# An Augmented Reality Mobile Learning Experience Based on Treasure Hunt Serious Game

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**Abstract:** One of the playful activities used in education is the treasure hunt, a serious game that allows students to work cooperatively. This activity stimulates different cognitive processes connected to accurately reading the clues and understanding them, and extremely effective to elaborate a collaborative strategy necessary to find the hidden objects. Augmented Reality is an innovative technology with a growing potential in promoting new scenarios to support teaching and learning processes. In this paper we present a learning activity based on a treasure hunt serious game developed with ARLectio®. ARLectio® is an augmented reality authoring tool aimed at supporting the creation of educational resources that leverage the AR technologies to improve students' engagement. ARLectio® is characterized by an intuitive user interface that supports educational content creation based on different media types, such as: text, images, video, and 3D model, that will be accessed through mobile AR applications. From the architectural perspective, ARLectio® consists of a web-based AR authoring tool addressed to teachers for the creation of educational contents, and a mobile App in which the content is consumed by students within AR based educational activities. In the scenario described in this paper, ARLectio® is used by teachers to design an educational treasure hunt activity that will be accessed by students through their mobile devices. The topic of the treasure hunt is "Climate change and environmental sustainability". In a pilot study presented in this paper, students were divided into small groups, and they collaboratively interacted to solve some treasure hunt enigmas. The clues and enigmas are related to the school curriculum. For example, clues include the solution of simple mathematic and linguistic problems as well as historical references and notions of geography. The results of the pilot demonstrated a positive effect of the use of AR technologies in the level of engagement of students in the learning activities.

**Keywords**: augmented reality, treasure hunt, mobile learning

## 1. Introduction

The increasing use of mobile technologies in school education offers new opportunities for students to improve motivation, engagement and learning. Mobile learning involves the use of handheld devices such as smartphones and tablets (Sharples et al., 2009), offering new opportunities to overcome classroom boundaries and supporting outdoor learning activities (Arrigo, Taibi and Fulantelli, 2014). Recent research indicates an increased acceptance of mobile technologies in teaching and learning (Nikolopoulou, 2018). Mobile learning in recent years is taking great advantage of the use of Augmented Reality (AR), a growing technology that provides innovative approaches and new tools to support teaching and learning processes in education. In (Azuma, 1997), AR is presented as a technology that enhances the user's perception and interaction with the real world. For example, the real world can be augmented with virtual objects, such as textual information, as well as images, or 3D objects that provide additional information that the user could not directly detect with their senses. Several studies show that students can increase their motivation and improve their learning since the technology makes studying more engaging, stimulating and dynamic (Tosto et al., 2020; Sayed, Zayed and Sharawy, 2011; Lukosch et al., 2015). In fact, AR allows to associate theoretical concepts with practical and experimental activities, making the learning process more playful and immediate and creating interactive learning scenarios to facilitate learning by doing (Sungkur, Panchoo and Bhoyroo, 2016). Moreover, it can stimulate creativity, collaboration skills and critical thinking. In the literature, there are many experiences of using AR technology in education. In mathematics education, for example, AR systems can be used to help students to understand solids of revolution and improve spatial visualisation skills (Salinas and González-Mendívil, 2017). In language learning, this technology can be used to support students' comprehension of literature and the permanence of learning (Godwin-Jones, 2016). Bursali and Yilmaz (2019) have demonstrated that using AR systems, students perform

better than students reading with traditional methods. In history education, AR systems can support students and help teachers to make classroom activities more engaging through videos related to the historical lessons that are displayed on mobile devices when a target image is scanned (Raghaw, Paulose and Goswami, 2018). In anatomy, AR can allow the study of human organs in a simple way, through the printing of a 3D model of a scanned organ and a mobile device that displays all the information related to the composition of the organ under examination, simply by framing it with the camera (Argo et al., 2018). In physics, through the use of AR systems, it is possible to demonstrate various properties of kinematics by dynamically evaluating an object that changes its velocity and acceleration over time (Lee, 2012). When applied to behavioural education, which focuses for example on studying how the environment influences long-term changes in behaviour, this technology allows to show, for example, the correct behaviour to be assumed in specific situations. This may be the expected behaviour in a school environment, where Augmented Reality can be used to teach shared values such as respect for others and the environment (Chiazzese et al., 2021).

Mobile learning and augmented reality can greatly enhance learning in education. Serious games represent a further technological solution widely adopted for engaging students in educational paths. The term serious games (SGs) is used to describe games and video games applied to non-playing contexts, i.e. used to foster the achievement of an educational objective (Laamarti and El Saddik, 2014). SGs are used to enhance learning at different ages and in several branches of knowledge. They allow learning based on game levels, group activities and the achievement of objectives through scores and rewards. There are different types of serious games, from the simplest ones that only require paper and a pen, to the more complex ones that use technologies such as augmented reality and virtual reality to reproduce situations in which the player can learn by doing (Signa et al., 2019).

The treasure hunt is an example of a serious game that can be used for educational purposes.

## 1.1 Treasure hunt in education

In Treasure Hunt games, participants compete to reach different target locations by correctly interpreting the clues that are proposed to them. Participants usually have to execute specific tasks or solve specific problems to obtain the clues. Mobile technologies can support such activities since they allow to trace participants' locations in real time, to use different multimedia formats for the clues, to support the execution of interactive activities related to the locations, to effectively activate communication between participants and with the game's instructor. Moreover, data related to the participants activities can be collected and analysed through learning analytics techniques to monitor the learning experience and promptly intervene when participants are struggling at a certain step (Fulantelli et al., 2013).

In (Mobius et al., 2015) a Treasure Hunt experiment was conducted with 789 junior and senior students at a private US university. Treasure hunt is used as a tool to study social interactions between students. The dynamics of the conversational networks that arise in the context of Treasure Hunt activity have been also investigated. Authors used treasure hunt activities to study the social dimension of the learning process, by taking into account the models of aggregation and how to detect imperfect diffusion of information in the network of students.

The need for a general framework for the development of augmented reality-based treasure hunt games was emphasized in (Bálint et al., 2012), since the existing frameworks to design treasure hunt games have some limitations, such as the use of physical objects whose placement is often an expensive task, and the use of GPS technology to localize participants that cannot be used in indoor scenarios. Authors reported the relevance of using AR technology to overcome these limitations, but the framework they proposed is not specifically focused to support educational experiences.

The work presented in (Shakouri and Tian, 2019) is more focused on the educational aspects. Authors present a location-based treasure hunt AR app to improve users' engagement during the visit of the Avebury heritage site in England. However, the paper of Shakouri and Tian focuses on the App and on the users' experience, and there is no reference to an authoring environment for teachers.

An interesting work aimed at providing teachers with a dedicated environment for designing location games conducted via mobile phones is presented in (Kohen-Vacs at al. 2021). However, AR technologies is not used in their environment.

In this paper we present an Augmented Reality mobile learning experience in which the framework ARLectio® (Farella et. 2020) has been used to support the authoring of treasure hunt activities in different places. After describing the framework ARLectio® (section 2), we illustrate how teachers used the framework to create the AR mobile learning experience. Finally, some conclusions are drawn.

## 2. ARLectio®

The ARLectio® framework was developed with the aim of facilitating teachers' task in creating AR educational resources and their visualization through the use of markers. The system consists of an authoring toolkit and a mobile application with a simple user interface to facilitate human interaction with the mobile system. The authoring toolkit consists of a web application designed for teachers to create educational content implemented by AR technology and is designed to be easy to use and to manage content easily. The teacher will be able to visualise their resources (Figure 1) as well as create, edit, delete and organise resources (Figure 2). To create a resource, the teacher has to select the category into which they want to place it, which corresponds to the topic or subject name, and enter a title and description for the resource. Since the system is based on a type of AR that uses markers to add the additional information to the real world, the teacher will have to select a marker that will work as an activator. In fact, the mobile application, by pointing the device's camera on the specified marker (an image or a QRCode), is able to recover the stored information in order to display the augmented object accurately. After selecting the marker, the teacher can choose the type of augmented content to be added (text, video, image or 3D model) and its position in relation to the marker (top left, top centre, top right, middle left, middle right, bottom left, bottom centre, bottom right). In fact, the marker is considered as a 3x3 matrix, and each box of the matrix corresponds to a position (Figure 3). Once saved, the resource is stored on a server and can be used through the mobile application. This application is for students or users of AR content created through the authoring toolkit. In fact, the user can access the category related to the AR resource, and by pointing the camera of his device on the marker will be able to access the augmented content. It has a simple and easy-to-use interface and can be used on most possible devices that are not necessarily the latest generation.

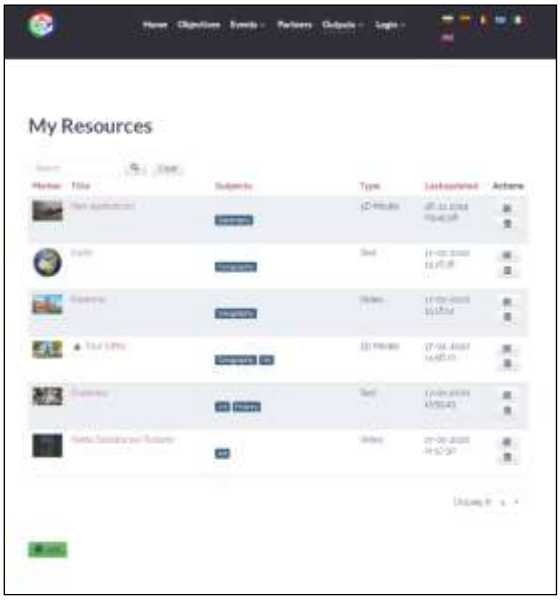


**Figure 1**: Educational resource list


**Figure 2**: Create an AR educational resource


**Figure 3**: ARLectio® mobile application

## 3. Use case: Treasure hunt (we respect our earth)

The enigmas of the treasure hunt implemented were based on the theme "Climate change and environmental sustainability". Various problems were placed in a room, and each problem was activated by the device by framing an image (marker) and superimposing or replacing the image of the marker framed by the camera with the corresponding problem. The augmented content (displayed by framing the marker) could be a media of one of the following types: text, image or video.

In particular, 9 enigmas were produced, all of them relevant to the educational theme of the event (Climate change and environmental sustainability). Each enigma provides a clue for the next treasure hunt step. The nine elaborate enigmas re divided into seven types.

Dolly the whale

This enigma proposes to the students a reflection both on geographical aspects (testing them on notions of orientation linked to the cardinal points) and, above all, on the pollution of the seas that afflicts our planet. Some AR contents are presented in order to guide students in their search for the correct solution.

Animal extinction

Many animals and plants are becoming increasingly rare and at risk of extinction for various reasons. These include the destruction of their natural habitat, climate change, hunting and pollution. In this stage the student is challenged to find endangered animal species around the world. By framing the planisphere with a mobile device, different animals distributed over the various continents will be displayed in AR mode. Using their own knowledge, students will have to identify which of the animals displayed are at risk of extinction.

Differentiated

This test combines mathematical concepts with the issue of recycling materials. The student is given 6 cards with a QR code. Each card corresponds to an object, which the student must place in the correct container. The object represented on each card will be displayed in AR mode by framing the QR code. The containers in which to place the objects are related to "glass", "plastic", "paper" and "organic" and are also displayed through augmented reality so as to differentiate the possible combinations for each user. The test is passed by solving a mathematical formula such as:

8 x Plastic - 7 x Glass + Paper = ???

which will give the exact value if the classification has been made correctly.

Unplugged coding

The fourth task brings the student's unplugged coding skills into play. Set in a polluted pond, the student is asked to drive a bulldozer to remove harmful debris using right-left-forward commands given to the bulldozer. The location of the debris and all the elements in the environment are displayed in AR mode on a poster depicting a pond. The student is given a series of differently colored cards/cards depending on whether they give an instruction turn right left or go forward. The test is passed if the correct sequence of tiles is given.

Climate change/Pollution/Water contamination

Three of the stages of the treasure hunt are proposed by means of in-depth video clips that are activated in AR mode. When students are near a specific poster that highlights one of the themes proposed in the stage, they are led to reflect on the main causes and solutions for limiting climate change or water pollution or contamination. The in-depth video content will be used to answer the questions of a questionnaire that will be proposed to pass the test.

Interwoven words crossword clue

In this stage of the treasure hunt, the student will have to focus on foreign language (for the Italian students was English) terms related to the issues of climate change and environmental sustainability. By means of a crossword puzzle displayed in AR mode, she/he will have to identify some terms hidden between the letters presented. The test is passed if all the hidden words are identified.

A bit of physics

The ninth stage of the treasure hunt is linked to the problem of pollution from factories to the groundwater. The students are then asked to solve a small physics problem using an AR chart, so that they can work out how many years it takes to restore environmental contamination caused by the spillage of harmful substances.

Moreover, the above enigmas were administrated in random order as well as with different education contents in order to differentiate the treasure hunt path among students.

The pilot conducted in this study was carried out during the scientific event Esperienza inSegna 2020, a wide-ranging scientific event, built around annual themes and organized by the association PALERMOSCIENZA (https://www.esperienzainsegna.it/). Three classes of about 30 students aged 11-14 years participated in the trial, and the treasure hunt was repeated for each of the participating classes. The students were divided into small groups of 3-4 persons who were given a tablet with the AR application to use. The groups solved the puzzles with a notebook and pen for calculations or notes, independently, without the support of the app. Once they had found the solution to each quiz and checked that it was correct, they were given two objects:

- a piece of a jigsaw puzzle, useful for the composition of the final marker to get the solution to find the treasure.
- a clue to find the next image, the marker.

The winner team had a symbolic award, and all the participants had a certificate for participating to the experience.

## 4. Discussion and conclusion

In this paper we introduced an Augmented Reality mobile learning experience based on treasure hunt serious game. This experience leverages the potentiality of the ARLectio® framework to support teachers in authoring learning experiences based upon Augmented Reality technologies.

A qualitative analysis of the students' experience, conducted through semi-structured interviews, has highlighted the increased level of engagement of the students participating to the treasure hunt pilot when they used the AR technologies. In particular, students reported a positive attitude towards the immersive experience that they had with the AR technology. They also liked the possibility to use their own mobile device that usually is not allowed in the classroom during traditional learning activities. Finally, even though the group consist of students that use their mobile phone intensively, they were not too much familiar with the AR technology and the possibility to interact with virtual 3D object was highly appreciated.

Further study based also on quantitative analysis will be conducted to prove the effectiveness of the AR technology in these learning scenarios.

To this end, the ARLectio® framework will benefit of Learning Analytics techniques to collect data and provide evidence about the learning processes that are supported by the AR technology. In fact, further developments are going to be carried out to integrate Learning Analytics approaches in Augmented Reality learning experiences through the xAPI standard (Farella et al., 2021). The xAPI standard will be introduced into the ARLectio® framework to trace the interactions of the students and providing teaches with monitoring tools helping them to promptly intervene when students struggle during their learning experiences. Moreover, the use of the xAPIs could improve the user experience by keeping track of the enigmas solved, the time spent solving them as well as by keeping track of the user's interaction with the system and virtual objects.

Finally, it should be observed that the type of AR based learning activities that can implemented through the ARLectio® framework are not limited to treasure hunts, thus supporting the investigation of new scenarios not limited to treasure hunt based on AR technology.

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