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Augmented Reality Applications in Education: Teachers Point of View

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Abstract: A common conclusion of several studies is that augmented reality (AR) applications can enhance the learning process, learning motivation and effectiveness. Despite the positive results, more research is necessary. The current work aims to study the degree of diffusion of AR technology and teachers' opinion about the need for continuous training, the process of creating 3D models, and the feasibility of AR applications development by teachers and students in school settings. Teachers are the common element in every different educational system and play a key role in the integration and acceptance of technology in education. Qualitative research was conducted in February 2019 in rural and suburban areas of North-Western Greece on secondary education teachers of different specialties and the results showed that AR applications development is feasible under certain conditions, including the limitation of the curriculum as the main negative factor and the teacher's personality and the desire for co-operation among teachers of different specialties as positive factors.

Keywords: augmented reality; learning process; 3D digital models; multimedia; cultural heritage

1. Introduction

Nowadays digital media produce new ways of working, living and interacting [1]. Digital augmentation reshapes experiences for even more people due to the advances in mobile technology and the widespread use of mobile devices in the public and in more and more fields. Mobile technology contributes positively in education [2,3], and augmented reality (AR) along with virtual reality (VR) and mixed reality (MR) are considered to be "key educational technologies over the next decade" [4] (p. 46).

The educational use of AR has been studied and a common conclusion of several researches is that AR applications can enhance the learning process, learning motivation and effectiveness [5,6]. Despite the positive results, questions remain to be studied such as the development of AR experiences by teachers and students [7] and the creation of virtual content and 3D models [8].

In Greece the use of AR technology in education is limited [3] and thus it is important to study the key factors that can affect its future acceptance and effective use in the educational process. Teachers are the common element in every different educational system and play a key role in the integration and acceptance of technology in education.

The purpose of the current work is to study the degree of diffusion of AR technology and the teachers' opinion about the need for continuous training, the process of creating 3D models, the feasibility of AR applications development by teachers and students in school settings. Teachers' opinions are very important because teachers of different specialties will examine an issue from different perspectives, have long and multifaceted experiences of the education system, and can identify factors that might not initially be taken into account.

The current study focuses on the teacher's viewpoint about the AR technology. More specifically, in Section 2, a brief review of the literature about the AR technology in education and in culture heritage fields and the barriers to AR technology utilization are presented. The aim of this section is to identify issues and questions that need further study, some of which the current research will try to answer. In Section 3, the current research is described and in Section 4, the results combined with the discussion are presented according to the research questions.

2. A Brief Review of the Literature

2.1. Augmented Reality in Education

Augmented reality (AR) has been defined as "systems that have the following three characteristics: (1) Combines real and virtual, (2) Interactive in real time, (3) Registered in 3-D" [9] (p. 2) while generally it is described as a state between real and virtual environments [10]. AR technology provides a mode of interaction between the real and virtual worlds at the same time. Digital information (text, audio, images, video, 3d objects) is overlaid on the real world in a way that makes it appear to be part of the real environment. It does not isolate the user from the physical environment and that feature "is perhaps one the main factor for AR's increasingly popularity" [11] (p. 2). Applications in augmented reality are divided in two main categories: (i) image-based and (ii) location-based applications. Image-based applications are divided furthermore into two categories: (a) marker-based which require specific labels (e.g., Quick Response Code) and (b) marker-less tracking, in which an image becomes the trigger for playback of multimedia content. Location-based applications are triggered by the user's arrival at a certain location [12].

In recent years, numerous studies have focused on AR technology [13] with a notable increase during 2008–2013 [8] on education and other fields [7]. Particularly, and based on a literature review from 2007 to 2015 [14], studies on the educational use of AR have steadily increased since 2007, dramatically increased since 2011, and intensified in 2013–2017. Thus, AR technology is one with the highest growth [15], becoming more popular as it was forecasted [14] and this growth is expected to be continued. AR technology has been recognized from educational associations as one of the most promising technologies [13] that will be adopted by educators the next years [16] and along with virtual reality (VR) "have the potential to be a standard tool in education" [17].

The educational use of AR has been studied in all educational levels, in early childhood education, in primary and secondary education [12], from elementary school to university levels [16], including diverse learners types at kindergarten level, K-12 students, university students, adult learners, elderly people, technical and vocational higher education [2] and students with special needs [14] as well, focusing on a variety of study topics (e.g., city history [18]) [19], both in formal and informal learning environments [20], in the context of situated learning theory [18] and constructivist learning theory [19,21]. The common conclusion of these researchers is that AR has the potential to offer different learning opportunities [18] with multiple benefits for teaching and learning [3,15,21]. Furthermore, AR applications can enhance the learning process, learning motivation and effectiveness [5,6]. AR triggers the motivation and interest of students, significantly improves learning motivation [2], student creativity [2,22], provides more authentic learning experiences [16], and allows users to learn by experience [15] in the real world [14]. More specifically, many studies and systematic reviews of research and applications as well, conclude that AR applications improve student performance, help user concentration on specific tasks [2], increase student motivation [13–15], enable new learning experiences [23], reduce instructor work load in the laboratory and save time (because, e.g., "students finished their experiments earlier, used equipment more properly" [24] (p. 339), improve students' laboratory skills and their attitudes towards their labs [24], and help students develop skills such as critical thinking, problem solving and communication [14].

2.2. Augmented Reality in Culture Field

The preservation, protection, and collection of cultural heritage assets has become increasingly important for future generations and nowadays Information and Communication Technologies (ICT) can be used as a solution in cases were valuable historical and cultural assets are being lost or destroyed [25]. AR technology is considered suitable for spreading and enhancing the value of cultural heritage [18]. In the cultural heritage field, AR applications can improve a visitor's experience of a cultural heritage site, enhance student understanding [25], and help users learn history through game-based or tour explorations of urban environments [26].

Various applications and projects have been developed for intangible [26], tangible or underwater cultural heritage [27], either in the form of tourist routes or location based games at specific geographical locations (historical places, archaeological sites, museums) [12] such as Virtual Hagia Sophia by MITALab at University of Geneva, Ancient Malacca Project, Virtual Campeche, Virtual Pompeii, AR Based System for Personalized Tours in Cultural Heritage Sites (ARCHEOGUIDE), Archeological Maya Cities (VR and AR system) and the PRISMA project in which users can retrieve interactive multimodal information about monuments and historical buildings [25]. In a museum context, an example is the game "The 23 Skulls" of the Vejle Museum project for communicating the history of Kolding through an augmented reality game ("the players are put in the role as a journalists investigating the disappearance of a museum inspector") [1] (p. 346) and the "Trust No-One" project aiming to create an AR game about cultural history of Kolding for tourist purposes [1]. In the tourism sector and in urban environments, representative examples are Tuscany+ and "Augmented Reality for Basel", as digital tourist guides, the Urban Sleuth as a real-life city 'adventure' and StreetMuseum for visualizing the city of London at various points in history [11]. AR technology is also used to visualize intangible culture [26]. Project Digital Threads was funded and aimed to make the invisible stories visible, about prehistoric finds in the landscape of Central Jutland in Denmark. A location-based application for smartphones was developed that reveals in digital form the prehistoric finds that were detached from the archaeological sites and since then have been in museums far from their original place [28].

2.3. Augmented Reality: Barriers and Limitations

As with all technologies, limitations, drawbacks, positive and negative impacts of educational AR applications have been identified by researchers [6,13,14] and, at the same time, solutions have been proposed. Some of the limitations most frequently mentioned in the surveys are:

- Usability issues: usability issues [13] have been reported based on the fact that students find AR complicated and difficult to use [13,14], face technical problems while using an AR app [14] due to device characteristics such as a small size screen, network speed, or battery capacity [16]. Other studies describe as a drawback of using AR technology the student distraction [13] and cognitive overload [19]. On those issues, a well-designed interface, guidance [14], training both students and teachers in using augmented reality technology [13] and managing of experience complexity level [19] have been already proposed as solutions.
- Features of available software: financial cost [16,17,21], current state of the art mostly on GPS [19], the lack of tools designed for education [8] as general-propose AR applications are not education-oriented and inadequate for educational use [8]), limited availability of built-in monitoring features and assessment tools that are either not provided at all [29] or are available only on commercial (paid) editions [16], are some of the barriers of AR adoption and research conducting. Researchers have already suggested the ideal features which an AR development platform should contain to achieve teaching and learning goals such as easy to use authoring tools through e.g., browser-based editors, functions for various multimedia content integration, location-based functions, dynamic triggers, embedded assessment, data collection functions for assessment and evaluation purposes, social networking and abilities for creation of differentiated role–based AR experiences through different scenarios and participant roles to meet diverse

educational needs [8,19] (pp. 742–743). Among the suggested ideal features, the most important features also noted by other researchers are: (a) the use of tools that "incorporate virtual content in a simple way" [8] (p. 8) and visual programming environments (such as Scratch or App Inventor) because they have been proved successful in classrooms and are able to overcome barriers faced by educators [29]; and (b) features for testing students, collecting data [8,20] (p. 8) and social interaction (e.g., "for sharing content, thoughts") [30] (p. 278), [11] (p. 4).

- Research and practical restrictions: for conducting a survey either in the class context or in the natural environment, difficulties and limitations must be addressed. In an outdoor natural environment, the weather conditions and physical characteristics could change initial plans (e.g., when physical objects are used as triggers every change in lighting and vegetation affects the overlay's launching) [7,31] while in the in-class context a more extensive setup (e.g., arranging desks, markers or QR Code on each desk, adjusting the lighting) is required [12]. Common important factors in both contexts are adequate technological equipment, trained educators [7], student willingness and the school administrations' collaboration [3], additional lecture time for the effective use of AR applications [14], a small research sample, limited research duration and use of the application as information tool and not as an instrument for experimentation [3].
- Diffusion of AR technology: AR technology is still relatively new to education [16,29]. In Greece, the use of AR in education is limited [3] while in other countries it is widely used in all education levels [14] Also, in [5], the study concludes that students are not familiar with the use of mobile technology in the learning process, although they are familiar with mobile technology in everyday life [5]. Another study has shown "that AR technology can be misunderstood by some students and may encourage them not to study outside the class" or students "find the AR components more interesting" than the course topic [24] (p. 341).
- Complex process of AR applications development: the development of an AR experience is a time-consuming [7,16,29] and complex process that demands more than one instructor for proper implementation, especially in location and place-depended applications [19]. It poses technical challenges, requires skilled instructors, the involvement of computer specialists [29] and the use of software for image and video editing and computer graphics creation [16].
- 3D modeling: the creation of virtual content and 3D models, which are a necessary component of applications in the cultural heritage field and their representation is considered the most powerful feature in AR, by teachers is seen as complex process "that cannot afford" [8] (p. 3) and as "one of the greatest disadvantages to using AR" [8] (p. 7).
- AR applications development in the cultural heritage field: the implementation of applications in the cultural heritage field is a complex task that requires a diverse group of scientists' to collaborate [27], a demanding 3d modeling process for the digital reconstruction of historical monuments (e.g., ancient cities), and AR development in order to offer users a unique immersive experience [4]. 3d modeling demands an initial time-spending phase of data gathering and pre-processing of collecting data [27,32] and/or collaboration with experts [33] and local authorities either to provide the necessary data or the entire 3d model (e.g., 3D model of a part of Vienna city was obtained from the cartography department of the city administration [24]). Additional factors affecting the implementation of applications in the cultural heritage field are the characteristics of the urban environment (e.g., an area open enough should be chosen to allow reception of GPS signals [33], the location of the study area which should be close enough "to allow frequent visits for development and testing purposes" [31,33] and sponsorship/financing of the project [33].
- Constant changes in technology and the social requirement for continuous training: continuous and rapid changes in technology, the limited longevity and changes of software platforms create the need to keep up to date [23]. In addition, in some cases inadequately trained educators [7] or negative attitudes [14], and the required technical expertise (computer skills [21] and programming skills [8,29]) for AR applications development and the social demand for efficient professionals [29], create the need for continuous training.

- Teachers' and students' involvement in AR applications development: the active involvement of both teachers and students in AR applications development is proposed [12] in order to achieve better learning outcomes. The teachers' involvement is also proposed because there is a difference between a designer's and teacher's perspectives [19] and teachers are more pedagogically trained than ICT experts.

Technical problems which have been noted as some of the barriers of AR adoption [17] will be overcome by the evolution of technology and pedagogical issues will be addressed by the transformation of pedagogical practice. Usability issues, features of available software, research and practical restrictions are some of the challenges that are relatively minor because they are gradually studied by researchers and will be overcome by the evolution of technology. Other issues, such as teachers' and students' involvement in the development of the AR application, the need for continuous teacher training, still needs to be clarified in order to make the AR technology use more effective and acceptable both in educational and social level. Social acceptance is considered as a more challenging factor than expected [34] and even though new applications appear, there is a slow diffusion to the public [31].

3. Research

3.1. Research Questions

Based on the previous discussion, the current research will examine the issues of: (a) diffusion of AR technology; (b) the need for continuous training; (c) 3D modeling; and (d) teachers' and students' involvement in AR applications development. Thereafter, the research questions are:

1. Is AR technology widespread at a social and educational level?
2. What is the teacher's opinion about the need for continuous training?
3. What is the teacher's opinion about 3d modeling?
4. What is the teacher's opinion about AR application development in school settings?
5. What is the teacher's opinion about the factors that can affect the AR application development in school settings?
6. What role would teachers like to have in AR application development process? A similar question, "What is the role of the teacher in the learning environment in which mobile games are used?" has been raised as a subject for further investigation in another survey [20] (p. 16).

3.2. Research Methodology and Tools

Qualitative research was conducted on secondary education teachers of different specialties in February 2019 in rural and suburban areas of North-Western Greece. A semi structured interview guided by a questionnaire and the technique of observation [13] were deployed. The use of dialogue can better interpret user responses [3] while mixed evaluation methods are mostly used in studies [6] and various data collection tools such as questionnaires [2,3,6,12], interviews [6] from teachers and students [12] and observation [6,12] are deployed.

The questionnaire included five sections (questions are listed in Appendix A):

1. Teacher's profile (the fourth and fifth questions were adjusted based on [8] (p. 3) survey).
2. Diffusion of AR technology (to answer the research Question 1, where the first and fourth questions were adjusted based on [8] (p. 3) survey).
3. Need for continuous training (to answer the research Question 2)
4. 3D modeling (to answer the research Question 3, where the second and third questions were adjusted based on [8] (p. 3) survey).
5. Teachers' and students' involvement in AR applications development (to answer the research Questions 4, 5 and 6).

Teachers initially responded to the first four sections, then they were informed about AR technology (concepts, examples of applications in different areas, implementation process), then answered the questions of Section 5 and the interview was completed with dialogue with the participants (hereinafter referred to as P1 for the first participant etc.), during which, the participants were given unlimited time to freely express their views on the research topics. During the whole process a researcher was taking notes about the participants' answers, comments and their attitude as well.

For the current research needs a non-probability sample [35] was selected based on purposeful random sampling [36] in order to cover most major specialties, school types of secondary education and levels of teaching experience. Teachers were interviewed individually in order to give them more time and the ability to freely express their opinions. The research decision for personal interviews led to a limited sample of 20 teachers, because more time was needed.

Content analysis was used to process the data that was organized according to questionnaire-guide sections and research questions, while for the presentation of the results diagrams and tables were used [35,37]. Even though the sample was small we decided to present the results in a percentage mode -rather in raw values- in order to make them more comprehensible and comparable for the reader.

3.3. Participant's Profile

The research was conducted in a random sample of 20 teachers, 13 women and seven men, working in secondary education with different specialties (Table 1) and with diverse teaching experience (Figure 1) in junior high schools (general, model, musical, adults) and senior high schools (general and vocational).

Table 1. Participants specialty.

Specialty	Answers
Philologist	4
ICT	4
Mathematics	3
Artists	2
Graphic Arts	1
Civil Engineer-Architect	1
Environmental	1
Physical Education	1
Chemistry	1
Physics	1
English Studies	1

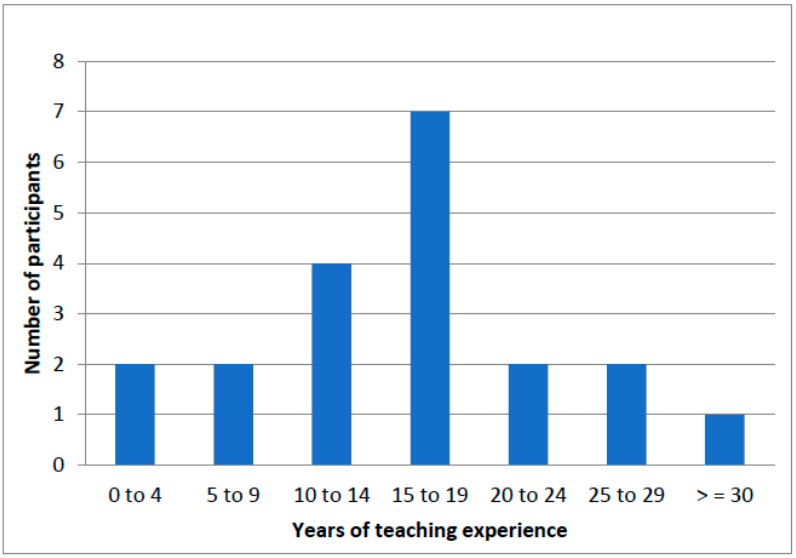

Figure 1. Participants teaching experience (years).

Concerning the additional studies, other than the basic degree, 60% of them have postgraduate studies (Table 2), while in terms of experience, 75% of them have teaching experience from 10 to 27 years (Diagram 1).

Table 2. Participants additional studies.

No	In Progress (2nd Degree or Postgraduate)	Postgraduate Studies
25%	15%	60% (10% PhD)

Based on Table 3, 70% had been certified on ICT skills and regarding the knowledge and use of basic ICT skills, they answered that they could use word processing (100%), image processing (85%), video editing (55%), presentation software (85%), electronic communication (100%), the web (100%) and some programming language (35%). 90% of the participants noted that they used some of the popular social media networks (Table 4). 90% of them used digital material in teaching, whereas only 20% created their own material, 60% sometimes created such material and 20% have never created any digital material.

Table 3. Participants ICT skills certification.

No	Yes
30%	70%

Table 4. Participants responses on social media use ("Which of the following social media do you use?").

Social Media	Answers
Facebook	15
Twitter	2
Google+	14
YouTube	14
Blogger	5
LinkedIn	6
Instagram	8

4. Results and Discussion

4.1. Diffusion of AR Technology

Based on the answers presented in Table 5, no diffusion of AR in teaching was observed since 100% of the participants state that they had not used any AR application in teaching. On the contrary, diffusion in the personal—social level was observed since 50% state that they have read or heard something about it. Based on the researcher's observations, contact with AR technology was due to personal interest (P5—engineer-architect teacher), (P8—chemistry teacher) and involvement in educational actions (P2—ICT teacher), such as University conferences and actions of cultural institutions [38]. In addition, teachers who had traveled abroad for personal reasons or in the context of educational visits had experience of AR technology with museum applications (P10—artists teacher, P18—philologist teacher, P20—mathematics teacher), but they didn't know that those applications were AR applications, a fact that became understood in the second part of the interview where they were informed about the AR technology. This fact also explains the difference between the results in the second and third question. While in the second question only 15% answered that they had used some AR application and 25% answered "don't know", in the third question 45% answered that they had used some of the specific AR based applications. Therefore, we will accept 45% as the percentage of teachers who have used some AR application for personal reasons.

Table 5. Questions about the diffusion of augmented reality (AR) in social and educational level.

Question	Yes	No	I Don't Know
"Have you heard or read about augmented reality?"	50%	50%	-
"Have you ever used an augmented reality app?"	15%	60%	25%
"Which of the following apps have you used?"	45% [1]	55%	-
"Have you used augmented reality applications in teaching?"	0%	100%	-

[1] SkyView 5 of 9, QR Code 6 of 9, "Pokémon GO" 4 of 9.

4.2. Need for Continuous Training

The first question about the need for continuous training, "In which of the following ways are you informed about seminars/trainings?" aimed to reveal their interest about seminars/trainings asking the way they are informed. Just over half of the teachers (55%) stated that they were systematically informed about seminars and training (Table 6), 35% officially and 10% occasionally.

Table 6. Responses on first question about the need for continuous training.

Occasionally	Officially	Systematically
10%	35%	55%

The second and third questions aimed to define the most important factors both for attending and not attending a seminar. On the second question, "for which reasons would you attend a seminar/training? (you can select more than one)", personal development was the most important reason to attend a seminar or training course (Table 7). Development has emerged as the main motivation for attending seminars since personal development was selected by 15 teachers and professional development by 11. Particularly the personal development factor in three of the 15 participants was the only reason for training. Professional need and personal interest were selected from half the participants and were indicated along with other factors.

Table 7. Responses on the second question about the need for continuous training.

Reason	Answers
professional development	11
professional need	10
personal development	15
personal interest	10
no reason (not attending seminars)	1
other	0

On 3rd question, "for which reasons you wouldn't attend a seminar/training?", almost all participants, 17 out of 20, considered the available time as the most negative factor in attending a seminar. Additionally, 14 out of 20 indicated program financial cost as an important obstacle, while the time of conducting a seminar and program subject were selected approximately by half of the participants, nine out of 20 and 10 out of 20 respectively. Other factors, and more specifically teachers' attitudes, professional motivation, administration support, ways of conducting a seminar and program requirements were specified by fewer participants (Table 8).

Table 8. Responses on the third question about the need for continuous training.

Reason	Answers
attitude	3
available time	17
professional motivation (e.g., graduated seminars)	4
administration support (e.g., educational leave)	4
program financial costs	14
way of conducting a seminar (e.g., distance)	7
time of conducting a seminar	9
program subject	10
program requirements	3

The fourth question, "the constant and rapid changes in technology and the social demand for effective professionals create the need for continuous training. How stressful is this situation?", aimed to explore the participants' feelings about the need for continuous training. None of the participants stated not at all, 15% a little, 25% moderate, 45% enough and 15% very (Table 9).

Table 9. Responses on the fourth question about the need for continuous.

Not at All	A little	Moderate	Enough	Very
0%	15%	25%	45%	15%

Based on the researcher's observations the fact that the strong personal motivation (personal development) overcomes negative factors (P8—chemistry teacher, P11—ICT teacher) was revealed. If they find a seminar interesting, they will spend personal time, meet the needs and even spend money (P4—ICT teacher, P7—physics teacher). Another point that was revealed was that, although teachers have a positive attitude towards training, the lack of utilization of the already acquired knowledge in teaching finally works as a negative factor, as stated (P12—philologist teacher).

Concluding, the fact that 55% of the participants were informed systematically about seminars/training, reveals their personal interest which goes beyond the narrower limits of official information (35%). Personal and professional development were noted as the most important factors in attending a seminar/training, a fact that is confirmed both by teacher's answers and researcher's observation. The need and interest are also highlighted since 50% of the participants referred to these factors. Time and financial cost are the most important obstacles that would prevent them from attending a seminar. Finally, 60% (45% quite and 15% very) of the participants consider the pressing need for frequent training.

4.3. 3D Modeling

On the first question, "are you familiar with the creation of 3D digital models?", where it was further clarified that they are asked if they have ever created a 3D model, 70% state not at all, 10% a little (one mathematics, one graphic arts teacher), 5% moderate (one ICT teacher), 10% enough (one engineer-architect, one artists teacher) and 5% very (one chemistry teacher) (Table 10). On the second question, "do you use digital 3D models in teaching?", 75% responded not at all, 5% a little (one engineer-architect), 10% moderate (one chemistry and one artists teacher) and 10% enough (one philologist and one artists teacher). On the third question, "are you interested in training in the creation of digital 3D models?", all participants showed some interest and more specific 0% not at all, 10% a little (one philologist, one English studies teacher), 30% moderate (one ICT, two philologist, one physics, one mathematics, one graphic arts teacher), 35% enough (one environmental, one physics, one chemistry, two ICT, one artists, one mathematics teacher) and 25% very (one ICT, one artists, one engineer-architect, one mathematics, one philologist teacher).

Table 10. Responses on first three questions about 3D digital models.

Questions	Not at All	A Little	Moderate	Enough	Very
"Are you familiar with the creation of 3D digital models?"	70%	10%	5%	10%	5%
"Do you use digital 3D models in teaching?"	75%	5%	10%	10%	0%
"Are you interested in training in the creation of digital 3D models?"	0%	10%	30%	35%	25%

On 4th question, "which of the following 3D design tools you know and you could use to create digital 3D models?", 55% stated none and 45% mentioned at least one (three ICT teachers, one engineer-architect teacher, one environmental, one chemistry, one artists, one philologist and one graphic arts teacher) (Table 11). On this question it has been clarified that the word "know" means that they are familiar with the basic functions and if they needed to implement something, they would be able to meet creation demands with a short preparation. That's why there is a difference in the number of ICT teachers on the first and fourth question responses about their familiarity and knowledge respectively.

Table 11. Responses on the fourth question about 3D digital models.

None	At Least One
55%	45% [1]

[1] Sketchup 5 of 9, Maya 2 of 9, Blender 2 of 9, 3dsMax 2 of 9, AutoCad 4 of 9.

On the fifth question, "if you had to create a digital 3D model how would you feel and why?", mixed feelings were recorded (Table 12). Based both on participants comments and researchers observation, positive feelings were due to the fact that they considered the whole process to be an interesting and creative procedure, while negative and neutral opinions had to do with the implementation requirements (e.g., degree of detail) (P2—ICT teacher, P11—ICT teacher, P15—English studies teacher, P19—graphic arts teacher).

Table 12. Responses on the fifth question about 3D digital models.

Feeling/Approach	Answers
difficulty, pressing, demanding	3
pleasant-creative	7
interesting	5
anxiety	3
curiosity	1
exciting	3
neutral	1
No answer	2

Concluding about 3D digital models, the majority of participants (70%) were not familiar with the creation of digital 3D models. It was also interesting that different specialties were familiar with the process of 3D creation (30%). Twenty-five percent of them use them in teaching, usually by educational videos with 3D representations in areas like history and arts, as they explained to the researcher. Half of the participants did not know any 3D design software while 60% stated that they would be interested in training in the creation of 3D models.

4.4. Teachers and Students Involvement in AR Applications Development

On the first question about AR application development in school settings, "is the AR application development by teachers and students possible in school settings?", 55% answered that application development by teachers and students in the context of teaching is feasible, under certain conditions. Thirty percent said slightly, 10% quite possible, 5% no and none of them yes. More generally, 35% (no and slightly) have negative, 55% neutral and 10% positive opinion on the matter (Table 13).

Table 13. Responses on the first question about AR application development in school settings.

No	Slightly	Under Conditions	Quite Possible	Yes, Definitely
5%	30%	55%	10%	0%

The second question, "how adequate/appropriate are the following factors for the development of AR applications by teachers and students in the context of teaching?" aimed to reveal if, how (negative, neutral, positive) and to what extent the proposed factors can affect AR application development in school settings. Six factors were evaluated by teachers (Table 14).

Table 14. Responses on the second question about AR application development in school settings.

Factors	Not at All	A Little	Moderate	Enough	Very
the technological equipment of the school	20%	30%	20%	30%	0%
the available laboratory	15%	30%	10%	30%	15%
the available hours	5%	65%	10%	10%	10%
your ICT skills	0%	25%	40%	30%	5%
working conditions with co-workers (e.g., different working hours)	15%	30%	35%	15%	5%
the conditions of cooperation with the administration	0%	20%	20%	40%	20%

Based on the results, the technological equipment of the school was not adequate in 20%, 30% a little, 20% moderate and 30% enough. The available laboratory received equal percentages in positive and negative cases and more specifically 15% not at all, 30% a little, 10% moderate, 30% enough and 15% very. The factor of available hours was not adequate in 15%, 65% a little, 10% moderate, 10% enough and 10% very. Teachers' ICT skills were adequate 25% a little, 40% moderate, 30% enough and 5% very. Working conditions with co-workers (e.g., different working hours) are appropriate 15% not at all, 30% a little, 35% moderate, 15% enough and 5% very, while the conditions of cooperation with the administration were appropriate 20% a little, 20% moderate, 40% enough and 20% very.

On the third question, teachers were asked to briefly mention other factors that can limit/restrict the development of AR applications by teachers and students in the context of teaching (Table 15).

The most restrictive factor is time, since 65% of the participants stated that the available teaching time is not enough (Table 14) while the strict/restrictive timetable was highlighted by the teachers (Table 15). As was revealed during the discussion, the actual teaching time is reduced because the hours of a lesson are not continuous but are spread over different days, interrupt students' workflow and thus losing precious teaching time. Among the factors mentioned by the teachers, another restrictive factor concerning students is the degree of familiarity with ICT skills and with cooperative work and also their willingness to work on such a task. Teachers propose that they will work with students who are eager and able to participate, they will inform and train them suitably and they will plan the action in time with a methodical and detailed manner, even from the previous school year.

Table 15. Responses on the third question about AR application development in school settings.

Other Factors	Answers
students' knowledge level on ICT	4
different cognitive level among students	4
reluctance of students to participate	3
student's attitude towards technology	2
student's general attitude (focusing on formal obligations and not on creative tasks)	2
level of student collaboration	3
absences of students	1
strict/restrictive timetable	5
reluctance of teachers to participate	2
teachers' attitude towards technology (difficulty in using and exploiting)	1
teachers' workload	1
lack of material infrastructure/equipment	2
excessive curriculum	1

In the fourth question, "what role should the teacher play in the AR application implementation? (you can select more than one)", 70% answered that they prefer cooperation with teachers with various specialties in the context of subjects that require cooperation of teachers (Table 16). Their wish for cooperation with other teachers and especially with ICT teachers (who have the technical skills for the implementation) was also noted in the discussion. Specifically, they noted that they need and wish to cooperate because one specialty can complement the other leading to a better result. Fifty percent of the participants prefer to use available AR applications as learning tools. Forty-five percent note that they would prefer to implement the application themselves working with their students on a subject they are interested in, 40% note that they would prefer the implementation to be done by specialists and offered as educational tools that the teacher will use in his educational intervention for specialized fields, 25% the implementation to come up through collaboration of teachers of different specialties and students in the context of special courses for courses topics, and 15% the implementation to be done by the teacher and the students in the course context for any field. Of course, that requires training on the development on AR applications after having been convinced for its pedagogical value, as they noted.

Table 16. Responses on the fourth question about AR application development in school settings.

The AR Applications Development to be Done:	Answers
by the teacher and the students in the course context for any field	3
by the teacher and the students in the course context for course topics	9
through collaboration of teachers of different specialties and students in the context of special courses for any field	14
through collaboration of teachers of different specialties and students in the context of special courses for courses topics	5
by specialists and offered as educational tools that the teacher will use in his educational intervention for any field	10
by specialists and offered as educational tools that the teacher will use in his educational intervention for specialized fields	8

Since the use of mobile phones is not permitted in school, student familiarity with the use of mobile devices was examined hypothetically. Ten percent of the teachers were concerned towards the use of the mobile phone as a learning tool and the possible lack of cooperation because students are used to focusing on their typical obligations. Nevertheless, the majority of teachers thought that if the teacher methodically and systematically organized an action based on specific educational focus, students would cooperate in an effective way.

The results in Table 17 reveal the attitude of teachers and students in ready-made AR applications in culture field and cover the case of teachers and students non- involvement in AR applications development. In question, "would you use them as teaching tools?" stated 10% moderate, 45% enough and 45% very, which shows that 90% of teachers will use an AR application as a teaching tool (45% enough and 45% very). In the question, "would students be interested?" noted 5% a little, 20% moderate, 35% enough and 40% very and thus 75% of them believe that students will show interest (35% enough and 40% very). In question "would you come up against practical issues (available time, school program, etc.)" answered 5% not at all, 30% a little, 20% moderate, 35% enough and 10% very, even though 65% of the participants believe that they will come up against management issues they are willing to overcome (e.g., applications use in the context of educational visits).

Table 17. Responses on questions about ready-made AR applications in culture field.

If There Were Available Cultural Content Applications that Would Require a Visit to the City	Not at All	A Little	Moderate	Enough	Very
Would you use them as teaching tools?	0%	0%	10%	45%	45%
Would students be interested?	0%	5%	20%	35%	40%
Would you come up against practical issues (available time, school program, etc.)	5%	30%	20%	35%	10%

In addition to the above results, teacher's main comments are:

- Conditions: (a) necessary disposal of teacher's personal time (P10—artists teacher); and (b) more feasible implementation in specific types of schools. For example, in a model high school (P13—physics teacher, P16—philologist teacher) where students have very good knowledge of ICT and can meet the requirements of implementation, there are fewer limitations of the curriculum (P15—English studies teacher), parents will cooperate, and they are willing to spend money for educational purposes e.g., programmable educational robots (P5—engineer-architect teacher). Also, the implementation is more feasible in elementary schools, in junior high schools and vocational schools than in the senior high schools because students in those schools focus on their own goals and interests and on the university entrance exams (P7—physics teacher, P11—ICT teacher, P16—philologist teacher).
- Points of concern: (1) doubtful learning outcome (P17—mathematics teacher, P20—mathematics teacher); (2) inadequate teacher collaboration (P19—graphic arts teacher); (3) poor student collaboration (P16—philologist teacher); (4) limitations due to the curriculum in terms of hours and way of teaching (P15—English studies teacher, P16—philologist teacher). The real time available is limited, since several hours are required to complete administrative issues (P10—artists teacher, P19—graphic arts teacher, P9—ICT teacher), leading teachers to focus primarily on teaching the mandatory course topics and less on other more general issues (P12—philologist teacher, P19—graphic arts teacher). (5) Students' general attitude since they are accustomed to focus more on formal obligations (P8—chemistry teacher) and a good result in examinations and competitions, which leaves no room for something different (P8—chemistry teacher, P19—graphic arts teacher).
- Suggestions: (1) selection of students teamed with availability, knowledge and positive attitude (P4—ICT teacher); (2) a careful choice of co-workers of other specialties (P11—ICT teacher); (3) a good preparation from the previous year (P7—physics teacher, P10—artists teacher); (4) reward for students and teachers (P15—English studies teacher); (5) support and coordination by central services (e.g., training on the specific technology) (P15—English studies teacher).
- Attitude towards technology: (1) digital applications stimulate students' interest (P5—engineer-architect teacher, P15—English studies teacher, P16—philologist teacher, P20—mathematics teacher), (2) students are interested and willing to collaborate

(P5—engineer-architect teacher, P10—artists teacher), (3) Parents and school administration support actions with pedagogical aim and outcome (P5—engineer-architect teacher, P10—artists teacher), (4) Teacher personality plays a key role (P4—ICT teacher, P10—artists teacher, P15—English studies teacher).

5. Conclusions

The qualitative survey was conducted on a small sample of teachers in order to give emphasis at the discussion. That was a research decision aiming to understand teachers' opinions in depth and better analyze the factors that can influence the effective use of augmented reality in education. The results of this research cannot be generalised, but they could be a solid basis for further research in the field with a larger number of participants. The current work mainly aimed at studying teachers' opinions and investigating the factors that can affect the implementation of AR applications in school settings, in order to contribute to the more effective use of technology in education. Teachers play a central role in educational actions and know in depth the field of education. Each different specialty approaches an issue, like AR application development, from a different point of view, contributing to a more holistic approach.

More specifically, the results showed that AR technology is not widespread at social and educational levels (research Question 1) since no diffusion of AR in teaching is observed while some of the teachers who had used some AR application didn't know that those were AR applications. However, a rising but slow diffusion of AR technology is noticed.

The need for continuous training is a stressful situation for 60% of the participants (research Question 2). Development (personal and professional) has emerged as the main motivation for attending seminars while available time, program and financial cost are the main obstacles. Generally, research participants have a positive attitude towards training, although training courses are not usually followed by practice for establishment and enhancement of the acquired knowledge, a positive attitude in digital technology and have shown particular interest in AR technology.

Teachers' opinions about 3d modeling (research Question 3) revealed both positive and negative feelings. The majority of the participants, although neither familiar with the creation of digital 3D models nor using digital 3D models in teaching, state that they would be interested in training in the creation of 3D models.

Based on the previous findings, the implementation of AR applications by teachers and students in the context of teaching (research Question 4) is feasible under conditions and teachers believe that it is more feasible in junior high schools and especially in model junior high schools. The limitation of the curriculum which reduces the available teaching time emerged as the most restrictive factor, while other factors, such as students' knowledge level on ICT and students' different cognitive level, have less impact because can be addressed by teachers (research Question 5). In the question about the role that a teacher should play in the AR application development (research Question 6), most of them prefer cooperation with teachers of various specialties. Among teachers' proposals, two of them are of particular interest, (a) reduction of the curriculum and emphasis on the quality and suitability and effectiveness of the actions and (b) support and coordination by central services (e.g., training on the specific technology). These proposals are not dependent on teachers' actions but on central educational services actions that, if taken, could lead to a more effective use of technology in education.

Results show that the most important factors for the effective use of AR technology in education are the enhancement of collaboration among teachers of different specialties and a more flexible course schedule. Emphasis should be given to collaboration since it is desired and accepted by the educational community. The support and coordination by the central educational services e.g., through know-how, is important in order to strengthen the utilization of knowledge gained by training.

The determinant role and the personality of teachers were also recorded during the interview, since they play a key role in dealing with emerging difficulties during the development process, and also in the way of using "ready-to-use" applications as a teaching tool. AR applications development should

not be considered as a one-way, nor that ready-made applications restrict students with "pre-packaged learning experiences" as supported in relevant research [7] (p. 8), because knowledge is also built through interaction [19]. Additionally, the exploitation of ready-made applications as learning tools can cover cases where it is not feasible to implement applications by teachers and students, especially in specialized fields such as cultural heritage.

Finally, the contribution of educational institutions and cultural institutions to the diffusion of technology, the need for more actions and the benefits of educational visits are highlighted.

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Appendix A

List of the questions asked on the questionnaires:
Participant's Profile
Gender, specialty, additional studies, years of teaching experience (check boxes and text box)
"Have you received ICT certification?"
"Which of the following social media do you use?"
"Which of the following digital media you use in teaching"
"Do you create the digital educational material used in teaching yourself? "
Diffusion of AR technology

1. "Have you heard or read about augmented reality?"
2. "Have you ever used an augmented reality app?"
3. "Which of the following apps have you used?"
4. "Have you used augmented reality applications in teaching?"

Need for Continuous Training

1. "In which of the following ways are you informed about seminars/trainings?"
2. "For which reasons would you attend a seminar/training?"
3. "For which reasons you wouldn't attend a seminar/training?"
4. "The constant and rapid changes in technology and the social demand for effective professionals create the need for continuous training. How stressful is this situation?"

3D Modeling

1. "Are you familiar with the creation of 3D digital models?"
2. "Do you use digital 3D models in teaching?"
3. "Are you interested in training in the creation of digital 3D models?"
4. "Which of the following 3D design tools you know and you could use to create digital 3D models?" (select more than one)
5. "If you had to create a digital 3D model how would you feel and why?"

Teachers and students involvement in AR applications development

1. "Is the AR application development by teachers and students possible in school settings?"
2. "How adequate/appropriate are the following factors for the development of AR applications by teachers and students in the context of teaching?"

3. "Other factors that can limit-restrict the development of AR applications by teachers and students in the context of teaching (please refer briefly)"
4. "What role would you like the teacher to have in the development of AR applications; (you can select more than one)"
5. "If there were available cultural content applications that would require a visit to the city:

    a. Would you use them as teaching tools?
    b. Would students be interested?
    c. Would you come up against practical issues (available time, school program, etc.)"

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