ISBN: 978-989-8704-46-7 © 2022

TRAINING CT WITH AUGMENTED REALITY-BASED RESOURCES – AN EXPERIMENT IN A CLASSROOM

Lazaro Lima[1,2], Ione Goulart[1], Luis Gonzaga Magalhães[2] and Pedro Rangel Henriques[2]
[1]Instituto Federal de Brasilia, Brasilia- DF, Brasil
[2]ALGORITMI Research Center, LASI, University of Minho,Braga - Portugal

ABSTRACT

The challenges in learning and teaching computer programming relate to everyone who needs to prepare others for the digital world. Learning and teaching computer programming is a challenge because it requires persistence and dedication. Nowadays, Computational Thinking is understood as an essential skill to overcome those challenges. In this paper, we propose an Augmented Reality (AR) environment that creates representations of complex programming constructs displaying engaging and playful activities that can be promptly done and do not require a heavy mental load. Such exercises are intended to be used as Learning Resources to train people in CT. The artifact enables people to explore CT concepts and several problem-solving approaches subtly. The artifact includes a simple AR-based activity, which is easy to handle and visualize based on "see-through video." We argue that users can develop CT problem-solving skills by interacting with this artifact. These learning activities supported by AR provide visual representations and interactivity to engage students while training CT. We also describe an experiment to test this artifact. The experiment was performed with 59 participants of the same age and educational level. The results of the feedback collected were positive.

KEYWORDS

Augmented Reality, Learning Resources, Active Learning, Mobile, Computational Thinking, Experiment

1. INTRODUCTION

Researcher Jeannette Wing consolidated the term CT (Computational Thinking) in her work (Wing, 2008), which states that developing skills related to PC concepts is essential to solving complex problems better.

An algorithm is a correct sequence of instructions for solving a problem. It is possible to build an algorithm by combining abstraction, decomposition, and pattern recognition abilities with logical reasoning. After successfully creating the algorithm, instructions must be translated into a programming language to achieve the problem solution. After running the program, it is important to analyze the output and the process and, if necessary, revisit the previous steps to improve the proposed solution.

However, training those abilities is difficult and requires appropriate resources. The author (Azuma, 1997) defines AR as virtual information integrated into a real environment in real time.

The author (Billinghurst et al., 2015) defines types of AR Display Technology, which depends on the proximity of display mediums. Handheld AR is a common method that uses smartphones and tablets to show AR content. Another technique is using headsets classified as optical see-through and video see-through like Hololens. The latter, nonetheless, although highly effective, is an expensive technology considering it would be used in public schools. The challenge of the activity is to create a virtual hero by following a sequence of steps. This resource supports a Plugged Activity using mobile devices guided with audio instructions.

This paper describes, in Section 2, some works related to our project; Section 3 discusses the ideas and motivations that led to the project; Section 4 presents the artifact developed; before the conclusion in Section 6, we discuss in Section 5 the results achieved in an experiment conducted after the development of the two pedagogical tools.

2. RELATED WORKS

Since the popularization of AR technology, society has been interested in developing new teaching methods. J. Wing (Wing, 2008) said that CT would influence all fields of action, thus raising the educational challenge of our society. We have to consider and develop the idea of creating new teaching/learning tools appropriate for training CT. The author also shows how social media has introduced a new industry segment to our economy, investing in Virtual and AR technologies.

Regarding the evolution of technologies, (Teng et al., 2018) presents an augmented reality (AR)-enhanced learning system that offers visual representation and interactivity to help students learn how to program 3D applications. The author demonstrates in his work’s results that, using AR, students had a higher learning efficiency than using the traditional system. Furthermore, the author's work claims that, by using AR, students have a better perception of usability, flow, and usage.

In two recent works by (Schez-Sobrino et al., 2020b) and (Schez-Sobrino et al., 2020a) with RoboTIC, different components integrated into the RoboTIC architecture are provided thanks to the use of AR and game mechanics designed to motivate students. The presented system, however, has high-cost wearable equipment. The works by ("Gardeli and Vosinakis, 2020) and (Gardeli and Vosinakis, 2019) suggest how to use RoboTIC in the classroom, first explaining the concept of programming and then letting students play the related game level to check if they really understand this concept.

It is possible to reduce the challenges of learning programming by using tools and graphical representations associating real-world elements with specific programming concepts. Thus, the main idea is to convert those complex programming concepts and associate them with metaphors easily created by AR. It is important to highlight that the future work suggested in the mentioned papers confirms that we are on the right path. The authors pointed out the need to work on a fundamental axis, which is the exploration of AR environments on mobile devices with current technologies, such as ARCore, ARKit, Vuforia, etc.

Following the related works, we identified gaps that align Augmented Reality and ontology to guide the development of activities that impact programming learning. Students find it hard to assemble mental models to solve ordinary problems. Feedback from previous work by (Araújo et al., 2019) describing an ontology model for teaching CT in schools and other works by (Lima et al., 2020) that present this idea motivated us to keep researching the impact of AR on CT training. In the next section, we will show how we associate the artifact’s activities with the skills to be developed in the CT.

3. PROJECTING AN AR ARTIFACT TO TRAIN CT

The learning activities projected and discussed in this paper require that students use CT key concepts. To limit the scope of this work, the artifacts developed and presented here were built using Handheld AR techniques, as illustrated in the general architecture depiction shown in Figure 1.

The idea is to plan activities in which the user will have to make choices and come to decisions according to a strategy resorting to mechanisms such as abstraction, decomposition, logic reasoning, pattern recognition, etc. Thus, it is possible to improve the quality of the reached solution in a loop until developing an effective final artifact.

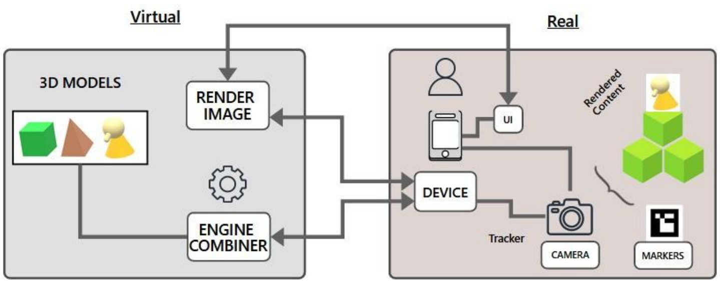

Figure 1. Artifact’s architecture

We developed an application called "Make Your Hero in AR," which was designed to perform learning activities based on the leading characteristics of CT. The artifact allows students to create several 3D heroes and change their attributes using Markers as cards. In the App, AR is used to display information and is also the environment used for interactions. The user plays with cards to interact and choose the character's attributes. The created heroes can be saved and then exported as a QR-Code to be imported later into a different device. Aiming to reduce energy consumption, we chose not to use wireless technologies to exchange information between devices. This approach was made possible by saving the information gathered as a JSON format file and then using this information to create a QR-Code to be read by another device.

It is important to notice that the activities use a Camcorder and consume more power from the device.

The QR-Code is generated with the information the user has customized using the markers. The option to use the camera to read the data of another device is only available when the camera is turned on. After reading a valid QR-Code, this routine is suspended so that scripts that use the camera do not consume power. By using interactive menus with buttons before the activity, we diminish the camera usage, reducing power consumption and using the camera in only two moments: in the Learning Activity with AR and the QR-code reading.

To implement the ideas, we used Unity 3-D® v.2018.4. The tool is useful when it comes to building AR systems supported by the Vuforia® library version 9.8. To create JSON files, we used the Newton soft library, and to exchange information between applications, we used QR-Code from the ZWING library. The technologies chosen make it possible to create scripts using the C# language to operate in the interface layer produced by Unity 3-D, and they also enable the use of libraries capable of generating visual information through QR-Codes. The following sections present a thorough discussion regarding the artifacts created to fit the concepts of CT using AR.

4. LEARNING RESOURCES TO TRAIN CT

CT is based on key concepts such as *Logical Reasoning*, *Algorithm Design*, *Decomposition*, *Pattern Recognition*, *Abstraction,* and *Evaluation*. As our goal is to train CT skills using a Learning Activity, the idea is to focus on the thought processes. With this activity, users will experience and explore an AR Activity aiming at customizing, recreating, or creating characters randomly. The key concepts associated with CT can be explored and improved while playing "Make Your Hero," as it will be later explained. **Pattern Recognition**: Players will begin to recognize patterns by interacting with the cards. **Decomposition**: The challenge is to create a hero with some attributes, such as *choosing a hero, size, special effects,* and *color*. **Algorithm**: The activity's goal is to follow the settled steps and use the modifier cards to customize a character, like in an algorithm, performing a sequence of elementary instructions; **Abstraction**: It is crucial to abstract how make the cards interact. Furthermore, the perspective view provided by AR to visualize the character from all angles gives the user a sense of analysis.

With the game, it is possible to create several characters with different effects, colors and sizes using six cards. Then, the students must save their characters to compare them with those created by other users. Finally, students must use the QR-Code to export/read the generated characters. It is possible to perform the activity in two ways: create a custom hero or select a randomly generated character. When creating a character, users are free to choose and customize their hero. We present a system designed as an appropriate system for training CT concepts using AR for mobile devices and cards as tangible objects. To use the system, it is necessary to print the Markers so that students can interact with them. There are six Markers in total. The printed Markers serve as Game Cards that will be used as an interaction tool in a routine that guides the users through the information displayed on the screen.

The activity of creating a character has five steps: Place the Player 1 and/or Player 2 card; place the Skin card and choose one of the available characters; place the Skill card to choose which effect will be displayed; place the Size card to change size and display; place the Color card to change RGB colors. The sequence of letters for interacting with the AR environment was fixed, relating to the concept of algorithm flow sequence. Users can create and save two characters at the same time. After choosing the character's characteristics, they can export their character using a QR-Code, and the character information will be loaded on another device. The system only shows panels for changing the character's attributes when the Player cards are combined with the modifier cards (character, size, color, and skill). Users can choose between four sizes, 19 characters, and ten different skills (effects), and they can even choose between ten colors to create other combinations.

Figure 2. List of basic Heroes available and Panel to customize the character

Figure 3 shows two screens of Make Your Hero during different occasions in the game.

When the user presses the button, the system responsible for the randomization functions generates information about all the customizable attributes of the activity. The textual information is presented for each attribute generated, allowing us to explore the abstraction concept.

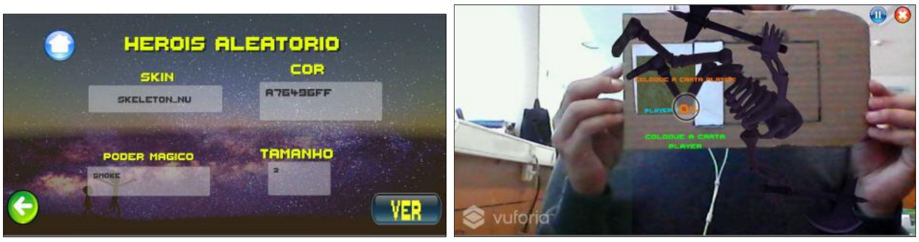

Figure 3. Screen shown when users press the "randomize hero" button and an example of the screen shown when we choose to randomize attributes

This plugged Learning Activity, which uses CT concepts, demonstrates that we can create numerous character customization options by using a few printed Markers for AR interaction. Furthermore, the application can export information in QR-code format, and students can exchange characters between devices.

The activity can also be used to create stories and use custom characters as their protagonists, combining it with other educational subjects. For instance, it can be used in subjects such as History, where the teacher and the students can create scenarios and replicate historical moments using mobile devices with cameras and printed markers.

5. THE EXPERIMENT, ITS RESULTS, AND FURTHER DISCUSSIONS

The experiment's presentation was given in a classroom with two groups of high school students in the first period in the morning. Because of this, some students were still sleepy during the presentation of concepts, but when the instructions and images of the proposed activities were shown, students woke up and identified an exercise different from the usual. A total of 59 students from ages 14 to 16 participated in the experiment, of which 23 were girls and 36 were boys. Students of the Computer Technician course, beginners in Logic programming. After showing the concepts related to Computational Thinking and how LR-AR works, a second teacher observed and recorded data collected from the experiment. Then, a link was shared to download the activity. The system was developed for a younger audience, but the objective is to test the motivation and usability of handling the system. Figure 4 shows the students' motivation in exploring the Learning Resource.

Figure 4. The figure shows the engagement of all students in the activity

Students were advised to work in pairs to solve some device compatibility issues. After installing the software, students were given 15 minutes to work on the activity so that the teachers could check if the students absorbed the given instructions. Then, the teachers met each group to present two other activities. Some students could not install the app because of parental control systems or because their device was of a brand that was incompatible with the system.

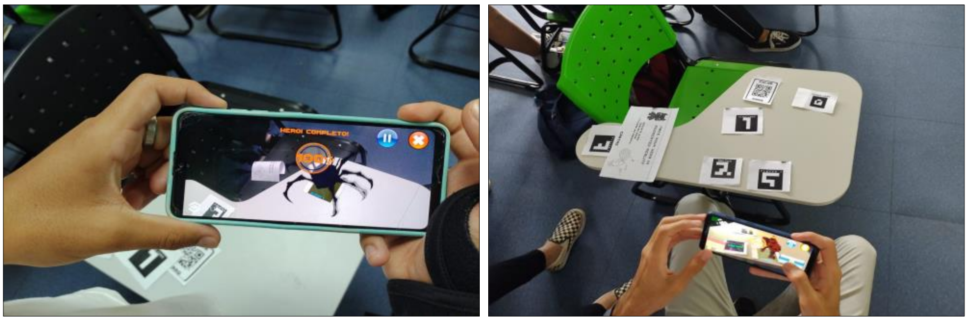

Figure 5. The figure shows that, after a few minutes, the students had completed the task

Figure 5 shows the sequence of completed tasks using the Handheld resource.

The first activity was to create a custom character and make notes of the chosen characteristics. The second activity proposed that students create a hero using fixed characteristics so that everyone could create the same character. At the end of the experiment and the two exercises, students were asked to complete the Evaluation of a Mobile Augmented Reality Game Application as an Outdoor Learning Tool questionnaire (Pombo et al., 2022). Four evaluation factors are defined for the MAREEA evaluation model: usability, engagement, motivation, and active learning. Students were motivated by the technology and way of operating the Learning Resource. At the school the experiment was carried out, students with special needs are not separated from other students. In the two referred groups, five students had autism spectrum disorder (ASD). They created custom characters and a specific hero following instructions, saving them with custom names. After creating it, the teacher passed it to another device, and students generated a QR code of the customized character and transferred such information to be used.

Ten answers were highlighted when considering both positive and negative reviews. A couple of students realized what the activity was for and enjoyed trying Augmented Reality, saying, "It is a great way for you to experience VR. I thought the app was cool, but it was hard to use it on old cellphones." The other student said, "I liked it because it has different characters, but I found it difficult to use the cards." Another student suggested "further information in the interface," showing us that not all information was clear in the system. Some comments were completely positive: "Everything, I loved it!" and "I liked everything in the app." Some students reported system errors, stating, "There could be a more practical access and a better way to access the QR codes" and "The letters were not focused on the cellphone." Two constructive criticisms stood out as teenage students understood design and human-machine interface: "the font color (yellow), besides being tiring, doesn't look good visually" and "I loved the game, but I would like to interact with my friends' heroes." There were also suggestions for future work, such as creating an online combat arena where battles with the custom characters would take place.

There was much praise, and students with autism spectrum disorder (ASD) were highly motivated and created custom characters. In this case, the students took the interaction cards home to show other customized characters later.

6. CLOSING REMARKS

The artifact presented in this paper trains the key concepts of Computational Thinking that we believe to be crucial in programming. The research and tests done to collect and analyze data and feedback regarding user experience while they played with our Resources showed that the overall opinion given was distinctly positive and encouraging. The concepts presented by the Make Your Hero app evidence the students' interest and its development potential to be largely used as a learning tool. The follow-up during the experiment allowed us to learn how people's interactions differ from one another. Participants used the system from different perspectives. Some participants moved the marker around to see the 3D environment and solve the problem, while others logically tested the presented tools' behavior patterns.

Summing up, we demonstrated that creating adequate AR-based tools to train CT helps to understand a problem better, analyze it, and produce solutions in a digital society. To overcome the existing challenges, users perform actions that rely on skills related to CT, such as *abstraction,* in which unnecessary details are removed to understand problems better. CT skills are currently considered essential to face those challenges. After abstracting the problem's essence, participants must apply the *decomposition* skill, dividing a problem into smaller parts to decrease its complexity. Then, they must use *pattern recognition*, which is the ability to recognize similarities among known problems, a skill to be used in reusing solutions. Another characteristic identified in the experiments is the light mental load to perform the activity. When using the artifact, users get smoothly involved in the game, easily performing the proposed actions. The activity was designed to be short, i.e. they can be completed without much effort and do not require a great amount of time to be completed., avoiding time-consuming and complex tasks that would lead to disinterest. The problem of identifying touches on the marker represents a feature that the AR library used to program the artifact needs to improve. For that purpose, new artifacts based on Augmented Reality technology using concepts of CT will be developed.

ACKNOWLEDGMENT

This work has been supported by FCT -- Fundação para a Ciência e Tecnologia within the Project Scope: “UIDB/00319/2020”.

REFERENCES

Araújo et al., 2019. Araújo, C., Lima, L., and Henriques, P. R. (2019). An Ontology based approach to teach Computational Thinking. In Marques, C. G., Pereira, I., and Pérez, D., editors, *21º Simpósio Internacional de Informática Educativa (SIIE)*, pages 83–88, Tomar, Portugal. Instituto Politécnico de Tomar.

Azuma, 1997. Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleop- erators & Virtual Environments,* 6(4):355–385.

Billinghurst et al., 2015. Billinghurst, M., Clark, A., and Lee, G. (2015). A survey of augmented reality. *Foundations and Trends® in Human–Computer Interaction*, 8(2-3):73–272.

ISBN: 978-989-8704-46-7 © 2022

Gardeli and Vosinakis, 2019. Gardeli, A. and Vosinakis, S. (2019). Arquest: A tangible augmented reality approach to developing computational thinking skills. In *2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)*, pages 1–8, Los Alamitos, CA, USA. IEEE Computer Society.

"Gardeli and Vosinakis, 2020. "Gardeli, A. and Vosinakis, S. (2020). The effect of tangible augmented reality interfaces on teaching computational thinking: A pre- liminary study. In Auer, M. E. and Tsiatsos, T., editors, *The Challenges of the Digital Transformation in Education*, pages 673–684, Cham. Springer International Publishing.

Lima et al., 2020. Lima, L. V. O., Araújo, C., Magalhães, L. G., and Henriques, P. R. (2020). Learning Resources with Augmented Reality. In Queirós, R., Portela, F., Pinto, M., and Simões, A., editors, *First International Computer Programming Ed- ucation Conference (ICPEC 2020)*, volume 81 of *OpenAccess Series in Informatics (OASIcs)*, pages 15:1–15:8, Dagstuhl, Germany. Schloss Dagstuhl–Leibniz-Zentrum für Informatik.

Pombo et al., 2022. Pombo, L., Marques, M., Afonso, L., Dias, P., and Madeira, J. (2022). *Evaluation of a Mobile Augmented Reality Game Application as an Outdoor Learning Tool*, pages 321–343.

Schez-Sobrino et al., 2020a. Schez-Sobrino, S., Gmez-Portes, C., Vallejo, D., Glez- Morcillo, C., and Redondo, M. A. (2020a). An intelligent tutoring system to facilitate the learning of programming through the usage of dynamic graphic visualizations. *Applied sciences*, 10(4):1518.

Schez-Sobrino et al., 2020b. Schez-Sobrino, S., Vallejo, D., Glez-Morcillo, C., Redondo,

M. A., and Castro-Schez, J. J. (2020b). Robotic: A serious game based on augmented reality for learning programming. *Multimedia Tools and Applications*, 79(45):34079– 34099.

Teng et al., 2018. Teng, C.-H., Chen, J.-Y., and Chen, Z.-H. (2018). Impact of aug- mented reality on programming language learning: Efficiency and perception. *Journal of Educational Computing Research*, 56(2):254–271.

Wing, 2008. Wing, J. M. (2008). Computational thinking and thinking about comput- ing. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 366(1881):3717–3725.