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Empowering teachers to create Augmented Reality experiences: the effects on the educational experience

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Well-designed educational Augmented Reality (AR) experiences support collaboration, transferability to the real world, situated, and experiential learning. Nevertheless, envisioning engaging yet effective learning and teaching experiences is a challenge. Most teachers are not technologically ready to create AR experiences and rely upon closed products often regarded as fun activities but whose learning affordances might remain unnoticed and whose integration within the course activities is often shoehorned. End-User Development tools empowering not technical users like teachers to create their own AR experience could contribute to spread the use of this technology in educational settings. In this paper, we analyze whether a EUD AR tool based on mobile technology can have positive effects on the educational experience, both from a teaching and learning perspective. We performed qualitative and quantitative research in a high school analyzing the tool in a focus group with teachers and assessing its effects on the educational experience by using it in two real classes. Our results show that even if using the tool implies an additional workload for teachers, results can be rewarding for both, teachers and students who seem to be skilled enough to use AR technology as far as it is based on easy, familiar, and affordable devices like mobile phones and tablets. Finally, we formalize the factors that might positively influence the whole educational experience.

Keywords: learning experience; augmented reality; end-user development; high school; Student experience
1 - Introduction

We are experiencing a rapid growth of technologies so sewn into our daily lives that we are unconsciously changing not only our habits but also the way we relate to other people and our environment (Stankovic, 2014). This growing adoption of technology poses some challenges, including the need to rethink how to meet the learning and teaching habits, needs, and expectations of people who have increased exposure to technology (Prensky, 2011) (Smith & Ragan, 1999). This necessity has been highlighted by the effects of the education disruption experienced worldwide due to COVID19, which has put the focus on new pedagogical approaches that use technology to support active and experiential learning (Kolb & Kolb, 2005). The design of learning experiences that put the focus on the learners and the way they experience the learning process is becoming a new paradigm in instructional design (Nakakoji et al., 2003). This approach, that is assumed in this work, is more concerned with generating valuable experiences than courses or learning material (Donald et al., 2009). Hence, technology-based learning experiences have to not only engaging but efficient, that is, they should support learning acquisition. In this sense, the use of technology might introduce an extraneous cognitive load that turns it into a distractor factor, since “the more of the brain the user has to allocate to the interface, the less is available for learning” (Peters, 2014). Augmented Reality interfaces (AR henceforth) that increase the real-world view with digital resources might help to alleviate this problem as discussed in (Slijepcevic, 2013). In an experiment on the student’s cognitive load, pupils using AR interfaces experienced a 15% reduction in cognitive load respect to students using images and text-based content. Moreover, well-designed educational AR experiences support collaboration, transferability to the real world, situated and experiential learning (Dunleavy & Dede, 2014).
In spite of its benefits, the adoption of AR in education is still slow. As stated in (Garzón et al. 2019) teachers show resistance to use AR technology. Most of them lack the abilities and motivation to create their own AR learning experiences (Bacca et al., 2014) and, therefore, they rely upon closed products often regarded as fun activities but whose integration within the course activities is often shoehorned. In this paper we posit that such resistance could be alleviated if teachers could take a more active role and produce their own AR experiences, the ones that make sense in their classroom and for their students, in the same they use tools like Kahoot¹, Genially² or Socrative³. The availability of end-user development (EUD) tools that empower educators to generate their own AR content could contribute to increase the adoption of this technology (Grant, 2019) (Santos et al., 2014) (Dunleavy & Dede, 2014).

In this work we focus on the educational experience of teachers and students using a mobile AR EUD tool in a high school. We consider that the educational experience includes both the teaching experience (TE henceforth) and the learning experience (LE henceforth). Therefore, we analyze two research questions: (a) “Does a mobile AR EUD tool have positive effects on the teaching experience?” that focuses on whether the tool can be used by both teachers and students for educational activities, and (b) “Does a mobile AR EUD tool integrated into current class activities have positive effects on the students’ learning experience?” that explores the effects on the LE of the integration of AR in the classroom. Our study was carried out in a Spanish high school and it is

¹ kahoot.com
² www.genial.ly
³ socrative.com

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composed of two activities. The first one was a focus group with seven high-school teachers that was aimed to analyze properly the context by understanding current educational practices and to explore the potential effects of integrating the AR EUD tool in such a context. The second activity was an experiment where students used the AR learning experience created by one of the teachers to confirm findings from the focus group and to explore the students’ perceptions about the use of this technology.

The rest of the paper is structured as follows: in Section 2 we report the work related to AR in the education context, then in Section 3 we show the research methods adopted to investigate the two research questions. In 4 we present our mobile AR Creator system used in our research. In 5 we describe the focus group activity and derived claims. The final part of the section reports an experiment in a real environment. Section 6 presents the limitations of the study while, in section 7, final remarks and some conclusions are given.

2 - Related work in AR for education

The use of AR systems in education has already been the subject of extensive research. In the Dunleavy and Dede’s survey (Dunleavy & Dede, 2014), the authors report that AR can be useful to support teaching in different contexts but especially when the topics present a spatial component, transforming such component in a learning opportunity (Klopfer, 2008) (Klopfer & Squire, 2008). Moreover, AR present different learning affordances such as exploring content from a different perspective and in different contexts, supporting situated and constructivist learning by improving the transfer of knowledge to and from real situations. This can be the case when AR content is located in the surrounding environment and students use AR tools to explore it such as playing a treasure hunt. AR has also been integrated with collaborative learning.

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approaches in (Klopfer, 2008) (Wang, 2017) (Squire, 2010), such as investigating and solving a given problem, etc.

Another learning affordance of AR is the ability to link multiple and heterogeneous resources to increase understanding of a given problem. These resources do not necessarily have to be available in the same AR system but can also come from various resources on the internet, such as streaming videos, animations, or simple links.

Regarding students’ motivations, several studies reveal that AR significantly increases it (Garzón et al. 2019) (Squire, 2010) (Dunleavy & Simmons, 2011) (Yilmaz, 2016). Examples of application of AR in education can be found in (Bower et al., 2013) (Harley et al., 2016) (Laine et al., 2016) (Bressler, Bodzin, 2013), which show a large variety of possible subject matters such as history, art, foreign languages, and science. In (Santos et al., 2014) different types of AR applications for learning are classified including Magic Book (Billinghurst et al., 2001), a textbook augmented with virtual content. As shown by Bursali and Yimlaz in (Bursali & Yilmaz, 2019) (Hung et al., 2017) students obtain better results in reading comprehension and learning permanency when they use an AR application in the classroom.

However, one of the obstacles to the adoption of AR in the classroom is the need to prepare AR activities and content that focus more on the educational value than on the fancy features of this technology (Cheng, 2018). Democratizing innovation by empowering users to create or adapt technologies (Von Hippel, 2005) can contribute to alleviate this problem. If we put technology (that is AR) in the hands of those who experience and are experts in the problem (that is teachers and students) then they will be able to adapt the technological artifacts to their real and unique needs (Von Hippel, 2005). Teachers or students are not usually programmers or technologically experts. They need
EUD tools that, as stated in (Santos et al., 2014) (Dunleavy, M., & Dede 2014), empower them to create their own augmented experiences. In (Dunleavy, M., & Dede 2014), authors pinpoint that such tools should be made accessible for users without programming or 3D modelling competencies and should be able to work with the already existing user’s content. Finally, they should allow them to easily share the final AR experiences played in several devices.

The reviewed literature suggests that the content offered to students in the form of AR is largely considered stimulating and useful for learning. Moreover, the necessary technology is already feasible and affordable. In spite of these considerations, we still lack studies about the effects that empowering teachers, educators, and students to create their own AR experiences has on the whole educational experience, both the TE and the LE. In the next sections we describe how we study this problem in the specific and particular context of a high school where we analyze two research questions: (a) “Does a mobile AR EUD tool have positive effects on the teaching experience?” and (b) “Does a mobile AR EUD tool integrated into current class activities have positive effects on the students’ learning experience?”

3 - Research method

To answer the two research questions, we prepared a study performed in a Spanish high school (k8-12). The study was divided into two main steps aimed at exploring the two research questions.

To explore the research question (a), we adopted a qualitative research approach based on a focus group with teachers since, as stated in (Breen, 2006), pedagogic research can benefit from a focus group to study how students’ experience a specific teaching method, to generate ideas, or to assess how a new methodology will be perceived. Such
an approach was selected among others also to allow teachers to envision new ways to use AR in their teaching practice including also the possibility that students create AR experiences. The whole session lasted about two hours including a ten-minute break and a technology probe, a mobile application capable of generating and sharing augmented reality experiences was used. It involved two researchers and seven teachers from the same Spanish High School (k8-12), between 40 to 60 years old. Two of them teach Technology, two Literature, and the last three English, Geography and Art. Six of the participants consider themselves to be really technologically proactive using devices for their professional and non-professional life. The focus group included two activities: the first activity was dedicated to investigating the experience in AR and the second one to envision how it could be used to improve their students learning experiences.

Questions were open-ended to allow flexibility and encourage the discussion. Examples of the included questions were: What is the role of technology in your working activities? Is technology relevant in the communication with students and colleagues? What do you think about the technology used by your students as a learning support? Given the AR creator, can you envisage how to use it in teaching and learning? Given the AR creator, what do you think about its effects on your work? Given the AR creator, what do you think about potential effects on the learning experience? Further prompts, when needed, were used in order to clarify and to extend concepts.

The focus group results were examined using a thematic analysis method (Merton, 1975) that is suitable to analyze qualitative data including those about people’s experiences (Clarke & Braun, 2013). Study validity was achieved through cross-checking of the transcripts by the researchers. Moreover, to ensure that different researchers code the same text in the same way, we adopted a reliability analysis based on Cohen's Kappa

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(Cohen, 1960). The Cohen’s Kappa rates interrater reliability from 0 to 1, where 1 means perfect reliability between the coders. Two researchers were in charge to code the focus group results. First, we developed a set of coding instructions. The two coders were trained and tested the code with some data. The coded data were measured using the Cohen's Kappa analysis. The Kappa coefficient is calculated as follows: $K = (P_a - P_c) / (1 - P_c)$. $P_a$ represents the percentage of cases on which the coders agree, and $P_c$ represents the percentage of agreed cases when the data is coded by chance. A coefficient bigger than 0.6 is considered satisfactory, bigger than 0.8 is considered near a perfect agreement. When the Kappa resulted satisfactory (above 0.6) the coders started the formal coding.

To explore the research question (b) we performed an experiment in two real classes with 52 k10 students. A teacher used the EUD tool to create AR experiences to use and share during her classes to complete her teaching method. At the end of each class students filled out a questionnaire on their experience and the teacher was interviewed about her observations on the students’ results and behaviors and the relative differences she detected with a regular class. The choice to carry out an experiment with a UX questionnaire instead of carrying out a further focus group with the students is due both to the possibility of experimenting the AR creator in a real context with two regular classes and to the practical question of being the less invasive as possible for the high school and for the students by involving them only during class hours.

The questionnaire contains items related to the perceived usefulness of the AR in classroom that allow participants to compare the perception of their results using AR with normal activities. The questionnaire results were validated through a reliability analysis test based on the Cronbach’s Alpha coefficient (Cronbach, 1951) preceded by a Principal
Component Analysis (Van Belle et al., 2004). Regarding the students’ profile and the context, the school is located in a peripheral and working-class populous district of the city, they use smartphones, and most of them can use a computer for learning.

4 - Technology probe: the mobile AR creator

In this work, we used the AR Creator mobile authoring tool presented in (Romano et al., 2016) as a technology probe to study the potential effects of AR on the teaching (TE) and learning experience (LE). Technology probes offer users the possibility of experiencing how to use technology in the real world, to solve their real needs and problems, with a view to identify opportunities, limitations, and challenges (Hutchinson et al., 2003). Compared to other qualitative methods, such as interviews or questionnaires, technology probes allow participants to have the first-hand experience with the technology before thinking about its possibilities. In this way, the participants of our study were able to experience by themselves how to create and use an educational AR experience.

AR Creator was originally conceived as a general-purpose tool to allow non-technical people to create and use AR experiences. The system exploits technologies that are supposed to be familiar to many potential users, such as mobile devices or the Dropbox cloud service. It consists of two applications: an AR Creator app designed for tablets and a viewer that can be used in other mobile devices (including tablets, smartphones, and smart glasses). An AR experience is composed of a number of AR interactions that can be created using the Creator app in the same physical place or object that will be augmented. Each AR interaction is composed of a physical target that is captured through a picture and it is augmented superimposing digital contents stored in the user’s Dropbox folder.
Figure 1 shows the process of preparing an AR experience with an image of a book about the principles of motion along inclined planes. In (a) the user sees the list of existing AR experiences that can be edited or can choose to add a new one. If the “+” icon is selected, then the device camera is open, and the target of the augmentation is displayed on a canvas (see the red dotted box in Figure 1 (b) showing the image captured from the students’ book). The next step is to add augmentations for which the user only needs to click and drag-and-drop the digital items to be superimposed in the scene. In Figure 1 (c) the user is preparing an AR experience to explain the forces acting upon an object that is positioned on an inclined plane. In the red dotted box, it is positioned the target to augment that is a book image representing the inclined plane. The user has added two augmentations for the same image: an explanatory video that will be shown below the real image (see blue dotted box) and an image with additional explanations shown above the real book image (see green dotted box). This experience is stored in the same Dropbox folder and when the AR viewer is open, it is available to be used. The AR Creator usability was already evaluated as reported in (Romano et al., 2016).

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5 - Exploring the potential effects of AR EUD tools on the educational experience

With the aim to investigate the effects that an AR EUD tool might have on the educational experience, we deployed AR Creator in a real learning scenario to encourage teachers to reflect upon the possibilities of integrating this technology in their current teaching practices and to enable them to create their own AR experiences that will be used by their students. We first investigated further the learning context, that is the current educational experiences, to identify how augmented experiences could improve the current situation, and, then, we tested in a real setting whether the augmented experience could be beneficial or not. To get relevant findings, we carried out our research into a real environment, a public school in a peripheral and populous working-class district of the city.

**Step 1: exploring the teaching experience**

To understand the role of the technology before, during and after a class and the additional value that a technology like the AR Creator could bring to the whole educational experience, we run a focus group with 7 teachers of the High School. Participants were K8-K12 teachers between 40 to 60 years old. Two of them teach Technology, two Literature, and the last three English, Geography and Art. Six of the participants consider themselves to be really technologically proactive using devices for their professional and non-professional life. Additionally, two researchers participated in the focus group: one
of them lead the discussion dynamics whilst the other took notes and observed participants. The focus group was run in the High School facilities so participants could feel more comfortable than in a research lab.

We started with some icebreaking activities like presenting the area of our research and allowing participants to make questions about it and asking them to introduce their own work. Then, they were asked to explain the way they currently use technology to prepare or teach a class, and whether they use it to stay in contact with students and to coordinate themselves with other teachers. Moreover, they were also asked to explain how and when technology is used by students. Finally, we introduced the AR Creator and invited them to try it out ideating some scenarios and give their opinions about its potential use in their teaching activities. The whole session lasted about two hours.

Regarding the use of technology in their activities, all the teachers stated to regularly use a computer to prepare their classes. They search on the web for additional material like tutorials, manuals (especially for technical subject matters), more recent information about authors and artworks and multimedia to include in their teaching material. Even if in general technology seems to be broadly accepted, the main concern of more senior teachers is about the possibility that it can become too intrusive and force teachers to radically change their way of teaching. Regarding the progressive integration of the technology in the educational context, they consider that mobile technologies, such as tablets, would be more easily adopted by those teachers not especially technologically proactive or savvy since most of them are used to this type of device. In general, younger teachers seemed to be more motivated to look for new teaching practices using ICT to make their students more engaged. On the other side, senior teachers were more distrustful and would use new technologies only as complementary support. However, all

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of them take into consideration not only that the local and national political directions are oriented towards fostering the use of cutting-edge technologies during a class, but also that they need to meet the necessities of students who are becoming more visual and experiential learners.

Regarding the use of the technology by the students, our participants stated: “about 80% of our students normally use the class blog and emails to study and communicate with the teachers after the class hours. Approximate 99% possess a modern smartphone, which is also the device mainly used. Generally, the students’ families have a PC, but students still prefer to use their mobile phones. They use a computer to study just when it is explicitly required as when they have to do a presentation or write a document”. Actually, all the participants agreed with this: “Nowadays, the technological abilities of students are high, but they are lazier than before. It is not easy to convince them to read or search in a book. They would use their smartphones for everything. Even during a class, their attention is really low, and it can be easily diverted by their devices”. On the other hand, the use of technology in the classroom seems to be a strong motivator and smart whiteboards, videos, or interactive applications are already appreciated by students.

![Figure 2](image2.png)

**Figure 2.** One of the teachers working on the LE scenarios. (a) is for the AR Postal Card scenario and (b) for the “Discover Local Culture” scenario.
After a break, in the second part of the activity, we invited participants to experiment and comment on the AR Creator by creating some AR learning scenarios. The only real example that so far teachers had of AR technology was the famous Pokémon Go\(^4\). After a quick explanation, each participant had the opportunity to play with the prototype and create an augmented experience for which researchers provided a number of heterogeneous objects that could be used as AR targets and that are usually available in classrooms such as a small painting, reading books, a grammar book, a calendar, magazines, and postcards. The group dynamic was quite homogeneous. In the beginning, they showed interest and described a lot of activities where AR could be applied. One said: “even using a computer to download additional multimedia materials from the textbook makes students annoyed. The AR technology makes this quicker and more interesting”. The art teacher noticed the advantage to exploit the mobile component: “Thanks to the tablet I could go to the streets with my students to create new street furniture or an exhibit letting everyone to immediately see how it looks”.

Then, they were afraid that such technology could be too intrusive and that a massive use could make students bored. They finally agreed that AR can be useful to catch the students’ attention and to generate learning experiences, but its integration must be gradual.

Finally, participants were asked to select a subject and to envision scenarios where AR and in particular the AR Creator can be a useful tool for students. Scenarios were designed using a whiteboard, coloring markers, magnetic figures, paper and other

\(^4\) www.pokemongo.com
stationery material as shown in figure 2. Kalbach (2016) states that drawing helps participants to focus on the objectives of the activity and that scenarios and storyboards allow to experiment with different ideas and therefore envision future experiences.

The proposed scenarios were then used to start a constructive discussion on the potential utility of AR to enhance TE and LE. The facilitator asked the group to comment on each scenario pointing out and explaining the strength’s points and highlighting, when possible, the difference with the current student learning experience. The scenarios are described in detail in the appendix. They present an age target, a subject of study, description, rationale, and design strategy. Through the scenarios, the teachers agree that students from 12 to 18 years old may get the benefit of creating AR content in a variety of situations. Indeed, the AR creator can be used by students to foster analytical observation and an in-depth study of the environment by providing a natural affordance that invites students to explore and examine in depth the surrounding environment to identify relevant targets to develop through AR. It also allows students to scaffold experiences that require them to observe and manipulate the physical environment, and to frame the information guiding students through it. Finally, it may work as a hook to make them more engaged and can improve the sense of control of their work.

**Step 1: findings**

To analyze the focus group results, we adopted a thematic analysis method (Merton, 1975). In (Clarke & Braun, 2013), the authors state that such an approach is suitable to analyze qualitative data for a wide variety of research questions, including those about people’s experiences. The authors also state that the method can be used with both large and small datasets. The thematic analysis method is mainly composed of data coding and searching for themes. Therefore, according to the focus group data, we formalized three
main themes containing the factors that might positively influence the TE (see figure 3): Integration in the classroom; positive effects on the LE and Usability. Regarding the reliability of the coded data, at the final iteration $P_a$ was 0.83, $P_c$ 0.34 and the coefficient $K$ was 0.74 that definitively is a good agreement result.

- Integration in the classroom: one of the themes extracted through the focus group is related to the ways to integrate such new technology in the current teaching activities. In this theme, two main factors emerged as able to influence the teaching experience. They are related to the necessity to avoid a major transformation of the current practices to avoid an excessive workload for the teachers and, on the other hand, to enable opportunities to explore new forms of teaching that meet students' necessities and expectations about technology. Although each teacher was inclined to one of the two factors, both factors were taking into account by all of them:
  
  - Use AR as a complement to the current practices: teachers value the possibility of using a new technology according to their own philosophy and criteria. They don’t want to use AR as a closed product but as a tool to envision useful and personalized learning activities. More enthusiastic participants thought about using AR to ideate innovative activities oriented towards implementing collaborative, situated and experiential learning activities. Anyway, the younger teachers were more motivated to explore new ways of teaching and engaging students.
  
  - Using AR as an opportunity to explore new forms of teaching: more conservative or risk-averse participants focused on augmenting the material they already use in their classes. In particular, senior teachers felt motivated because they realized that technology can complement their activities, for

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example, just adding digital notes to a textbook and thus meet some of the students’ necessities whilst keeping a manageable teachers’ workload.

- **Desired effects on the LE**: the teachers showed interest in the effects of the AR technology on the experience of their students. Indeed, the participants highlighted that the efforts to adopt new technology are directly linked to the effects that such technology is expected to have on the experience of their students. In particular two issues were raised:
  - **AR as a class dynamic changer**: this is a relevant factor for teachers who aim at producing a new class dynamic, for instance supporting situated learning activities outside the classroom walls, or those who aim at ideating enjoyable and engaging activities, such as exploring the same concepts using different multimedia contents integrated into the same physical space.
  - **AR as an enjoyable and engaging experiences for the students**: they thought that using AR content during a class could be motivating for students because the class dynamics can better meet their necessities of visual and experiential activities. Hence, the LE is expected to be perceived as enjoyable and engaging.

- **Usability**: also the usability is very closely related subject to the participants. The theme is composed by the issues related to the adoption of the technology and ease of use of the system.
  - **Use AR with common and familiar technologies**: the kind of platform used, and its ease of use are all aspects that may influence the TE. After all, any new technology or method requires an additional effort from the teacher. This

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effort has to be related to how to ideate better activities not with how to master or access such technology. In this sense, the use of more immersive devices like HMDs might put additional barriers since HMDs are not as familiar and affordable for all teachers as mobile devices are. In particular, teachers and students seem to be skilled enough to use AR technology as far as it is based on easy, familiar, and affordable devices like mobile phones and tablets.

- **Ease of use of AR experiences.** The AR Creator system was considered easy and intuitive to create and share content and using a mobile device instead of a computer desktop seems to convince also teachers technologically distrustful. This causes positive effects on the TE because it is perceived as a familiar didactic tool easy to use.

- **AR creation from a timesaving perspective.** Usability is also related to the concept of the time required to learn the technology, to integrate it in current activities and use it. Complicated devices or systems that impose a slow learning curve increase the workload of teachers. Teachers are concerned not only with having to learn a new technology to give class but also with students having to learn how to use it in the classroom or at home, because this would also entail further intervention to the teacher. Despite this, teachers envision that the use of AR can relieve some of their tasks, allowing students to obtain more detailed on-demand explanations without resorting to the teacher.
Step 2: exploring the learning experience during real classes

With a view to assessing the effects on the educational experience of integrating AR content in a regular class, we invited one of the teachers to use the tool to prepare the content for two real classes of k10 students. She is a physics and technology teacher very familiar with mobile technology and she decided to use the prototype in a practical class of physics. Normally, in the kind of class, students study a chapter of the textbook on their own and then practice with some problems proposed and supported by the teacher. Students work alone or in small groups of 2-3 classmates and the teacher helps by giving some explanations if they get stuck. Before the class, the teacher created 17 AR experiences using as targets some images of the workbook and augmenting them using videos from YouTube, explanatory images, and text labels. The AR experiences were designed both to better explain the theoretical content of the chapter and to explain the goal of the proposed problems. The experiences were about the different transmission mechanisms as the inclined plane, the pulley, and sprocket and chain.
She used the Dropbox folder to collect there some multimedia content to use in the AR experiences and exploited the ability of the AR Creator to take photos, and record videos to produce other digital content directly from the real world. Students were divided into couples and each couple was provided with a worksheet with the problems and a 10-inches tablet running the AR Creator viewer app. We preferred to install the viewer on a tablet cause the small phone screen can negatively affect the students’ experience, as reported in (Wang, 2017). The only explanation given to the students was about the use of the app. A total amount of 52 students participated in the experiment (see figure 4). After the class, we asked students to fill out a questionnaire about their LE. A user experience questionnaire based on the technology acceptance model (TAM) (Davis, 1989) (Davis et al., 1989) (Venkatesh, 1999) was used for this purpose. In addition to the common scales already investigated TAM literature (namely Perceived ease of use (EU), Perceived usefulness (PU), Perceived enjoyment (PE), and Intention to use (IU)) we also considered the Ergonomics of the device (ED).

Indeed, in (Balog & Pribeanu, 2010) the authors experimented with an AR glasses device in a classroom and highlighted that ergonomics directly affects both the Perceived ease of use and Perceived enjoyment. Table 2 summarizes the items of the questionnaire that were answered using a 5-points Likert (being 1 Strongly disagree and 5 Strongly agree), which according to the literature seems to increase the response rate and the response quality along with reducing respondents’ “frustration level” (Babakus et al., 1992) (Buttle, 1996).

Table 2. The TAM questionnaire prepared for the students.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
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ED1  Using the tablet has not obstructed me to carry out the class activities.

ED2  Holding the tablet while watching the augmented reality is easy.

ED3  The workplace is comfortable.

ED4  Observing through the tablet screen is clear.

EU1  Understanding how to operate with the application is easy.

EU2  Learning to operate with the application is easy.

EU3  Remembering how to operate with the application is easy.

EU4  Becoming an expert of the application would be easy for me.

EU5  Reading the information on the screen is easy.

EU6  Understanding the oral explanations is easy.

EU7  Focusing the camera on the target images to see the virtual objects is easy.

EU8  The overlap of the virtual objects over the real ones is clear.

EU9  Overall, I find the application easy to use.

PU1  Using the application helps to understand the lesson more quickly.

PU2  The application increases my attention to the class content.

PU3  After using the application, I believe that I will get better results at tests.
PU4  After using the application, I have learned more on the topic.

PU5  The application helped me to deeper understand the topic.

PU6  The application makes learning easier.

PU7  Overall, I find the application useful for learning.

PE1  The application makes learning more interesting.

PE2  I like interacting with real objects while using the application.

PE3  Performing the exercises is captivating

PE4  Overall, I enjoy using the application.

PE5  Overall, I think that the application is exciting.

IU1  I would like to have this application in school.

IU2  I would use this application for learning.

IU3  I would recommend using it to my schoolmates.
Figure 4. Pictures of the experiment in a real class – permitted by parental written permission.

After the class, the 52 participants filled out the questionnaire to evaluate their LE while using the application. Table 3 shows the results of the questionnaire. The first column represents the item ID, the second one the number of collected answers for each item and the two last columns are properly the mean and standard deviation. According to the data, participants were satisfied with the experience.

Table 3. Questionnaire results.

<table>
<thead>
<tr>
<th>Item</th>
<th>N.</th>
<th>M.</th>
<th>S.D.</th>
<th>Item</th>
<th>N.</th>
<th>M.</th>
<th>S.D.</th>
</tr>
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<tbody>
<tr>
<td>ED1</td>
<td>52</td>
<td>3,77</td>
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<td>49</td>
<td>3,67</td>
<td>0,94</td>
</tr>
<tr>
<td>ED3</td>
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<td>3,62</td>
<td>1,12</td>
<td>PU4</td>
<td>49</td>
<td>4,06</td>
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</tr>
<tr>
<td>ED4</td>
<td>51</td>
<td>4,16</td>
<td>0,83</td>
<td>PU5</td>
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<td>0,84</td>
</tr>
<tr>
<td>EU1</td>
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<td>0,67</td>
<td>PU6</td>
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</tr>
<tr>
<td>EU2</td>
<td>52</td>
<td>4,54</td>
<td>0,78</td>
<td>PU7</td>
<td>49</td>
<td>4,37</td>
<td>0,60</td>
</tr>
<tr>
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<td>52</td>
<td>4,71</td>
<td>0,50</td>
<td>PE1</td>
<td>49</td>
<td>4,22</td>
<td>0,87</td>
</tr>
<tr>
<td>EU4</td>
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<td>3,79</td>
<td>1,05</td>
<td>PE2</td>
<td>49</td>
<td>4,41</td>
<td>0,84</td>
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</table>

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The students perceive the tablet device as adequate to work in a classroom and the application as ease of use, enjoyable and useful for learning. All the items’ scores are about 4. The lowest values, though positive, are the EU7 and the PU3 (3.4 and 3.67). EU7 is about the ease of focusing the camera on a target. Indeed, the teacher noticed an initial difficulty to point the device camera towards the book’s images and explained that it seems to be due to the size of the tablet. Anyway, after a while, students got used to manipulate the device and this task was easy for everyone. PU3 is about obtaining better results at tests after using the app and its 3.67 score whilst all the other items related to the learning perception are close to 4.

We ran a reliability analysis test based on the Cronbach’s Alpha coefficient (Cronbach, 1951) preceded by a Principal Component Analysis (Van Belle et al., 2004) on each scale as recommended in (Samuels, 2015) to validate a questionnaire with a sample size between 30 and 100 participants. Results enable to discard items with a correlation value of less than 0.3 that will imply they are not strongly correlated with the overall scale. In our case, only EU4 has a correlation value of less than 0.3 which is 0.208, so we eliminated it from the EU scale. After that, we calculated the Cronbach’s Alpha and obtained values above 0.6 as recommended in (Field, 2009) (Kline, 1999) (Hertzog, 2008). More precisely: ED $\rightarrow \alpha = 0.6$ N=4; PEU $\rightarrow \alpha = 0.8$ N=9; PU $\rightarrow \alpha = 0.9$ N=7; PE

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<table>
<thead>
<tr>
<th>EU5</th>
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<th>4.37</th>
<th>.72</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU6</td>
<td>52</td>
<td>4.33</td>
<td>.86</td>
</tr>
<tr>
<td>EU7</td>
<td>52</td>
<td>3.40</td>
<td>1.32</td>
</tr>
<tr>
<td>EU8</td>
<td>52</td>
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<td>.89</td>
</tr>
<tr>
<td>EU9</td>
<td>50</td>
<td>4.64</td>
<td>.56</td>
</tr>
<tr>
<td>PU1</td>
<td>49</td>
<td>4.16</td>
<td>.94</td>
</tr>
<tr>
<td>PE3</td>
<td>49</td>
<td>4.41</td>
<td>.86</td>
</tr>
<tr>
<td>PE4</td>
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<td>4.29</td>
<td>.91</td>
</tr>
<tr>
<td>PE5</td>
<td>49</td>
<td>4.33</td>
<td>.90</td>
</tr>
<tr>
<td>IU1</td>
<td>49</td>
<td>4.63</td>
<td>.93</td>
</tr>
<tr>
<td>IU2</td>
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<td>4.4</td>
<td>.86</td>
</tr>
<tr>
<td>IU3</td>
<td>50</td>
<td>4.4</td>
<td>.78</td>
</tr>
</tbody>
</table>
Since preliminary results seem to be reliable, the questionnaire could be used for further studies to include a larger sample size. The questionnaire results are confirmed also by the teacher’s perception and observations.

Normally, during the class, the students work alone or in a small group with their textbook and the teacher interacts with them individually to give some more explanations if they get stuck, which is usually the case. During the interview the teacher said that using AR she almost did not need to give more explanations and pupils worked more engaged in the problem to solve. She explained that AR even improved the behavior of some difficult students “Even those students who generally goof around or do not participate to the activities worked without problems and with attention”, and in general “all the students demonstrated to have reached better results by solving more problems than usual”. Moreover, she also highlighted that a positive and stress-free collaboration among the students in the same couple was possible also thanks to the characteristics of the shared large-screened device: “I think that AR glasses or a small smartphone may not give the same result for the collaboration”. As regards to the TE, we asked her thoughts about the usefulness of the prototype, her enjoyment, and intention to use it regularly. She explained that the creation of the AR experiences allowed her to better take the role of her students and look for more adequate didactic solutions with obvious results. Regarding her enjoyment, she said: “Seeing all the students working with interest is really gratifying”. Nevertheless, asked about her intention to use the system regularly she explained that finding or elaborating good AR content was a real time-consuming activity: “I would regularly use this kind of tool if publishing house made available a library of AR content”.

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Step 2: findings

The experiment results back the findings reported in the previous section, such as the positive effects on TE of using the tool to change the class dynamics and, additionally, it shows also the positive effects on the students’ LE.

Analyzing the teacher’s interview, the field notes collected during the experiment, and supporting the qualitative data with the questionnaire analysis, we were able to categorize the factors positively influencing the LE into two main themes (see figure 5): Interest - Enjoyment and Usability. In supporting the themes, we considered in particular all the questionnaire items with a score on average bigger than 4 since they represent a strong mutual agreement among the students. Below, the factors collected in these themes answer to the question (b) related to the LE:

- Interest - Enjoyment. The introduction of AR experiences generated ad hoc by the teachers demonstrated to clearly push interest and enjoyment into students while attending a class. This is possible by providing students with more dynamic and interesting learning activities. The general high results of PU and PE scales support the observations of the teacher and researchers. In particular, the teacher stated that the students worked more and made fewer questions as they comprehended quicker the exercises. Indeed, PU4 and PU5 items support this observation as the students felt an understanding of the matter deeper and quicker. This can be reassumed in one factor that we named: “Deeper and quicker understanding of the matter”.

Moreover, the teacher acknowledged the use of AR to foster collaboration that in our case was facilitated by the fact that the device can be easily shared and is minimally intrusive. Then, we resume it in the factor named: “Collaboration enabler”.

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From the point of view of the teacher, the main impact on the educational experience will be the capability of ideating interactive activities not only funny but also increasing the attention and the understanding (PU1 and PU2), generating interest (PE1, PE2), making exercises more captivating (PE2, PE3) and fostering intellectual enjoyment (PE4, PE5) by engaging students in the development of learning outcomes. Then, this can be synthetized into two factors, namely “Class dynamics changer” and “Captivating and interactive activities”.

- **Usability.** Again, and for the same reasons than in the focus group, our results suggest that technologies that require an extra effort to learn can discourage students whilst already familiar and easy to use technologies like mobile devices can foster their adoption. On the basis of the questionnaire we can point out that tablets were perceived generally as adequate to work in the classroom (ED scale), and in particular using the tablet screen to observe the overlapped virtual and real content is clear (ED 4). This is due to the choice of using AR “Based on common and familiar technologies”

- Moreover, both the use of the application (EU1, EU2, EU3) and the understanding of the content (EU5, EU6, EU8) are perceived as easy, even if, as was observed a certain difficulty, lighter and smaller devices could make easier correctly pointing the camera (EU7). This is of course led by the “Usability”.
6 - Limitations of the study

The study here presented is limited in its scope, since it was applied in just one school, and in the number of participants since not all teachers were available nor willing to participate. In any case, the casuistry of learning settings is almost infinite so that generalizing results is not always possible. There are many factors that shape the educational experience from the participants, who can be more or less familiar with technology, to organizational and social structures, which can be more or less supportive of technology-based education, or even economic reasons that determine how and when to use technology in the classroom. In any case, our initial findings suggest that further research on how to empower teachers and students to create their own AR educational experiences can increase the adoption of educational AR by relying upon the power of democratizing innovation. Some factors that can influence AR adoption were also identified both from the teaching and the learning experiences perspective. These factors are not intended to be exhaustive but they identify a number of relevant issues to be considered in order to move forward in the integration of AR in real educational settings.
7 - Final remarks and conclusions

Previous works show that the adoption of AR in the classroom is linked to some challenges that include the teachers’ lack of technical knowledge and motivation, the difficulties to integrate an AR system in a classroom especially when applied to young students, the high cost of the devices and usability issues. To deal with some of these challenges, EUD tools can be used to move teachers, and students, from AR consumers to AR producers, and, in this way, contribute to pushing this technology from the motivational honey-moon effect towards supporting useful educational experiences.

In this work, we deployed an AR EUD tool for mobile devices called AR creator in a real high-school context to study its effects on the educational experience. In this work, we consider that the educational experience includes both the teaching experience and the learning experience. Regarding the TE our study reveals that it is influenced by three principal aspects that are: Integration in the classroom, Desired effects on the LE, and Usability. Indeed, the AR EUD tool is considered by teachers gratifying and adequate to support a variety of integration according to their own philosophy and criteria and that can be used to change the teaching dynamics even by allowing students to create their own learning experiences in a way to implement at the same time collaborative, situated and experiential learning. Moreover, the produced AR content is expected to be motivating for students meeting their necessities and inclination to the technology. Moreover, in our research the mobile device arises as an important factor for the teachers’ acceptance of the technology, since participants considered it as familiar and are more predisposed to consider AR in their activities.

Regarding the learning, two factors manly affect the students’ experience, which are Interest – Enjoyment and again the usability. The tablet was perceived by students as
ergonomic and comfortable to work with it during the class and it promoted a stress-free collaboration among the students, which unlikely can be obtained with smaller screens or AR HMDs. In the developed class dynamics, students perceived AR enjoyable and engaging as well as useful for improving their learning. Students suffering from lack of attention or very uncooperative clearly benefited from a more dynamic and attractive learning experience.

Though initial results are promising, the effects on the educational experience need to be explored in longer-term experiments to collect objective evidence on the real effects on learning outcomes. The study validity is limited in terms of the number of participants and their availability, but also because the learning settings variety is almost infinite. Further research is required to go deeper into the educational experience and understand how different factors (individual and collective, organizational, social, economic, and cultural) influence them and how EUD tools can be envisioned to favor the adoption of educational AR. In any case, empowering teachers and students to manage their own AR experiences seems an adequate path to explore to make the learning affordances of this technology available to a wider audience.

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Appendix – AR learning scenarios

| Field trip |
| --- | |
| **Target:** | 14-18 years’ old |
| **Subject:** | Literature |
| **Description:** | During a field trip, the teacher gives the students a subject to explore by using the AR Creator. Students must collect information on the site they are visiting and have to develop their subject through pictures and videos. The result can be shown to the whole group and discussed during the trip or using photos to be augmented in a second step. |
| **Rationale:** | Field trips have been traditionally a useful way to change the students’ context and make learning more interesting. This is especially true for younger students (under 14 years), but grownups usually consider them just as a non-school day and they do not focus on the didactic aspects of the trip. To keep up with the lack of interest, teachers usually assign homework related to the trip, but this is often considered boring. |

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The AR exercise stimulates cooperative learning in a totally new and dynamic way. Thanks to the mobility of the device and the immediacy of the AR technology, students are immediately focused on the physical context of the trip and they can actively participate in the production of information. Moreover, they become an active part of their learning experience and this will bring students to exploit the trip time to discuss the project.

**Design strategy:** one of the main learning objectives is the analytical observation and an in-depth study of the environment in which the students are located. AR creator provides a natural affordance that invites students to explore and examine in depth the surrounding environment to identify relevant targets to develop through AR. The AR experience should be designed to make the targets self-explanatory and interesting. Then, for each desired target students have to create a specific AR experience. The tool allows them to create a simplified experience structure, such as a superimposed image, or an increasingly complex experience as the students’ abilities increase, such as grabbed voice or videos recorded by them, or multimedia content fetched in the shared library prepared by the teacher. Even if it is possible to add textual information to the AR experience, it should be always replaced by subtitled audio to make it easily comprehended by other students on small screens in mobility. A good way to allow each student to take advantage of the AR experiences created by the others, when possible, the teachers can divide students into small teams assigning to each team a specific area to explore and work. Then, they can share the AR content through the AR creator with classmates who will explore that area in a second time.

**Discover Local Culture**

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Target: 16 – 18 years old

Subject: Language and culture

Description: Students can use the AR system to create typical life scenes set in their city. For example, they can use store signs or monuments as targets and connect them to explanations, tips, and short typical representations. Foreign students can use the results to learn about local culture and improve their linguistic skills.

Rationale: This exercise allows students to study and give value to their own culture. At the same time, this helps them to understand problems related to foreign students immersed in a totally new context and improve respect towards different cultures.

Design strategy: the main learning objectives are to practice with a foreign language, rediscover their own culture, observing authentic environmental situations, and interact. The AR creator allows students to scaffold experiences that require them to observe and manipulate the physical environment as for example, observing a butcher shop, collecting typical local products or sampling sand etc…. Then, similarly to the field trip, first they have to identify potential interesting targets representative of their own local culture, and then they have to elaborate specific AR experiences. AR experiences should be mainly voice and videos grabbed by the students alone or in the group telling in the foreign language stories and anecdotes about the target. Moreover, students should also produce subtitled audio to make them practice with the written language and make more understandable the videos to foreign students. Finally, differently by the previous scenario, choosing a location that students know may provide familiar mental and physical models, decreasing the cognitive load of the work.
AR Postal Card

Target: 12-18 old

Subject: English culture

Description: To learn about a foreign city like London, the teacher selects a number of significant postcards to be augmented by the students as homework. Students must search for information about the targets and present it as an AR content based on videos or images. For example, they can record themselves while explaining a particular scene and add it to the postcard. Finally, the postcards can be shared with the other students to compare results.

Rationale: Current students learning is mainly focused on mnemonic or superficial factual knowledge. They apply the “Information is always on your smartphone” so that they do not easily remember what they study. In addition, there is too much information and students have real problems to manage it. Postcards can help to frame the information and guide students through it. With this exercise they can develop different abilities: 1) looking for the right information, 2) organizing and re-elaborating content, 3) expressing themselves. “This is a way to create one’s own knowledge, the things where we are directly involved are the ones we remember easily”. Moreover, students use one of their favorite devices to work on this exercise and this makes them more comfortable with the technology, while AR makes quicker and funnier the execution. Finally, sharing the postcards with a group of students also intrinsically motivates them to do their best.
**Design strategy**: the objectives are to learn about a foreign culture, develop the ability to express oneself and to elaborate and search for information. Initially, the teacher has to choose emblematic targets to be augmented. Some of the targets can be popular to allow students to easily retrieve information about them or even use personal experience, others can be niche targets to make learners force themselves to focus on specific information. The students use the AR creator to add videos they grab, and some multimedia fetched on the internet. Asking them to create the experiences as a narrative can work as a hook to make them more engaged and can improve the sense of control of their work.