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# ScoolAR: An Educational Platform to Improve Students' Learning Through Virtual Reality

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**ABSTRACT** Augmented Reality (AR) and Virtual Reality (VR) applications has been investigated in several domains. As such, their application in educational settings has witnessed to a growing interest by the research community. Teachers can be assisted by AR/VR, in a way that students can strength the learning outcomes, gained during the classroom lecture. However, despite their potential has been widely assessed, there still exists a bottleneck preventing a widespread adoption in the education domain: the lack of easy to use platforms enabling teachers and students to become producers of AR/VR experiences. This paper fills this gap, by proposing a novel platform named ScoolAR, developed for didactic purposes. ScoolAR allows to create AR/VR applications without any programming skills. Up to now, there is no evidence in the state-of-art of a didactic tool that allows to create AR/VR applications without programming skills. From such premises, ScoolAR has been developed to overcome these limitations and to enable an autonomous content creation system and thus boosting more engagement and awareness in the exploitation of AR and VR applications in everyday educational scenarios. Beside describing the architectural framework of the proposed platform, this paper presents the results of experiments conducted in a real didactic scenario. Considering two group of students, the first group was assisted with the ScoolAR framework, the second one conducted the study phase with frontal lecture. The test performed proved that the first group outperformed the second one on all metrics of evaluation. Thus, the combined effort between common didactic activities and technological innovation permits to achieve superior results in terms of both knowledge and competences, especially for those disciplines (e.g. Cultural Heritage and History of Architecture and more) where the transversal learning is fundamental.

**INDEX TERMS** Cooperative learning, AR/VR contents, educational field, reality task.

## I. INTRODUCTION

In recent years, Technology-Enhanced Learning (TEL) research has progressively concentrated on technologies such as Augmented Reality (AR), and Virtual Reality (VR) for improving users experiences in enriched multimodal education environments. New possibilities for learning and teaching provided by AR and VR are gaining increasingly importance in the school domain [1]. This aspect is due to the appeal of these technologies on the younger generations, which is confident with AR and VR devices, especially for video games [2].

Nonetheless, compared to other innovations, the educational values of AR and VR are not entirely based on the use of technologies, but it is closely related on how they are designed, implemented, and integrated into learning settings. In fact, to promote the concept of ''cooperative learning'' through AR and VR technologies, learners will be able to gain immediate access to a wide range of information. In this way, students become protagonists, working together to achieve shared learning goals [3]–[5]. Several studies have confirmed that students strengthen their motivation to learn through this kind of teaching activities [6]. Anyway, the role of the teachers is still fundamental, since they intervene with subjects and contents, making these tools efficient and useful. Besides, the figure of the teacher disposes the level of training and the correct and complete transmission of knowledge through the adoption of different teaching/learning approaches. Another issue to be treated is to avoid that immersive technology overloads the students by reducing their ability to process

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information correctly [7]. Lessons supported by AR and VR applications must be planned and structured as they could be misleading for students, who get used to the different learning dynamics created within the classroom. Among the most popular educational contexts (such as robotics [8], transportation [9], and business [10] just to mention some) AR and VR technologies are gaining importance in the humanities and arts [11], [12].

Considering the aforementioned context, this paper aims at describing a novel platform named ScoolAR, specifically designed to enable teachers and students in creating tailor-made contents for didactic purposes. In particular, it follows and extends a previous manuscript [13], in which the benefits of using AR and VR applications for educational scope have been proved, highlighting the necessity to expedite the development of multimedia experience even by non-expert programmers. ScoolAR arises from the necessity of developing a didactic tool that allows to create AR/VR applications without any programming skills. Up to now, these expertise are essential for using tools such as Unity3D [14], Vuforia [15], ARToolKit [16], which are not purposely designed for the school. To overcome this drawback, ScoolAR has a dedicated cloud environment which communicates with a mobile application, where all the developed contents are ready to be experienced with head mounted devices (e.g. Cardboards or VR headsets). Experimental results with real tests carried out in the classroom have highlighted this aspect. The combined effort between common didactic activities and technological innovation permits to achieve better results both in terms of knowledge and competences, especially in the experiences in which the disciplines interface in a transversal way. This manuscript has two fundamental novelties: the first one is technological, as the developed framework has an innovative architecture which facilitate the exploitation and evaluation of AR/VR experience from the web to the app. The second one is theoretical, in terms of educational benefits. In fact, supported by the results achieved so far and from the data collected in terms of improved knowledge and students' satisfaction (in synergy with a traditional activity of knowledge transmission), the validity of ScoolAR framework is shown, together with its main concept and design.

The general research question (RQ0) is to verify if, and how, virtual environments can better transfer knowledge during the teaching activity. Moreover, the following research questions intend to establish whether the cooperative and experiential methodology implemented with the digital technology represents a valid support to the learning process:

- RQ1: Does the use of a digital platforms facilitate the didactic experience of cooperative learning?
- RQ2: Can the creation of virtual tours for educational purposes be considered a tool for learning the history of architecture?
- RQ3: Is it possible to measure/evaluate the learning of the students who have used the ScoolAR platform?
- RQ4 Does ScoolAR platform, and the subsequent VR experience, positively affect the experiential learning of cultural heritage?

The paper is organized as follows. Section II provides a description of the works that adopted AR and VR in education. Section III describes ScoolAR, and offers details on its development. In Section V, an extensive comparative evaluation of is offered, as well as a detailed analysis of each component of our approach. Finally, in Section VI, conclusions and discussion about future directions for this field of research are drawn.

## II. RELATED WORKS

Albeit ongoing AR and VR studies have reached a forty-year milestone, its regular usability and capability in the educational domain is still at the primary phase. Most AR and VR works deal with the technological issue instead of its pedagogical benefit, especially in collaborative learning.

In [17], the authors have developed Virtuoso, an educational-based collaborative handheld game for studying the history of art. This game aimed at sorting a set of artworks with their creation date in three different conditions: cards, a PC and a PDA (Personal Digital Assistant). For increasing the collaboration, the participants obtained a huge score with a high team rather than individual. The results have confirmed that there were not meaningful differences in the educational outcomes, despite the three different game conditions. Furthermore, through the results obtained during the experimental phase, they demonstrate not only the effectiveness of AR tools for unskilled users, but they have also introduced a fun factor when visiting public museums. However, Virtuoso had a small screen and low quality audio, this characteristics can inhibit the collaboration procedure and influence the measures.

An AR application called Protein Magic Book (PMB), has been developed at the Human Interface Technology Laboratory (HIT Lab) as a learning tool for studying chemistry [18]. The aim is to demonstrate the effectiveness of peer learning in an environment that uses AR applications to learn scientific concepts. The users who had to study the concept of protein structure were divided into three groups based on the type of learning: individual learning with AR, peer learning with AR and individual learning without AR. Before the experiment, the students thought that learning with peers would help them to understand the content better and more easily, while the tests showed greater efforts for this. Then, students that studied with AR alone performed better than the other two groups. The evaluation was assessed by a questionnaire submitted to 96 subjects.

Another AR system specifically developed for teaching students of primary school is proposed in [19]. SMART (System of Augmented Reality for Teaching) is an educational system that uses AR to enable children to explore categories such as means of transport, types of animals and other similar semantic categories using a set of rackets that are used to manage a TV show with 3D models that are superimposed on the video feed in real time of the whole class. The experiments were performed with different classes of students in three different local primary schools. The results demonstrated that SMART is efficient in maintaining high levels of motivation among students and that SMART has a positive impact on the learning experience of students, especially among the students that are weakest.

In the field of mobile games, it is important to mention the work developed by Dunleavy *et al.* [20], which is called Alien Contact! It has been designed to help students in learning math, language arts, and scientific literacy. The game scenario is an alien invasion. The goal is to discover why the aliens have landed on earth. The subjects involved in the study has to work in team of four people with specific roles: chemist, cryptologist, Hacker, and FBI agent. They have to answer to problems related to science, math and language. It demonstrated a great engagement with three case studies. As part of a research project, researchers conducted multiple qualitative case studies in two middle schools (6° and 7° grade) and one high school (10° grade) in Northeastern United States to document the possibilities and limitations of AR simulations for both students and teachers. Researchers collected data through formal and informal interviews, direct observations, website posts and site documents. Teachers and students affirmed that the technology and interaction, situated and collaborative problem-solving offerings of AR simulation were highly involving, in particular among students who had previously presented behavioral and academic problems for teachers. However, this investigation was limited by GPS (Global Positioning System) error problems. Students and teachers are discouraged by GPS error, and this issue could have affected the experiment. ARiSE [21] is a research project that creates an AR technology for schools by using a virtual showcase used in museums. ARiSE has the aim to develop interactive scenarios for learning and associated software prototypes to assess the pedagogical efficiency of the AR technology. In a first test, observation, usability questionnaire and focus group have been used as evaluation techniques. Some problems of usability have been identified and also have been found problems related to speed and accuracy.

In [22], the authors proposed AReX (Augmented Reality Experiment) a prototype to investigate the potential of AR spaces to support collaborative learning and supports the means of communication and interaction. According to the authors, AR technology was used as a means to increase collaboration by adding virtual objects to the real world and sustaining real-time interaction. Moreover, this technology is still in the initial phase, in particular in the field of education. The main goal of their study is to investigate the potential of AR spaces as markers in providing communication cues and supporting collaboration in the learning environment. Questionnaires have been submitted to 12 participants. The study confirmed that AR is suitable for collaborative learning. The number of subjects was quite small and ARex lacks explanations and consequences related to the experiment.

A mobile AR simulation has been conducted by Lin *et al.* [23]. The authors focused on knowledge acquisition in the field of elastic collision. They designed an experimental phase with 40 undergraduates divided in two groups: the first one uses the AR system, the other aided by traditional 2D simulation system. The learning performance has been proven with a pre-test and post-test evaluation, and showed that the AR physics group has better results of the 2D physics one. Knowledge acquisition of students have been qualitatively represented according to a coding scheme adapted to three categories. The results demonstrated that students who learned with the AR system achieved significantly learning outcomes than those who learned with the traditional 2D simulation system. Furthermore, the behavior patterns suggest that the AR Physics system can be a valuable support tool and enable students to respond quickly to displayed results and support their knowledge-building processes to produce a positive result.

Educational domain also incorporated VR technologies into teaching, learning, and training. Notwithstanding VR is not newly, recent applications for visualization and interactions have made this technology attractive to scholars. The latest VR Head-Mounted Displays (HMDs), such as HTC Vive or Oculus Rift, allows an immersive experience, thus gives the impression of "being" in the environment in which the task has to be performed.

In this regard, it is worth to mention a user study carried out with military students, which described that the lecture-based teaching approaches, that are commonly used for the subject material, are less compelling than immersive VR-based teaching techniques [24]. In the work [24], the author studied the interaction effect of immersive VR in the classroom. The purpose of the experiment was to compare VR-based immersion and lesson-based multimedia education, in terms of learning, basic corrosion prevention and control with military personnel. The author accessed the learning results from pre-exam and post-exam scores and the usability of the VR system through questionnaires. VR-based learning produced better results and a statistically significant interaction between the type of education and time. The conventional learning group had an increase of 11%, while the VR group had an increase of 26%.

Taking into account the research question (Q0 and Q1), also the related works here presented have demonstrated that the use of AR/VR tools in the educational field, contributes to improve the teaching experience and therefore to facilitate the transferring of content with a view to collaborative and cooperative learning.

However, to date, there is no evidence in the state-of-art of a didactic tool that allows to create AR/VR applications without programming skills. From such premises, ScoolAR has been developed to overcome these limitations and enable an autonomous content creation system and thus import more engagement and awareness in the fulfillment of AR and VR applications.

## III. SCOOLAR PLATFORM

In this Section, all the components of ScoolAR platform will be detailed. As stated in the Introduction Section, the purpose of the platform is to create a deployment ecosystem of AR and VR contents. The idea is to provide a set of tools which allow any user to create own VR (e.g 360° panoramic images) and AR contents (information added on images). These contents can be shared and visualized.

ScoolAR is a sharing platform, which allows the management of users with different roles. It can be adapted with test within a tour. Moreover, it is possible to manage the tag for AR. This platform is developed in ''Black-box'' which means that it allows in-house integration as a service. The back end is based on Amazon Web Services (AWS) and the app is created with Unity in C#. The web editor for the tours generation is also Unity. The contents creation should be done directly with a web based front-end, while the cloud based back-end allows to exploit contents in the following ways:

- through iOS / Android App (for both VR and AR), also with support for Google Cardboard;
- via web;
- via Oculus Quest (only VR part).

### 1) VR SECTION

VR contents are substantially constituted by virtual tour formed by a series of interconnected 360° panoramic photos (defined scenes). Within each scene there are *hotspots*, that represent interactive points linked to the content. Through the *hotspot* is possible to jump to another scene or view information content in the form of text, image, video, audio, 3D model or quiz.

Each virtual tour can also have one or more maps. The aim of the map is to provide a spatial location of different scenes and a fast navigation method. Each map consisted of an image and a number of positions within it, each associated with a scene. The fruition mode of virtual tours depends on the platform used. Two different modes can be identified: 2D, in which the tour is visualized on a normal screen with interaction through mouse or touch; 3D, in which the tour is visualized with the support of specific hardware for the virtual reality (mainly Google Cardboard or Oculus Quest). Examples of the possible output allowed by the platform are shown in Figure 1.

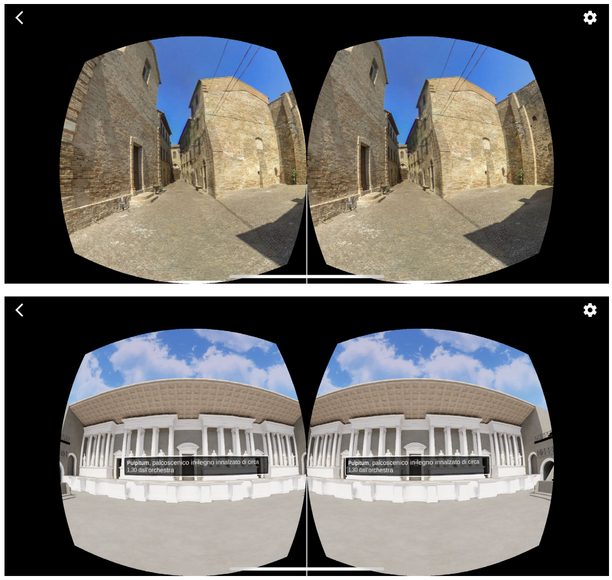

**FIGURE 1. Examples of tour realized for the immersive experience in VR. The pltform allows to manage both equirectangular images and 3D models in both web and immersive visualization.**

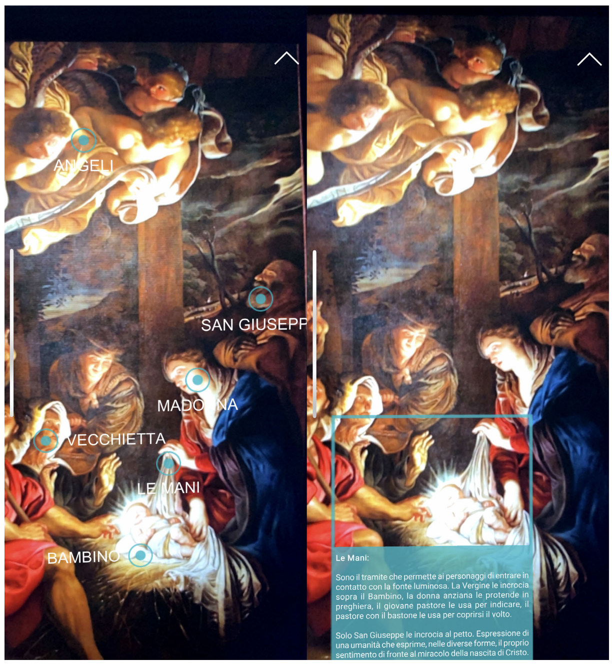


**FIGURE 2. Examples of AR experience. In the specific case, a painting is augmented with AR Tags and in-depth detail of the artwork.**

### 2) AR SECTION

AR contents consist of images that will be used as tags and associated contents. The tag is the image that is recognized and traced through the use of the device's camera. Once the tag is recognized points of interaction will appear on it, called *hotspot*, each associated with a content. The content will be showed after the user interacted with the *hotspot*. The possible contents are: text, image, video, audio, 3D model, quiz. To benefit from AR contents the use of iOS or Android mobile apps is necessary. This aspect is one of the main novelties of the platform, as it allows every user to have, directly in their smartphone, the augmented experience. Indeed, the specific function enables to manage different tags for the creation of AR experience. An example of the application running after the creation of the AR experience is depicted in Figure 2.

### 3) USERS MANAGEMENT

The users management is probably the most important aspect of the whole project. The basic idea is to have a single infrastructure for all users, defining also a set of roles and

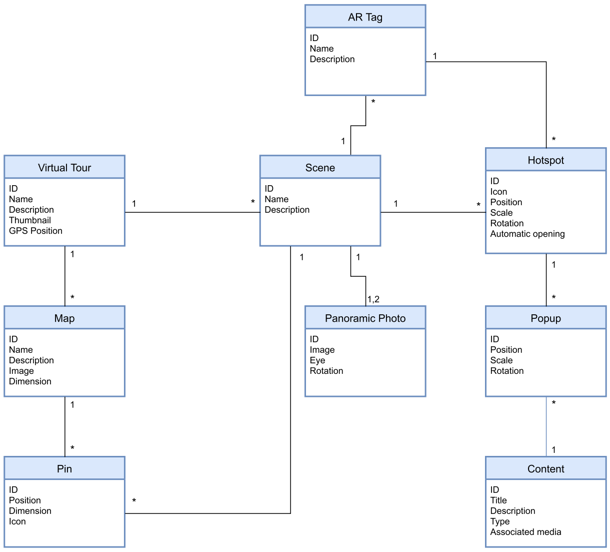


**FIGURE 3. Diagram for the representation of the data used within an AR/VR scene. The scene, which is the main component, has as components the virtual tour, the *hotspot* and the panoramic photo. In case of AR, the main content is created by linking to the AR TAG (first class on the left) to which it is possible to link more content derived from the other data structures (the 3 on the right *hotspot*, popup and content).**

authorizations. Since the platform is conceived to allow different users profile with different aims (i.e. the role of the student, the role of the teacher, cooperative learning and so on), different levels of interaction are structured as follows:

- **Master**: the highest role. It represents a customer in its entirety;
- **Creator**: the user who creates and modifies contents to be shared. One or more creator are related to a **Master**;
- **Reader**: the user who visualizes contents (only read). The contents must be shared by a Master and/or Creator.

The sharing of contents to be usable is a still open issue and partially related to the business model of the whole project. In general, a hierarchical structure can be considered:

- A user **Master** has one or more users **Creator** associated;
- each user **Reader** is associated with a **Master** or a **Creator**.

The presence of **Guests** can be evaluated. Hypothetically these would be users completely without accounts who view contents made public.

#### 4) DATA LAYER

Figure 3 reports the representation of the data used within an AR/VR scene. The scene, which is the main component, has as components the virtual tour, the *hotspot* and the panoramic photo. In case of AR, the main content is created by linking to the AR TAG (first class on the left) to which it is possible to link more content derived from the other data structures.

The data exchange format was JSON (JavaScript Object Notation) and Figure 4 presents some contents to be exchanged in the various Application Programming Interface (API) calls.

**TABLE 1. APIs methods and descriptions.**

| Method | Path | Description |
|---|---|---|
| GET | /tours | List of user tours |
| POST | /tours | Creating a new tour |
| GET | /tours{id} | Tour detail-full tour returns |
| POST | /tours/{id}/thumbnail | Set the thumbnail of the tour |
| PUT | /tours/{id} | Modify tour |
| DELETE | /tours/{id} | Delete tour |
| POST | /tours/{id} | Publish a tour |
| POST | /tours/{id}/scene | Create a scene for a specific tour |
| PUT | /tours/{id}/scene/{id} | Modify a scene |
| DELETE | /tours/{id}/scene/{id} | Delete a scene |

#### 5) BACK-END

Back-end is the set of online services that provide all the components needed for the whole ecosystem (API, storage, authentication). The API made available must make it possible:

- to obtain contents available for users (even filtered);
- to obtain all information concerning both VR and AR contents;
- to create new contents;
- to modify existing contents;
- to upload images in the storage;
- to share contents (to evaluate).

The OAuth 2.0 protocol, leaning to Cognito (Amazon), is used for the authentication. Table1 describes all the detected endpoint, a short description for each of them and the HTTP method with which to recall them.

The remaining endpoints are not explained but follow the same logic scheme of those listed above, then a hierarchical construction that starting from the tour and arriving until the specified entity. It will be provided a specific endpoint as in the case of thumbnail described in table 1, when an image or a thumbnail for an entity must be set. Regarding multimedia contents, such as images, audio, video, 3D models, they have appropriate API, with a specific indexing so to use each content how many times is needed. Even concerning these API, the concepts of REST architecture will be used similarly to tours, with base/medium path. In Figure 5 a screen shot of the web app running is reported.

## IV. METHODS

Experiments were conducted within the *Renaissance* didactic unit; this period is important due to the artistic, architectural and urban expressions related to the court civilization. In particular, the early Renaissance was developed through the architectural and artistic interventions by Luciano Laurana and Francesco di Giorgio Martini, performed at the Montefeltro court (Urbino, Italy). During the lectures, the historical period was introduced, as well as the social and political characteristics that led to the urban planning and building projects linked to the presence of the Montefeltro family in the city of Urbino. The description of the individual interventions carried out in the Ducal Palace of Urbino was then deepened. The interiors and the architectural characteristics related to the representative function of the Duke

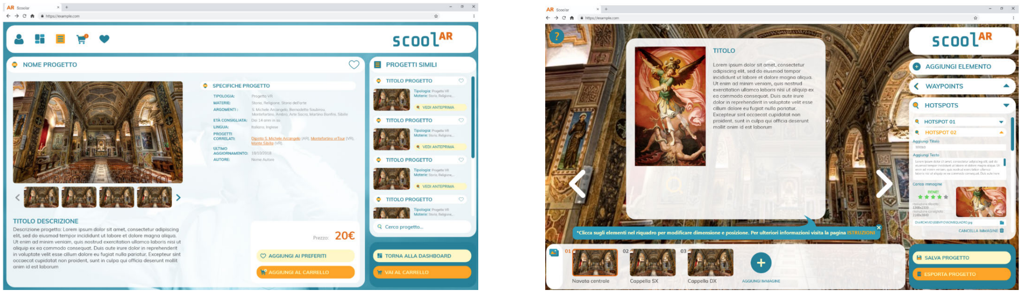

**FIGURE 4.** Project preview.


**FIGURE 5.** Example of tour creation with equirectangular images.

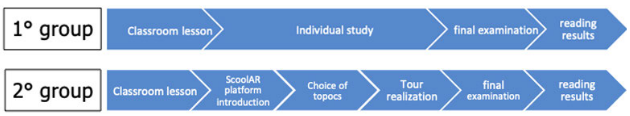


**FIGURE 6.** Description of the work phases of the "comparison group" (1$^{st}$) and the "research group" (2$^{nd}$). (1$^{st}$ phase: frontal lesson, 2$^{nd}$ phase: individual study for the 1st group, work with the ScoolAR platform for the 2$^{nd}$ group; 3$^{rd}$ phase: final check; 2$^{th}$ phase: reading of the results achieved.

were then described, together with the works of art, paintings and sculptures preserved. Then, a group of students was proposed to deepen the study and knowledge of these Italian architectural-urban evidences, through the creation of a virtual tour included in the ScoolAR platform. The remaining part of the class has followed the traditional study method, this latter group is considered "comparison group" in this research. Figure 6 describes the activities carried out by the two groups of students: the 1$^{st}$ group defined as "comparison group", the 2$^{nd}$ group defined as "research group".

## A. PARTICIPANTS

The students selected for the teaching experience attend the third year of an upper secondary school of a technical institute, and they are 17 years old. The sample is composed of about 50 students, split in one third females and two thirds males. We did not follow a specific selection criteria, since their experience was gained during the common classroom activities where the whole sample have participated. They began studying the history of architecture in the first two years. In particular, they start to learn the Italian Architecture and urban studies. The required knowledge foresees to gain the specific technical language to recognize the elements of historical monuments and to recognize the features related to the specified historical period. The students are computer literate and have technological skills; indeed, they have used graphics software such as AutoCAD[1] and SketchUp[2] for over a year. These software have been employed for the architectural design and rendering of surveys. The students have also acquired good knowledge of spatial plotting and design organization.

## B. TEST PHASES

In the first phase, the teacher has illustrated the functions and characteristics of the ScoolAR platform. Among the various functionalities of the platform, it was decided to create 360° virtual tours, rather than the creation of an AR project. The VR tour does not require markers to be associated on site.

The next phase involved the historical and architectural study of the chosen themes, also through a further in-depth analysis of the topic. Panoramic images were identified by their own by the students, in order to favour the self-learning capability by the students; points of interest and themes were chosen by the students as well. The 360° panoramas were downloaded from Google Maps[3] using the iStreetView.com[4] program.

The loading phase of the panoramas and the creation of the real tour have been made through the so-called *hotspot*, that are the points of interest chosen by the students to deepen their knowledge of the artifacts. The descriptive text of the point of interest has been inserted into the icon associated with the chosen *hotspot*. In this way, the students have carried out a work of re-elaboration and synthesis of what they have learned, not only in the classroom, but also through the work of study and further deepening, carried out autonomously.

Then, the *hotspot* and waypoint have been created. This phase allows to define the icon that contains the studied and developed contents in a synthetic and exhaustive way.

[1]https://www.autodesk.it
[2]https://www.sketchup.com/it
[3]https://www.google.com/maps/
[4]https://svd360.istreetview.com

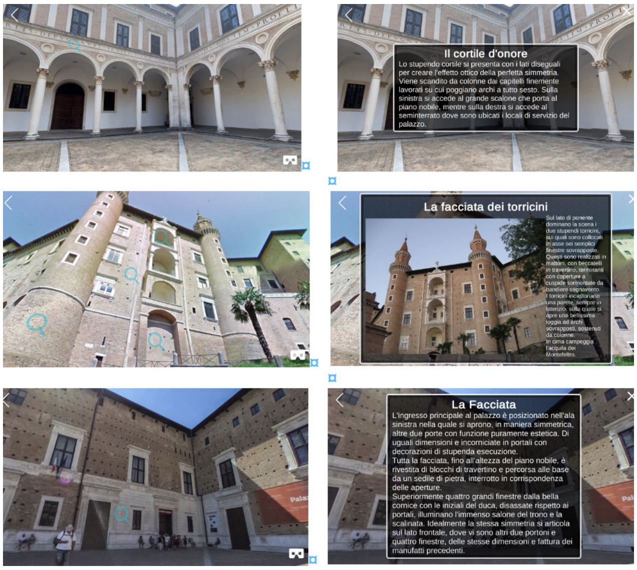


**FIGURE 7.** Examples of *hotspot* included in the tours made by the research group, with the ScoolAR platform.

**FIGURE 8.** Examples of waypoint included in the tours made by the research group, with the ScoolAR platform.

This phase of work was important in the initial experiential pathway, as it forced the students to have a greater spatial and wider knowledge of the monument that is the subject of the work. The creation of a tour is flexible, since the students can decide the preferred paths, points of view, meaningful details; this aspect leave improves the ability of the student to evaluate and synthesize the acquired knowledge. The work was followed by the teacher, who provided not only technical usage suggestions on how to use the platform, but also a close support on the content selected, developed and inserted within the windows connected with the *hotspot*.

Within each individual group, the work was carried out collaboratively, as the front-end allowed to work jointly on the single VR experience. In this way, they could exchange information and suggestions from both technical and content points of view. Different aspects where developed by each component of the group: someone was interested in overviews downloading, others has chosen and found the contents and summarized them (so that they can be inserted into the icons provided), others more has entered the material within the platform. Cooperative learning has thus found its most complete and creative form. The students could also transfer the theoretical knowledge learned during the traditional lesson, applying it in a context of real and direct knowledge of the architectural and urban heritage studied. The results obtained can be summarized in virtual tours that have highlighted not only the general descriptive part of the chosen context, but also the focus on points of interest detected by the students. In particular, the description of the famous ''Facciata dei Torricini'' is emphasized. The description has been created through the insertion of *hotspots* that lead the virtual visitor along the brick wall to the loggias made of stone and rich in decorations and classic references. Another point of interest of the tour was the description of the building within the urban context, inserting waypoints along the roads of the entire complex, up to the elegant courtyard of honour, the core of the entire palace. Here the *hotspot* inserted has favoured the architectural and artistic description of the entire environment, as a symbol of the architectural elegance of the Italian Renaissance.

### C. DATA ANALYSIS

At the end of this important phase of the teaching activity, the evaluation phase was carried out, aimed at verifying the learning level reached for the contents developed in the teaching unit. As previously described, the topics have been developed with the whole class through the methodology of the classroom lecture. Only the part related to the reality task has been carried out by a smaller group. The final examination's theme was the Ducal Palace of Urbino, a topic developed in more detail and in-depth with the whole class. In fact, the theme, which lends itself to transversal and interdisciplinary connections, has had further insights with multiple teaching materials such as: videos, critical readings, detailed sheets contained in the textbook, study of the works contained within the building, chronological reading of the historical development of the building, relationship of the building within the urban fabric and recent interventions to enhance the context. The final test, administered to all students, has allowed to evaluate the knowledge acquired by the entire class, but also to highlight the potential of the experience carried out through ScoolAR platform. It is essential to note how much the student ''knows how to do with what he knows'' [25] to validate the support offered by the platform as a facilitating tool for the transmission of content. In fact, the questions proposed to the students within the test, were not strictly related to the specific contents entered within the tour. This is neither to create disparities of treatment among the students who have not worked on the platform, nor to affect the accuracy of the results collected within the research.

The data collected with the questionnaire 1 ''Final verification of learning'' led to the final evaluation of each student. Before starting the analysis of the results obtained from the questionnaire, the reliability test has been performed. The percentage of correct answers provided for each question administered, allowed the data processing for questionnaire validation through the adoption of Cronbach's alpha coefficient. In fact as stated in [26], this coefficient is relevant and suitable especially under certain empirical circumstances. It is defined as follows:

$$\alpha = \frac{k}{k-1}(1 - \frac{\sum_{i=1}^{k} \sigma^2{}_{Y_i}}{\sigma^2{}_X}) \tag{1}$$

**TABLE 2. Description of the types, purpose and tools used to collect information through the questionnaires.**

| | Aim | Tool |
|---|---|---|
| **Questionnaire 1** | Final check of learning | Socrative |
| **Questionnaire 2** | Collection of experience information | Google forms |

where k is the number of items, $\sigma^2{}_X$ is the variance of the whole sample of items and $\sigma^2{}_{Y_i}$ is the variance of the *i-th* item w.r.t. the whole sample.

The coefficient alpha allows to check the internal consistency of the questionnaire. The minimum recommended value for the alpha value is between 0.60 and 0.70 to ensure sufficient internal consistency of the survey. A value between 0.70 and 0.80 indicates a fair degree of internal consistency. The internal consistency of the questionnaire stands at the value of $\alpha$ equals to 0.75.

From the data collected, there is a discrete internal consistency and a good value of Cronbach's Alpha ($0.70 < \alpha < 0.80$) which confirms the correspondence of the results obtained with the structure of the questionnaire. This means that the answers provided by the students present a complete uniformity with respect to the entire questionnaire. The mean of the standard deviation of the individual results is close to the mean of the standard deviation of the entire questionnaire.

## V. RESULTS AND DISCUSSIONS

### A. TYPES OF QUESTIONNAIRES ADMINISTERED

To illustrate the results obtained from this research, it is necessary to examine the results achieved within the didactic activity. This step was carried out through the administration of a first questionnaire, presented to the students as a final test, which collected information about the learning of the fundamental contents of the proposed teaching unit (knowledge of the historical period of the Renaissance, of its essential characters through the civilization of the court, of the architectural characteristics of a Renaissance artifact, of the artists and artistic works connected to it, of the existing links with the period of Greek and Roman classicality, etc.). The Socrative[5] online platform/app was used, which allows to create questionnaires for the evaluation purpose, obtaining percentages and statistics that can be reworked for educational purposes. A second questionnaire, created with Google forms, was administered to evaluate the experiential aspect (reality task) and the student involvement (cooperative learning), with respect to the use of the ScoolAR platform and the learning methodology through VR.

#### 1) TYPES OF QUESTIONS RELATING TO QUESTIONNAIRE 1: FINAL ASSESSMENT OF LEARNING

It is worth noting that the topics covered in the questionnaire do not correspond to the contents included in the virtual tours made by the students. The following table (Table 3) illustrates the type of topics developed through the questions of the verification questionnaire. It indicates the number of questions and the relative percentage of incidence on the total administered, defining the field of disciplinary contents treated.

**TABLE 3. Classification of the questions entered in the content verification questionnaire, administered through the Socrative platform. Indication of the percentage of valence on the total number of questions.**

| | Types of questions in the verification questionnaire | Nr Questions/Total | Rate (%) |
|---|---|---|---|
| **T1** | Description of the architectural elements of the Ducal Palace of Urbino | 7/30 | 23 |
| **T2** | Room description of the Ducal Palace of Urbino | 12/30 | 40 |
| **T3** | Famous artists and personalities linked to the Ducal Palace of Urbino | 6/30 | 20 |
| **T4** | Description of paintings in the Ducal Palace of Urbino | 5/30 | 17 |

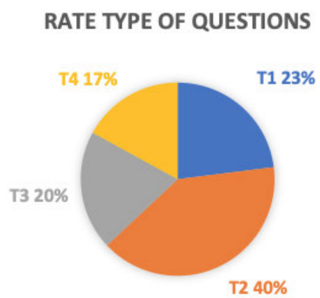


**FIGURE 9. Rate of incidence of the typological classes of the questions with respect to the total administered in the final verification questionnaire.**

Figure 9 shows the percentage of incidence of each type of question on the total administered.

The types of questions represent the different disciplinary aspects developed and deepened through the topics connected to them.

- **Type T1** deals exclusively with the description of the architectural elements of the building, with clear references to the history of classical architecture, which represents a preparatory knowledge. In fact, these topics were dealt with during the two-year course to provide students with the fundamental skills for a technical reading of the artifacts, through the definition of concepts and terms of the architectural language.
- **Type T2** deals with the description of the building. This allows a comparative reading of the styles and the building techniques. A specific disciplinary knowledge is required from the students, as well as a correct use of a technical language.
- **Type T3** refers to the knowledge of the figures of famous personalities and artists linked not only to the monument studied, but also to the political and social history of the time. In fact, an artistic period, such as the Renaissance, bases its stylistic characteristics on cultural choices closely related to court life.
- **Type T4** focuses on the description of the paintings in the National Gallery of the Marche Region, exposed in

[5]https://www.socrative.com

**TABLE 4. Questions given to students at the end of the experience with the ScoolAR platform. (S=single choice; M=multiple choice; A=open answer).**

| | Survey questionnaire on the use of the ScoolAR platform | |
|---|---|---|
| | **Questions** | **Answers** |
| Section: General information | | |
| Q1 | Age | S |
| Q2 | Gender | S |
| Q3 | Origin | S |
| Q4 | Course of study | S |
| Section: Predisposition to the use of technologies | | |
| Q5 | Are you familiar with the use of technologies? | M |
| Q6 | How important is the use of technology in daily life to you? | M |
| Q7 | In which of these activities of daily life do you use technology most frequently? | M |
| Q8 | What channels or tools do you usually use to study? | M |
| Q9 | Some general questions regarding the use of technology and mobile apps | M |
| Section: Some more information about ScoolAR | | |
| Q10 | How do you rate this first approach with ScoolAR? | M |
| Q11 | What usability issues have you encountered (if any)? | A |
| Q12 | Through the use of the app which goal did you set yourself? | A |
| Q13 | Did the app help you reach the goal you set yourself? | A |
| Q14 | Which app functions are most/least important to you? | A |
| Q15 | What aspects are not functioning as you expected? | A |
| Q16 | Are there any features you expected to find that you did not find in the app? | A |
| Q17 | What features would you add to the app? | A |
| Q18 | What do you think about the app? | A |
| Q19 | How to evaluate the graphical aspect of ScoolAR? | M |
| Q20 | Do you believe that the information received for the use of ScoolAR was | M |
| Q21 | Evaluate the overall quality of ScoolAR | M |
| Section: The experience with ScoolAR in the study of the history of architecture | | |
| Q22 | How do you evaluate the usefulness of ScoolAR content in the study | M |
| Q23 | How would you evaluate the ease of use of ScoolAR in the studio? | M |
| Q24 | How do you rate the use of ScoolAR 360° tours in the studio | M |
| Q25 | Do you think introducing applications like ScoolAR into the studio is | M |
| Q26 | Evaluate the support that ScoolAR has given you in studying the history of architecture | M |
| Q27 | Using ScoolAR made you passionate about the topic | M |
| Q28 | How much do you think you have learned about the History of Architecture using ScoolAR? | M |
| Q29 | You would recommend ScoolAR to your friends | M |
| Q30 | Evaluate your degree of satisfaction after the experience with ScoolAR | M |

the Doge's Palace. These works represent the culture of court, through portraits and symbolic images closely related to the Renaissance period. They should therefore be read with a language that interprets the themes of the society of the time.

#### 2) TYPES OF QUESTIONS RELATED TO QUESTIONNAIRE 2: COLLECTION OF EXPERIENCE INFORMATION

The second questionnaire, created with Google forms, was aimed at collecting more detailed information on the use of the ScoolAR platform, and was distributed only to the students who have carried out the in-depth work. The following table 4 details the questions administered to the students, divided into 4 sections. The multiple choice was presented according to the Likert scale, with 5 items.

The Section "General information" collects the students data. The Section "Preparation to the use of technologies" analyzes the type of confidence that exists with the technology and which are the most used sectors. The Section "Some more information about ScoolAR" mainly collects feedback on the use of the platform, its functionality and compliance with the operational approach. The Section "Experience with ScoolAR in the study of the history of architecture" explores the contribution provided by the platform to the approach to the history of architecture, to the experiential and motivational value provided by the use of tours.

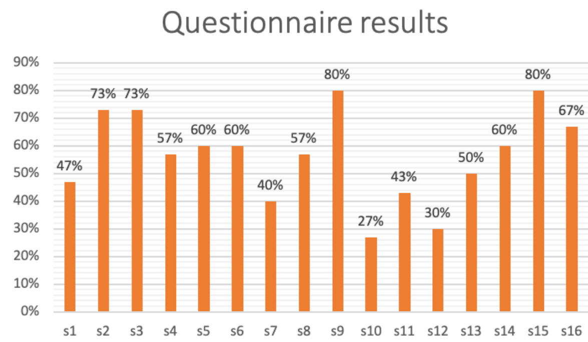


**FIGURE 10. Results, in percentage, of the correct answers provided by each individual student (labeled as "s" for privacy purposes).**

### B. DATA ANALYSIS AND ANSWERS TO RESEARCH QUESTIONS

The verification carried out with Socrative led to interesting elements of enhancement of the path carried out with the use of the ScoolAR platform. In fact, the group of students who has carried out the tour on the Ducal Palace of Urbino has obtained the best results at the end of the test (RQ0), expressed as a percentage of correct answers. This means that the cooperative and experiential study has made it possible to achieve not only a good level of knowledge, but also to strengthen competences, facing the assessment with greater ability. The expected result confirms the validity of the ScoolAR platform as a support to the experiential teaching: the reality task has been strengthened with the realization of the tour to complete the training action. The positive results have been collected in the graph (Figure 10) which highlights the percentage of correct answers which exceeds 70%, made by the tour group on the Doge's Palace,

This means that the discipline has been learned and the students have understood and reprocessed what they have learned during the lecture, deepening it, up to being able to realize their own tour. Another important aspect is the shorter time spent to complete the questionnaire by the group of students who worked with ScoolAR. The competences gained through the experience of ScoolAR have facilitated the reading and understanding of the proposed questions, so much so that students have completed the 30 questions in a significantly shorter time than the rest of the class. This makes the path carried out in cooperative learning (RQ1) valid: all the students who have collaborated in the realization of the project have contributed in a heterogeneous and participatory way. The more than positive results achieved by the entire group confirm that the work carried out has allowed each of them to add value to the project and contribute to the mutual exchange of information. This is also confirmed by the results of the questionnaire administered at the end of the activities.

Most of the students affirmed that they were familiar with technology (a lot 28.6%, normal 71.4%), stating its importance in daily use (quite important 57.1%, very important 42.9%), especially in communications (100%) and games (85.7%). They use digital and Information Technology (IT)

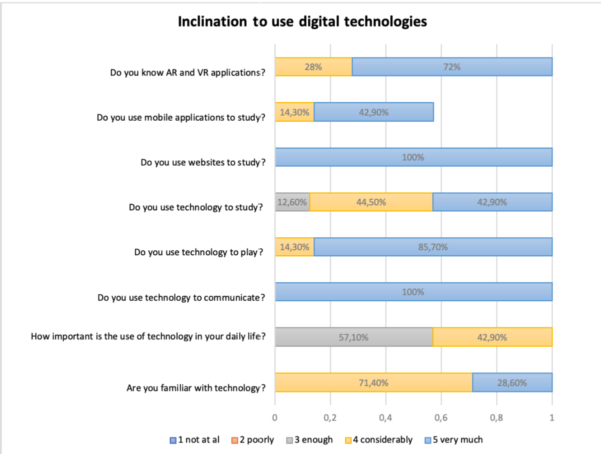


**FIGURE 11.** Comparative histogram of the responses obtained in the inclination to use digital technologies section of the questionnaire administered at the end of the activities with the ScoolAR platform.

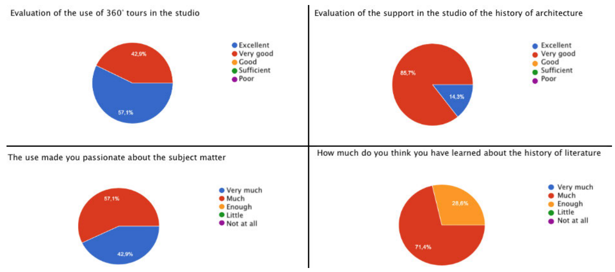


**FIGURE 12.** Some results of the questionnaire related to the Section The experience with ScoolAR in the study of the history of architecture. In the first histogram, students rate the use of the tour in the studio as excellent; in the second histogram they define the support provided by the platform in the study of the history of architecture very good; in the third histogram the use is defined as very passionate and in the fourth histogram it is stated that they have learned a lot using the platform.

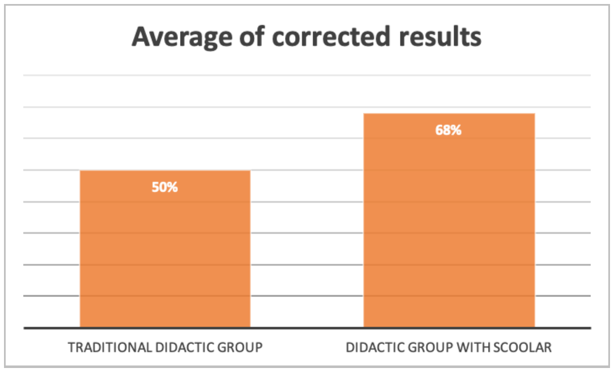


**FIGURE 13.** Average percentage of correct answers given by the two groups of students. The "comparison group" has obtained a lower percentage of correct answers (50%) than the second group. The "research group" has obtained the best percentage ( 68%).

tools for studying, such as websites (100%), even if they appreciate the traditional approach with the textbook, notes and material provided by teachers (100%), accompanied by the use of apps (42.9%). They know VR and appreciate it when it allows to learn more about a real place, such as a monument or a city of art. The approach with the ScoolAR platform was interesting (excellent 28.6%, very good 42.6%), also because particular problems have not been detected, with the exception of the final check of the entire tour at the end of the input data. This aspect was deliberately left to the teacher to evaluate the work. The platform intuitiveness and ease of use were also appreciated. This aspect confirms its validity in the study thanks to the possibility of deepening the topics covered. The realization of VR tours and their use, of which the students recognize the validity in the study (excellent 57.1%, very good 42.9%) has also allowed to experience the validity of the support given by the platform in deepening (RQ2) themes related to the history of architecture (very good 85.7%, excellent 14.3%), so much so that the students are involved in the topics dealt with (very much 42.9%, very 57.1%), declaring that they have learned the subject also thanks to the use of the platform (very 71.4%), whose use they recommend to their friends (most likely 71.4%) being satisfied (extremely satisfied 57.1%, quite satisfied 42.9%).

Table 5 reports the results of questionnaire on the use of the ScoolAR platform and digital knowledge and it summarises the results of the section on students' inclination to use digital technologies. Besides, Figure 11 depicted a comparative histogram of the answers obtained.

To verify the possibility of measuring and therefore evaluating students' learning with the ScoolAR experience (RQ3), it has been necessary to compare the results obtained by the 2 groups: the "comparison group" that carried out the learning path in traditional teaching and the "research group" that used the ScoolAR platform.

The highest percentage of correct answers provided by the second group confirms the educational value offered by the platform. Value that must now be analysed and measured, in terms of real learning. If one examines the types of questions correctly answered by the second group, it can be seen that the incidence of these questions on the total constitutes the highest percentage. The incidence of the correct answers provided by the "research group" is now verified with respect to the entire class group, to understand their value and therefore define their characteristics in detail, analysing the questions and their value in terms of acquired knowledge.

The second group has provided a higher percentage of correct answers compared to the typology T2, T3 and T4 (see second graph Figure 14), i.e. those relating to the description of the rooms, the artists and famous personalities and to the paintings of the Palazzo ducal. These topics are not included in the tour prepared by the students. This shows that the questionnaire did not favour the second group of students, but that they have understood the key concepts of the didactic unit regarding court civilization, whose cultural expressions translate into the production of artworks (type T4 of the questions) which symbolically represent the ideals of the men of the time (type T3 of the questions). This means that the students, during the realization of the tour, have explored in detail the aspects related specifically to the history of Renaissance architecture. The founding elements of the

**TABLE 5.** **Results of questionnaire on ScoolAR platform use and digital knowledge. The table summarizes the results of the section on students' inclination to use digital technologies.**

| Inclination towards digital technologies | | | | | | |
|---|---|---|---|---|---|---|
| | | Likert rating scale (from 1=not at all to 5=very much) | | | | |
| | | 1 | 2 | 3 | 4 | 5 |
| 1 | Are you familiar with technology? | | | | 71,4% | 28,6% |
| 2 | How important is the use of technology in your daily life? | | | 57,1% | 42,9% | |
| 3 | Do you use technology to communicate? | | | | | 100% |
| 4 | Do you use technology to play? | | | | 14,3% | 85,7% |
| 5 | Do you use technology to study? | | | 12,6% | 44,5% | 42,9% |
| 6 | Do you use websites to study? | | | | | 100% |
| 7 | Do you use mobile applications to study? | | | | 14,3% | 42,9% |
| 8 | Do you know AR and VR applications? | | | | 28% | 72% |

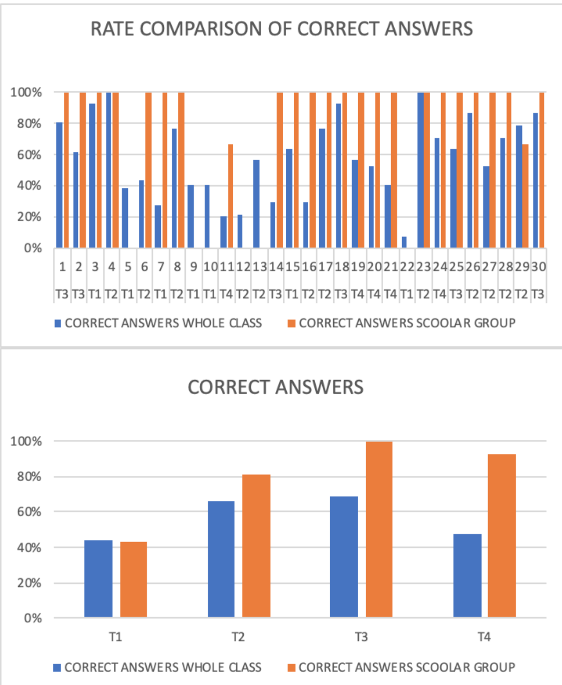


**FIGURE 14.** **The graphs show the percentage of correct answers provided by the entire class group and by the research group. In the first graph the individual questions are compared, in the second graph the comparison was made by type of questions.**

discipline and associated to the Renaissance period were then assimilated and reprocessed. For the sake of completeness, it is important to highlight that the experience was carried out in the lockdown period, due to the global COVID-19 health emergency. The closure has occurred from March to June 2020, a period of the school year usually intended for guided tours and school education trips, which are configured as completion of the activities carried out in the classroom. The aspect to note (RQ4) is that an opportunity has been created for a virtual visit to locations and monuments that are temporarily inaccessible and therefore cannot be visited in a traditional manner. Creating the tour in VR has allowed the students to propose a virtual visit that otherwise would not have been possible. The use of the platform validated its experiential aspect not only by providing the students with an opportunity for cooperative work, but also by replacing the experience of the direct visit to the field of what was studied and learned in class. ScoolAR thus increases its value, as it can be exploited not only in emergency situation, where distance learning becomes the sole solution, but in a broader scenario it can act as a flywheel for expanding learning opportunity for both students and teachers.

## VI. CONCLUSION AND FUTURE WORKS

AR and VR technologies are gaining increasingly importance within the educational domain. This paper describes a platform named ScoolAR, which has been developed for didactic purposes. The experience conducted within the educational program, created for learning the history of Renaissance architecture with the support of ScoolAR platform, has allowed to achieve several interesting results in terms of students involvement and knowledge acquisition.

The questionnaire, which has been used to test the comprehension of the topics presented, has highlighted a positive knowledge acquisition of the subjects covered. The questionnaire has revealed a positive attitude with the platform. This aspect has favored not only the educational process, but also the collaborative relationship between the students, showing the experiential aspect of the research. In particular, the didactic aspects identified at the end of the educational and research experience, which are carried out with the ScoolAR platform can be summarized as follows:

- Transversal learning of the collection of data and information to be included in the platform;
- skills upgrading in panoramas management;
- improvement in the synthesis and adaptations of contents in the use of *hotspots*;
- use of digital skills in a multiple sector;
- collaborative involvement of students and development of cooperative learning;
- experiential involvement in the architectural heritage study.

The research highlighted significant advantages that can be further studied and deepened through experiences conducted with sample classes. It also presents some limitations that are related to the school times that do not always allow to develop more teaching units through the experience of cooperative learning. Furthermore, ScoolAR provides the creation of AR applications that extends the field of study. Besides, the experience conducted through the distance learning during the lockdown in Italy for the spread of the COVID-19 pandemic has provided an added value to the research. The platform is the link between the theoretical knowledge of the in-depth topic and the experience of direct viewing (i.e. in the field) which is normally achieved with educational trips. However, the study conducted in this paper can be extended even to other disciplines and educational fields also in the long life learning scenario.

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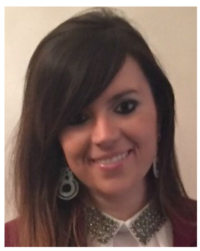

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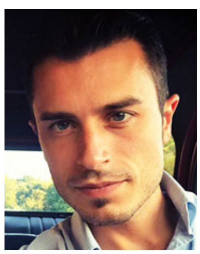

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