (10)	Simulation (experimental group) (10)	Simulation (control group) (10)
Average score	8.45	7.87	9.35	8.75
Number of approved students	36	40	50	48
Number of failed students	4	5	0	2

context of higher education. The identification of the actors of the experiment allowed us to plan and adapt the activities and resources of the course to an environment of digital natives, which facilitated the use of the TIC in SaCI.

In Table II the results of the first questionnaire are observed, indicating that 56% of the students do not have any knowledge of AR, which was a factor that motivated them to fulfill the activities and tasks defined in the course.

From the questionnaire one, we present some answers: “learn how to use AR, mainly in smartphones, and then to be able to apply them in simulation”, “learn to use and know how AR works”, “learn to use in Geo-location applications”. These opinions permit identifies the motivation of students to experiment in the field of AR in a SaCI.

At the end of the course, the relevant questions were reused to assess the knowledge acquired by each study group. With the results mentioned, some of the specific criteria linked to the teaching process are validated. For example, for the experimental group, AR led to an increase in student-centered learning, an improvement in the collaborative learning process, an improvement in the understanding of content, and an increase in the creativity in activities developed with AR. This is due to the fact that this group constructed and manipulated AR scenes using the author software for each of the three themes of the “Simulation”. In the case of the control group, some students failed to fully understand the use of the simulation, nor were there any spaces for creative and collaborative activities using AR, because the teacher was the one who exclusively used author software for AR. It is important to note that, in this case, the VLE agent did not use the SRA agent to provide AR based educational resources during the course of the control group -as it did with the experimental group- to improve the learning process.

To analyze the learning curve, the historical average grades[11] and satisfaction[12] during several academic periods (A, B and C) have been considered. Comparing the historical values of the two academic periods A and B, in relation to the study period C (see Table III), we can point out that the learning curve increased significantly in the experimental group, with less repercussion in the control group (both the average grade and the number of approved students substantially improved). The results of Table III allow considering the hypothesis H2: AR in a SaCI increases the learning curve of the students.

B. Questionnaire Two: Acceptance

Criterion: linked to the student’s mental state.

Subcriterion: higher motivation.

Extended subcriteria: higher attention, concentration and satisfaction.

To answer this questionnaire, case study B was used by the*experimental group*. The students used authoring tools to create AR applications, and to explain the three themes of “Simulation” course previously mentioned. The final socialization of the applications (3D animations, 2D photo galleries, hyperlinks to sites and videos, 3D models, among others) was carried out through the VLE agent, through a Forum. In addition, as a final activity, a peer evaluation was carried out of the shared applications. When performing the evaluation, the students interacted with the application visualizing AR scenes constructed with 3D objects, while others navigated the added hyperlinks, among other application functionalities.

For the *control group*, students were able to see the use of AR through videos and other learning resources offered by the VLE (these learning resources did not use AR) for the three themes of “Simulation”. They did not interact with SRA.

[11] https://docentes.unl.edu.ec/

[12] https://evaluaciondocente.unl.edu.ec/

TABLE IV
DESCRIPTION OF QUESTIONNAIRE TWO

Question	Value	Percentage (%) Experimental group	Percentage (%) Control group
Satisfaction with AR applications	A lot	81	11
Design of AR applications	Simple and nice	77	16
Use of AR applications	Very friendly	63	4
Functionality of AR applications	Yes	95	7

TABLE V
STUDENT SATISFACTION IN THE STUDY GROUPS

	Period A	Period B	Period C	
	Simulation (100)	Simulation (100)	Simulation (Experimental group) (100)	Simulation (Control group) (100)
Average Satisfaction	70.6	83.4	93.3	87.4

The lack of practice and real experiences of AR reflect the low percentages obtained by the *control group* (see Table IV).

The results of this section (see Table IV) allow answering the question raised in section V.A: *What is the level of student acceptance of AR applications used during the course?*

From the results obtained in Table V, it is verified that the criterion on the mental state of the student, linked to the increase in the motivation of them (experimental group) to learn in the course of "Simulation", and the average satisfaction of the students during the periods A and B, increased significantly (93.3%), in relation of the students of the control group. This confirms that there is a great satisfaction when developing the activities with AR by the students of the *experimental group*. This makes it possible to accept the hypothesis H3: AR in SaCI motivates the students.

C. Questionnaire Three: Opinion

Criterion: improvements in the process of understanding contents.

Subcriterion: improvement in memorization.

The results of the third questionnaire shown in Table VI can answer the question raised in section V.A:*What is the opinion of students about the application of AR in learning processes?* It is observed that the lack of real experiences with AR during the development of the course (control group case) limits the students' understanding of the content of the course, as well as AR paradigm. In particular, the results of Table VI show that using AR tools improves the understanding of this paradigm, which is an added value of knowledge acquired by the students of "Simulation" course. This is a result of having interacted with the SRA agent during the course.

These results allow us to conclude that the criteria for *improvements in the content understanding process* are validated, due to the fact that AR caused in the students of the *experimental group* an increase in the attention to details and memorization. This is also reflected in the results shown in Table III, as students are able to obtain better results by the level of comprehension they reach. The hypothesis H1 is accepted: AR in SaCI improves the understanding of the contents of a course.

TABLE VI
DESCRIPTION OF QUESTIONNAIRE THREE

Question	Value	Percentage (%) Experimental group	Percentage (%) Control group
Understanding of topics through AR applications	Yes	100	3
Collaborative work through AR applications	Yes	95	5
Integrate AR applications into courses or subjects	Yes	90	12
Difficulty of using AR applications	Medium	57	7
Use of AR applications in the classroom by the teacher	Yes	90	0

VII. CONCLUSIONS

The main objective of this research was to analyze the use of AR to reinforce the theoretical or practical knowledge of a course in a SaCI, using AR. AR is a technology that allows the student to complement the perception and interaction with the real world, offering infinite new possibilities of interaction in an SaCI. AR gives access to the knowledge with a new perspective, enriched by the great variety of interpretations and interactions. The most important value of AR in a SaCI is the possibility of exploiting this variety of interpretations/interactions. In particular, AR permits access to a broader and diversified knowledge that is contextualized to the needs of the student.

In particular, AR helps the process of knowledge contextualization, the basis of the learning processes of a SaCI. One of the objectives of SaCI is that the students interact with the real world, in such a way that it helps them to obtain information or knowledge about what they need. In this sense, AR enables the contextualization of those knowledge needs so as to generate relevant knowledge for the student. However, the simple fact of using AR in SaCI in its teaching processes does not necessarily improve the results obtained by the students: it is when the students have a rich interaction with the SRA agent (case of the experimental group) that the best results are obtained (see Tables III and VI).

All of the above is reflected in the results achieved in the experimentation phase. According to the metrics obtained by the introduction of SRA agent in a SaCI, there is a strong motivation of students to use these tools (see Table V), which is reflected in the average scores obtained in the courses that use AR (see Table III), that is, AR permits reinforcing the knowledge of the course. On the other hand, the learning curve improves because SRA agent allows a process centered on the student, under the premise "learn by doing". Augmented objects admit the contextualization of knowledge, contributing to this premise. Finally, the real activities derived from the use of the AR applications managed by the SRA agent reproduce the contexts the most really possible to use the knowledge within a SaCI, which generate a greater memorization of the educational contents.

Future works should do more analysis for other types of courses (medicine, architecture, etc.) using different types of AR, and also trying to assess the other criteria defined in section III, in order to have a deeper appreciation of the potentialities of AR in a SaCI.

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