Use of Augmented Reality to Support Education
Creating a Mobile E-learning Tool and using it with an Inquiry-based Approach

Walter J. Rezende, Eduardo S. Albuquerque and Ana Paula Ambrosio
Instituto de Informatica, Universidade Federal de Goias, Goiania, Brazil

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Abstract: Education is the basis of human development. In recent years working professionals have demonstrated a considerable interest in new technologies, searching to enhance teaching quality. Tools such as e-learning, cellphones, video-conferences, web quests and others are becoming popular options to help motivate and enrich the knowledge of students. Now, with modern technology, society requirements for knowledge have gotten more specific and accumulated, but the traditional teaching model has not been able to keep up. This paper presents a mobile software educational tool for children, using the Jigsaw methodology and augmented reality (AR) technology, aiming to improve teaching experience. The proposed software contains an AR marker reader, a game library and a digital quiz module. By presenting book contents in three dimensions, together with the use of Jigsaw learning, we create an interactive and fun environment for learning, that can help increase the interest and motivation of students.

1 INTRODUCTION

The accelerated changes in the technological context, have increased evaluation of teaching methods worldwide (Murnane and Steele, 2007). As an outcome, we now need to find new ways to learn, a challenge for researchers and teachers searching for ways to maximize content absorption while preserving the individuality of thoughts. According to Murnane, we now face a challenge of identifying, distributing and improving teachers for current demands.

Personal computers have revolutionized the way humans interact with the world. As a silent side-effect, the current on-screen metaphor inevitably holds the users attention, in order to manipulate its ”selfish” interface. By combining the best of both worlds, augmented reality (AR) presents itself as an interesting solution for this problem and can be applied into almost any domain, including education, that has traditionally resisted significant changes (Hannafin and Savenye, 1993).

Augmented reality is one of the variations of virtual reality and can be seen as introduction of artificial stimuli over real ones, with the use of multisensory technology. In other words, it includes virtual information on human senses, enhancing men-environment relationship. The main characteristics present in AR are: mix of virtual elements in the real context; interactivity with resultant reality; positioning of virtual objects in a coherent manner according to the reality in question and influence over all senses (Azuma et al., 2001).

AR creates an intentional illusion that we can use to enrich the sense of vision. This allows us to include information of the surroundings in our sight or of any other relevant data at the time, like schedules, notifications, updates, etc. Naturally this feature can be used in education and there are many projects involving it. The fact that we can mix reality with virtual objects is, at least, an interesting prospect.

In addtion to advances in technology, new teaching and learning methodologies have arisen to enhance the learning experience and give students skills that will help them professionaly and in every day life. Many adopt a proactive approach, where students are encouraged to seek information that will help them solve problems.

Collaboration according to (Kaufmann, 2003) is one of the most important parts of educational environment, yet still the traditional learning model rarely stimulates it, through group activities every now and then. There is a need to discourage methods that individualize learning, such as using individual computers (Billinghurst, 2002). Even when working side by side, this methodology reduces effectiveness of pupils, who often feel this and end up grouping spon-

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taneously. Using a proactive collaborative model makes social activities common, and involves students in the process of teaching, allowing them to attempt their very own solutions yet still being aided and evaluated by supervisors.

The Jigsaw methology, introduces this proactive approach into a game-based learning methology, where students are grouped together to solve problems and compete against other groups. By associating AR to the Jigsaw methodology we aim to change the students' role, from passive learning to active, helping pupils develop self-teaching and collaborative work skills. According to (Milhomem et al., 2013), a technology that aims to give digital support to real experiences, are best used if the actual experiences are still stimulated.

The idea that will be presented in this paper, is to build a software tool that can offer students a different approach for learning. According to (Moran, 2007), what mainly pushes away students in fifth to eighth grade in Brazil is lack of interest. Poor connection between life and subjects, added to the lack of connectivity between them and the virtual world reduces the chance to create good professionals and citizens.

Combining both the AR book strategy and the inquiry-based learning model, we expect to reduce abstraction of subject content and offer a proactive and social experience that will help connect subjects to student lives. With AR as a tool, we will provide additional support to the Jigsaw methodology, allowing members of the groups to experience simulation of content. With different subtopics handed out to each member, they can look at the same model, and extract different information related to their particular focus and interest. While regular books present the content to pupils in a manner that requires imagination to fully understand what is being described, augmented contexts can reduce that abstraction, by replacing entirely or partially two dimension illustrations for three dimensional objects that could be interacted with.

The choice of mobile devices offers us an economically viable way to execute this strategy and yet still maintain the quality of the experience, specially due to it's less exclusive interaction metaphor compared to common desktop applications. The main advantages of AR include it's low requirements of hardware, as it is almost exclusively software dependent (Zorzal et al., 2006). Loosely speaking it requires not much more then a camera, processors, memory and an energy source. There are many available devices compatible with AR nowadays. This allows for a variety of strategies that make use of this approach. In the software that will be developed in this paper, an alternative that includes social interaction is considered. To solve this problem, we will use a method that includes dividing resources, in this case the mobile devices. Such practices can help to understand the need for sharing, and how that can help increase productivity, while relying on others to get the job done (Svanaes and Verplank, 2000).

This tool can be used to improve perception of knowledge, and at the same time, offer teachers a feedback. This can create a honest way to evaluate student development, something that typically had to be done exclusively considering the tutors skills. Paper organization starts with contextual learning, then we introduce some design patterns, followed by the description of the system being developed and the conclusion.

2 CONTEXTUAL LEARNING

Studies have shown the importance of context in learning, even stimulating the practice of outdoor teaching, with the aid of mobile and sensory technologies (Chiang et al., 2014). The passive learning model, has survived countless generations and has functional results, but in its most traditional form, does not encourage discussions and imagination efficiently. On short, the traditional method consists of a teacher dictating the content followed by possible questions, similar to lectures. It is a situation in which students tend to get anxious and unmotivated, specially for complex subjects and long classes.

The inquiry-based teaching experience is very different. Pupils have freedom to use their own sources and to choose their own methods, while working in groups, debating topics and finding information. This experience stimulates curiosity, social skills and searching, making them feel "rewarded" upon making discoveries. At the same time, this method makes classes less dependent on the supervisor's teaching skills.

There are many ways to implement inquiry-based learning, centered in five general elements according to (Heick, 2013) citation of Indiana University Bloomington:

1. Learning focuses around a meaningful, ill-structured problem that demands consideration of diverse perspectives.
2. Academic content-learning occurs as a natural part of the process as students work towards finding solutions.
3. Learners, working collaboratively, assume an active role in the learning process.

4. Teachers provide learners with learning supports and rich multiple media sources of information to assist students in successfully finding solutions.
5. Learners share and defend solutions publicly in some manner.

2.1 Technology and Inquiry-based Learning

The main purpose of technology since its creation, is to support humanity in activities that sometime in the past were impossible or harder. This purpose helps maintain its constant evolution, and rarely do we judge the need, before it actually happens. It is known that practice is essential to maintain brain acuity, and sometimes technology can actually disturb this practice, although we use calculators for example, it is still essential to know how to calculate.

Following this reason, it is advised to consider the challenge when developing learning technologies for their purpose to begin with, is exactly to learn, and that includes not only the content, but the subtle skills required in the learning process that need to be developed. It is essential in inquiry-based learning due to its focus in problem solving, and therefore being able to fully understand the problem is ideal.

The use of electronic media can have a positive and negative impact in children, especially television (Kirkorian et al., 2008). The largest impact of television, and probably of any type of media, is related to the content more than the time of use. This suggests that we should specially focus in choosing the correct content, that has to be adequate for the age of our niche.

Inquiry-based learning is a strategy that requires the posing of questions and scenarios to later connect them with facts or pieces of evidence, in order to reach conclusions. This method is important for the development of higher thinking skills, and can be supported with the aid of technology (Edelson et al., 1999). As mentioned by the author, there is a trend in science, for using technology-supported, inquiry-based learning to allow new forms of inquiry, which is the foundation of science. He states that researchers identified six contributions technology can make for the learning process:

1. Enhancing interest and motivation.
2. Providing access to information.
3. Allowing active, manipulable representations.
4. Structuring the process with tactical and strategic support.
5. Diagnosing and correcting errors.
6. Managing complexity and aiding production.

The hardware used for AR has very few restrictions, most of which are present in any computer based device. Most commonly used hardware include:

1. Smartphones: According to projections, more than 2 billion people will have smartphones by the end of 2016 (eMarketer, 2014). It allows users to move freely while holding the device. The weight of a Smartphone is usually around 200 grams, very light compared to other devices.
2. Tablets: Tablets have maintained approximately 200 million units shipped worldwide and should continue to do so for the next few years (Statista, 2016). It has a good user base, but not nearly as large as the one for smartphones. Technically, they are similar to smartphones, with particularities in their operating systems and size.
3. Smart Glasses: Worn as regular glasses but with augmented reality support embedded in their special lens. A great candidate, but the lack of studies around it, in addition to their restricted access, makes them unsuitable. Some companies have even advised for them not to be worn by children (Google, 2016).
4. Laptops: Portable computers, or laptops, are certainly an option. While portable, they are not handheld, and restrict movements. Like desktops they can have great hardware, large screens, and most of them have cameras, but the position faces the user which is not desirable. They are typically more expensive than mobile phones, and weight too much to move around, which is not ideal for group activities.

2.2 Augmented Reality in Education

There are many researchers looking into the application of AR in education, using tools such as instructive games and markers books. Evolution in this domain can help take reality to a future that has only been seen in sci-fi movies. In these films people interact with their context through movements and virtual objects manipulation.

AR can aid in the educational process, through the implementation of a solution that stimulates interaction with knowledge while searching for the solution. Today technology is becoming more ubiquitous and changing focus from constant computer and tool upgrades to influencing our decisions, our lives and connecting everyone to everything (Galloway, 2004).

Its very intuitive to imagine the possible gains from the use of AR in classrooms. Today students

are limited mostly to imagine the content they hope to learn from books and other sources, digital or physical, an easy task for some, not as much for others. With the use o AR, we can change this reality, by using virtual models to simulate a convincing, almost real, display of the content. This exposes the object of interest in a three dimensional interactive form, more natural then its current representations, and one day can become ubiquitous, such as image projectors and the Internet have become (Cardoso et al., 2014).

One of the best advantages of mobile devices is the possibility to take teaching to new places, innovating in paradigms that could prove to have better results for learning (FitzGerald et al., 2013). The author also mentions that mobile computing become a trend due to the Internet's ubiquity.

(Wu et al., 2013) classifies three major categories for approaches that use AR in education:

1. Emphasizing roles: includes participatory simulations, role playing, and jigsaw approach. Where different players function as interacting components of a dynamic system, affecting the outcome of the system. Because these approaches emphasize the interactions and collaboration among students, they are usually associated with mobile-AR, multiplayer AR, or game-based AR.
2. Emphasizing location: Emphasizes learners interactions with the physical environment, so mobile-AR with location registered technology is important. Therefore mobile technologies are often used because mobile devices make it possible to track learners current geographical location.
3. Emphasizing tasks: include game-based, problem-based, and studio-based learning approaches. Due to the diverse nature of the tasks, implementation does not necessarily rely on a specific subset of AR technologies..

2.3 The Jigsaw Method

The Jigsaw method (Aronson, 2016) is a technique that works as a game, hence the origin of it's name, from the Jigsaw Puzzle. This method consists in partitioning the problem into smaller problems and then dividing them between members of the same group, that later will explain to the other members his research results on the topic. In this approach, students become at the same time, learners and teachers, in a collective environment.

Many studies have proven the efficiency of the Jigsaw method. One of these studies is the work by (Kilic, 2008), where an experiment was undertaken involving two groups, with nearly the same scores on a quiz taken before the experiment. One group was then exposed to a traditional teaching method, and the second to the Jigsaw approach. These groups then were tested once more in a new quiz after the lessons, on the results showed that the group exposed to the Jigsaw method, scored 92.25 out of 100.00, while the other group, exposed to the traditional method, scored 75.5.

The Jigsaw method can be summarized in three steps:

1. Group division: The pupils will form small groups containing from five to six students, and an activity is defined by the advisor. These activities are divided in subtopics which the students distribute between themselves.
2. Experts reunion: Each member of the group will do research about their own subtopic as to familiarize themselves with the content. Then, members from the different groups that are working on the same subtopic will gather to discuss it and reach conclusions.
3. Group Reunion: After subtopic research, the original groups gather once more, each subtopic being explained to the group by their respective expert. In the end, a quiz is given by the advisor to check the results of each group.

3 DESIGN PATTERNS

Applications for using AR can be very diverse, therefore some design patterns were developed to simplify the implementation in these systems. The work of (Lamantia, 2009) states that Robert Rice, CEO of Neogence identified 3 recurring problems in AR applications for browsers. One is that they all try to make applications for their browsers instead of sharing, another is that different applications cant share resources, the last is the elaboration for single users. The author proposes 4 patterns to solve these issues:

1. Heads-Up Display: Echoes the targeting and navigation displays in military and other aircraft. Is the oldest of the AR interaction patterns. Augmented experiences using the Head-Up Display pattern add information about the real objects in view into a complete mixed-reality experience that built-in AR tools and devices generate. While many AR experiences rely on external devicesthat is, external to the body, those using the Head-Up Display pattern commonly depend on hardware that is integral to a vehicle or cockpit-like physical setting.

2. Tricoder: The essence of the Tricorder interaction pattern is that it adds pieces of information to an existing real-world experience, representing them directly within the combined, augmented-reality, or mixed-reality experience.
3. Holochess: The Holochess interaction pattern adds new and wholly virtual objects directly into the augmented experience, combining them with existing, real objects. The virtual items in Holochess interaction patterns often interact with one anotherand sometimes with the real elements of the mixed-reality experience.
4. X-Ray Vision: The X-ray Vision interaction pattern simulates seeing beneath the surface of objects, people, or places, showing their internal structure or contents. AR experiences using the X-ray Vision pattern often use a combination of projection and renderingfrequently, a schematic or abstracted renderingof the object of interest, as in Medical Augmented Reality (MAR).

There are some new strategies for AR games development that focuses on uniting teachers and programmers in the process of game development. One of these strategies is presented by (Tobar-Muñoz et al., 2016). In his work, he creates a process that divides participants in 6 rolls: Leaders, that manage the project and are a bridge between teachers and developers; Designers, that design the game; Teachers, that proposes the objectives and purposes of the game; Developers, that construct the game; Researchers, that proposes the research design; Students, who provide desires and feedback. Even with its game focus, this method could be considered for regular AR software development.

4 ARCEDU - AUGMENTED REALITY FOR CHILDREN EDUCATION

ARCEDU (Augmented reality for children education) is an educational tool that uses AR technology in mobile devices. The idea is to create a system that can help teachers identify student difficulty, motivate them and create a collaborative environment.

With this in mind, we have defined a tool that supports the Jigsaw methodology and offers AR resources to motivate the students and enhance the learning experience. We will make use of the Holochess design pattern, to combine virtual items with reality in a mixed-reality experience.

The ARCEDU system does not have restrictions related to subjects, being limited only by the capacity to create subject related content that can be used by the software. For testing purposes, we focused on three specific topics: math, science and geography. For each of these subjects, markers related to the most abstract parts of the content were defined. They can be used when a student wants to access relevant content. For example, if he is reading about wildlife or vegetation of a specific area in the map, with AR, we could project virtual object of the main types of trees, the animals or even the land relief.

The tool has been developed for Android smartphones, and all students can have access to the system. However, to promote collaboration and mitigate device-related problems, shared resources is something that should be stimulated, allocating a single device for each group of students, increasing the viability of the project and promoting an inclusive social interaction policy, stimulating sharing and collaboration. It should be observed that, as the smartphones have Internet access, students can also enjoy the vastness of accessible knowledge in the network, providing links to complementary information along with the scanned codes, which can be filtered and registered by the teacher.

4.1 Implementation

AR is a technology almost strictly dependent on software [Zorzal et al. 2006], facilitating distribution. But there are few tools that support AR application development. However, the processing cost associated to computational vision already makes it possible to construct digitally artificial objects of very high quality using it, with existing models that can map an environment without the aid of fiduciary markers.

The system was developed for the Android operating system, using version 4.2 ”Jelly Bean” that is compatible with more than 80% of Android devices connected to the Google Apps Store (newer versions are backwards compatible) at the time of publication of this article (Android, 2017). It also provides some essentials which match the needs of AR, making implementation possible, such as acceleration for 2D and 3D graphics. It is reasonable to speculate that devices that have such features have processing capacity and memory for third-party applications, thus favoring the project.

With most of the requirements of our system satisfied by features that belong to the skeleton of an Android system, we are left with the non-essential resources of the system, such as internet access and camera. Most smart-phones today have cameras, with different degrees of image definition, so we believe the system can require the existence of a camera in

the device. The system will also require access to the Internet to function properly due to the need for data synchronization.

One of the functionalities evaluated for this system was offline operation. This feature requires that the QR code templates be in memory, thus consuming resources that may not even exist, so it is something to be considered in practical final applications. Another limitation of cell phones is the size of the display, which can vary significantly in resolution, size and density of pixels, between devices. For this we will need to create system that adapts to different sizes, keeping the proportions on the display, something that is fortunately already natively supported in Android development through SDK.

One of the limitations that have been abstracted is the efficiency of the batteries of these devices, something that despite having a negative impact on usability, can not be circumvented and can be solved by the use of external chargers and batteries, enabling a satisfactory time of use. Fortunately, most smartphones run for a few hours at full load, using network and real-time interaction.

To implement the resources that involve AR, the ARToolKit library will be used. It offers several functionalities through markers, such as add, recognize, design objects relative to their positions and manipulate these objects [ARToolKit 2016]. For development purposes the Unity3D tool was chosen for simplicity,as it is fully compatible with ARToolKit by means of the plugin ARUnity available on the official ARToolKit.2 page.

4.2 Structure

To offer the desired capabilities, ARCEDU has been divided in three modules: reading of AR markers for access to content; activities, that implements the Jigsaw method; and a game module, that makes learning fun.

4.2.1 Marker Reader

This module will be used for AR general purpose reading, for books with AR markers of any subject. For this proposal, we will have a graphical interface that merges AR reading and some other features. The first feature allows the user to, after performing a successful reading, effectively rotate the object shown on the display using buttons for convenience, shown in specific regions on the screen. Thus, an object in 3D is projected from a valid marker, relative to the position and distortion of the pattern. This will create an illusion of the object that is related to the subject, in the current context, that can be rotated for better observing with a touch on the screen.

Another function that is present in this module is the display of links through buttons in a hidden panel, that is displayed when the user reads a marker and then clicks on a button to open the panel. These links can be inserted by teachers as additional source of information about the object that is shown and will open a browser on click with the respective link.

For the last part, there is another button that is also only shown after identifying an object, that allows the user to change the displayed content, this is useful for showing different aspects of a object, like the insides, a specific component or something entirely different yet still related to the same subject.

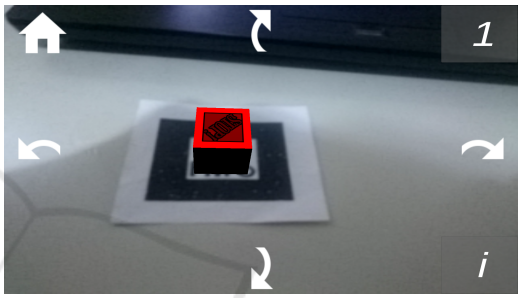


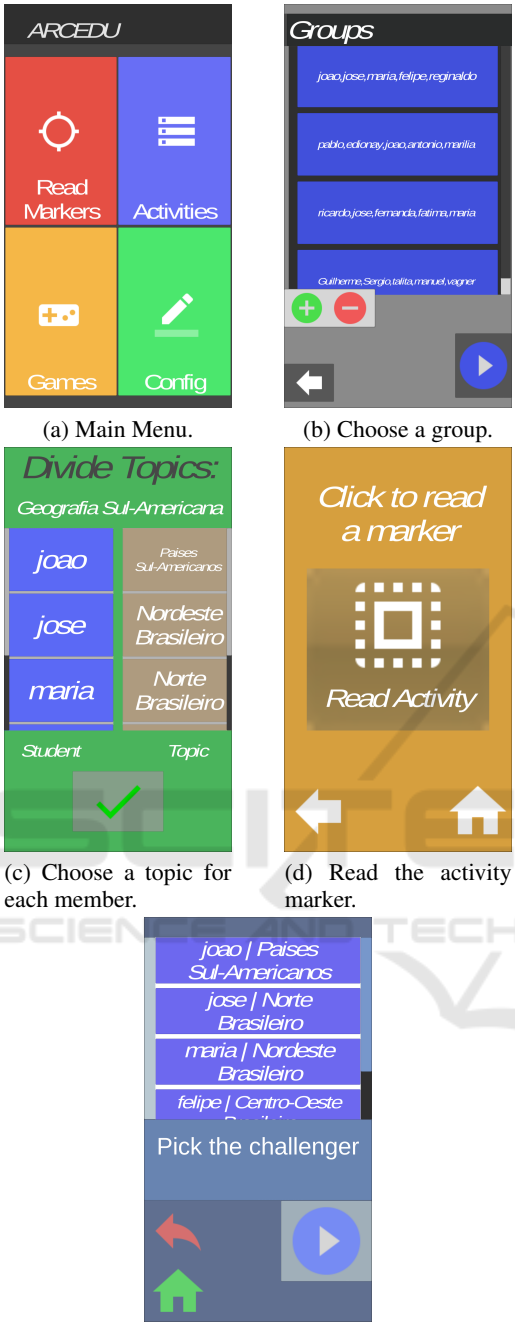
Figure 1: ARToolKit AR reader module, reading a paper marker.

4.2.2 Activities

This module helps the teacher make use of Jigsaw methodology. The students can create groups or select an existing one, read a marker to load an activity, handed out by the teacher, and then divide the subtopics however they agree. At the end of the activity, they can answer a quiz, that should be done after their research, generating a score that can be sent to a teachers e-mail if Internet connection is present. This can help tutors evaluate the students and keep track of who has more difficulty, focusing his efforts on those who score poorly.

4.2.3 Games

In recent years, researchers have seen the potential in games for educational purposes. According to (Gray, 2015) games are not bad for children, instead they are potentially beneficial and can help development of cognitive skills. If interesting, they should be stimulated and can help improve attributes such as: perception, attention, memory and decision making. For (Gray, 2012), video game addiction is a symptom, not a cause, and is related to general addiction problems. Considering options with an open mind is es-



(a) Main Menu.

(b) Choose a group.

(c) Choose a topic for each member.

(d) Read the activity marker.

(e) select a member to start a quiz.

Figure 2: ARCEDU systems activity module, in order, from left to right, top to bottom.

sential, as not every category of games is instructive (Hogle, 1996). According to him, the good games are fun, motivational and offer the right quantity of challenges, something that some classrooms already make use of.

This third module is a game library that contains games that make use of AR technology. These games aim to motivate the kids that naturally tend to get excited over different technologies. Another benefit from this module is the training in using the AR system for games, which can help use the other AR module present in this system. The games inserted could be puzzles, logic or of any other nature, as the main focus is in the entertainment purpose for this application.

5 CONCLUSION

In this work, we proposed a system to support learning for children, with a solution that merges a software and the Jigsaw learning method. Besides all the advantages of using AR systems listed in this paper, the choice of a mobile device allows the user to move while using the system. A simulation created by adding virtual objects to the environment added to the freedom. A mobile device can help reduce immersion of the digital world while still taking advantage of its benefits. The choice to add games to the system creates a fun and less stressful way to get children's attention to the system and therefore to learning.

If built correctly, AR education tools can help students learn and allows their teachers to evaluate their skills more precisely. Active learning techniques changes the roll of students and teachers in the classroom, creating a more cooperative environment and also helps students develop their learning skills. The ARCEDU system is entirely based on this notion, and uses the Jigsaw method to create a more favorable context, allowing to take better advantage of the systems features.

For future works, there are changes that can be made in this system and modules that can be added to raise its value for educational goals. Communication between groups members of the same topic in different devices through the Internet is an important functionality. To be able to download quiz and object resources from a server dynamically, allowing the teacher to add content and update to every user at once, is also interesting.

A suggestion related to the device choice, is to watch out for smartglasses, for they could prove to be a better choice than a mobile device, if it gets popular. They may even facilitate the use of X-Ray Vision design pattern, making it easier to see inside or under an object.

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