“Play and Learn”: Exploring CodeCubes

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Abstract. This paper presents a study carried out with a group of students from a robotic club, where they have used CodeCubes, a hybrid interface that combines physical paper cubes with Augmented Reality (AR). CodeCubes, intends to promote computational thinking through exploration and experimentation. The intervention, which we report here aimed at assessing children's interest and motivation for these types of interfaces, as well as identifying possible interaction difficulties with CodeCubes. The results indicate that the children were motivated to work with CodeCubes, and that the physicality of the interface combined with AR can potentially promote hands-on learning.

Keywords: Interaction · Augmented reality · Computational thinking · Tangible interfaces

1 Introduction

The Hour of Code is a global movement that attracts millions of students in over 180 countries [1], taking place once a year all over the world. The event has the duration of one hour and consists of programming activities that aim at demystifying programming and showing that everyone can learn the basics of programming. Further, the Hour of Code aims at attracting students to the field. A similar event, the Code Week, which is sponsored by the European Commission, takes place once a year all over Europe. It is conceived as “a grass-roots movement that celebrates creativity, problem solving and collaboration through programming and other tech activities” [2]. Such initiatives demonstrate well the importance of creating environments and materials targeting a wide audience, independently of age and previous programming knowledge, to promote the learning of the basic principles of computational thinking in an intuitive and compelling way. Outgoing from this context, we developed CodeCubes, a hybrid interface that combines physical paper cubes with AR technology.

The CodeCubes' game mechanic was inspired by a game from the Code.org platform [3], namely, Angry Birds - Classic Maze [4]. These types of games are often used to introduce programming to novice students. In the Code.org platform the players use visual programming through drag and drop to program and overcome challenges. In CodeCubes the visual programming blocks are replaced by physical paper blocks.

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Each face of each block has an augmented reality (AR) marker that triggers the basic programming instructions: right, left, up and down. The player must program a car to follow a defined path using these four instructions. This study aimed at investigating if and to which extent AR and tangible technology can be an effective complement in educational settings, as well to identify possible interaction difficulties with CodeCubes. The study was carried out with a group of children aged between nine and thirteen years of age that have experience with programming with blocks, i.e. Scratch [5] and robotics. None of the participants was familiar with AR.

2 Background

Augmented reality refers to the integration of virtual and real information, processed in real time. AR interfaces allow controlling and visualizing the information according to the users' needs [6]. Instead of replacing the reality [7], AR interfaces complement it, augmenting and superimposing the virtual information on the real world, without providing a complete immersion. This way, creating an interactive environment where the real is strengthened with virtual information in real time [8]. The use of AR in educational settings allows interacting with information, objects or 3D events in a more natural way [8, 9]. This enables the users - often with a high level of realism [11, 13] – to interact with the real world in a novel way. E.g., manipulating virtual objects and/or observing phenomena that are difficult to observe or manipulate in the real world, for instance, visualization, exploration and manipulation of the human body [20]. This technology also allows creating learning environments that combine virtual and real objects [11], e.g., using tangible interfaces for the manipulation of virtual objects, [8, 9]. Tangible user interfaces (TUIs) are physical objects embedded with computational properties that allow manipulating digital content [20, 21]. These interfaces create a seamless interaction between the virtual and the real and make it possible to change between both worlds. AR environments have three components: (i) combination of the real and the virtual world, (ii) real time interaction (iii) being inserted in a 3D environment [7].

The interaction and immersion made possible by AR has the potential to motivate the students and increase their willingness to learn [11, 13–15]. Studies have shown that the integration of AR in educational settings has a positive effect, increasing motivation, students' interaction and collaboration [10]. Relatively to the challenges of using AR in such settings these are mainly associated with usability issues and technical problems [11]. Same students may also find the technology difficult to use [11, 16] and the combination of real and virtual objects may create confusion [11, 12]. Some of these difficulties may as well be a result from poor interface design [11, 16]. However, overall the easiness of use of AR is considered an advantage [11, 16]. The involvement of educators in the design of such interfaces may help overcome difficulties of use and facilitate the integration of AR in educational settings [11, 13], although it may take some time to overcome these difficulties [11, 15].

3 CodeCubes

CodeCubes allows physical programming and virtual representation of the generated program. The users manipulate physical paper cubes that have an AR marker on each face, which is associated with a programming instruction and can be used to overcome a set of challenges. The programming, which is carried out through the physical manipulation of the cubes, allows its simultaneous visualization. This allows changing the program while it is running and visualizing the changes while the program is running. This approach to programming potentially promotes an interactive and engaging experience [19]. The game has three levels and consists of controlling a car to travel a pre-determined trajectory and reach the goal (see Fig. 1). The trajectory and the car are displayed on the computer screen.

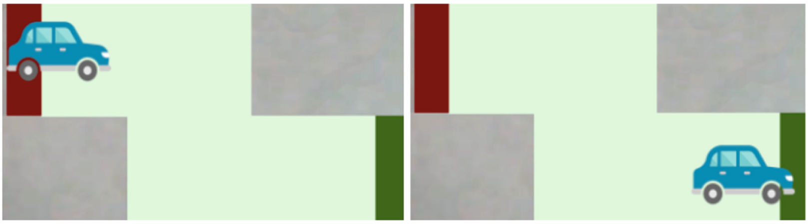

Fig. 1. Game elements (trajectory and the car) – level 1.

In order to reach the goal, the user has to program a sequence of actions that brings the car from the start to the end of the trajectory. In order to trigger these movements and make the car move forward in the right direction, the player needs to place the AR marker representing the required instruction (right, left, up, down) in front of the camera (See Fig. 2). The movements of the car are visualized on the computer screen.

Fig. 2. A participant using CodeCubes.

The car moves forward, according to the programming instructions, until reaching the end line. The player can progress by running the code step by step or programming the whole sequence (see Figs. 3 and 4).

In case the player is unable to program the instructions correctly but manages to bring the car to the end line s/he can move to the next level. The game is over when the three levels are completed. However, the users can always return to a previous level. The performance is measured by the time that the users need to reach the goal. This approach intends to motivate the students to learn how to program and to explore different possibilities.

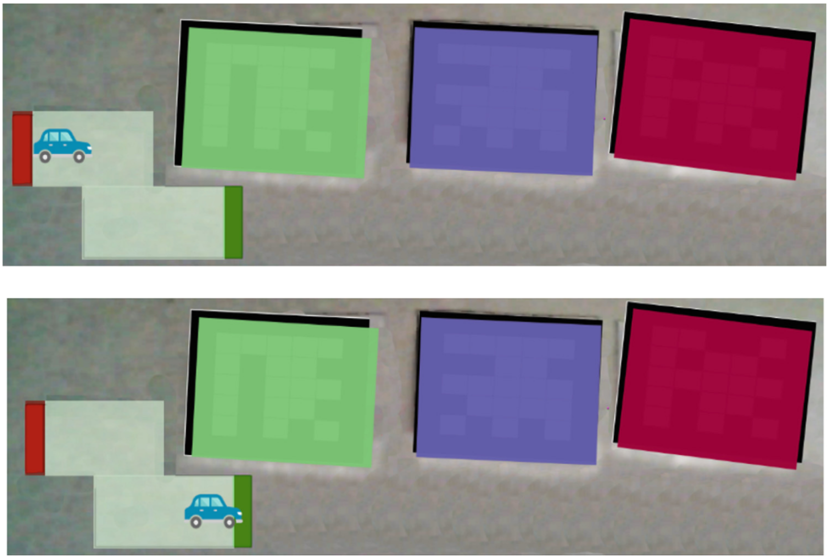

Fig. 3. The car trajectory

4 Exploratory Study

We carried out an exploratory study to (i) understand if the use of a tangible pedagogical resource combined with AR motivates and engages the students to carry out programming activities, (ii) to identify possible difficulties of use of CodeCubes, (iii) to gather ideas for future developments of CodeCubes.

4.1 Study Context

The intervention was carried out in a robotic club. The sessions took place during the opening times of the club, which is open daily from 6.30 PM till 7.30 PM. The students usually create projects using Scratch [5], as well as robotics' projects that are related to the school curriculum. We received written informed consent from the participants' parents.

4.2 Participants and Procedure

Nine students aged between nine and thirteen years of age, with an average of ten years, participated in the intervention. Four were male and five female. None of the participants was familiar with AR. The study lasted six weeks and comprised one hourly session per week, six sessions in total.

In order to find out if the students were motivated to use CodeCubes, it was compared with three other programming activities that the participants usually carry out in the robotics club, (i) Programming with Scratch [5], (ii) Programming with robots, and (iii) Programming with the Code.org platform [3, 4]. All the students programmed the same task using each of the three platforms (see Fig. 1), namely, (i) programming using visual programming blocks (programing with software) (Scratch); (ii), programming a Lego WeDo® robot to carry out the same trajectory as the car (programming with hardware); (iii) programming with CodeCubes.

The trajectory was pre-defined, and was the same for all the programming activities. For programming the Lego WeDo® robot the track was drawn on the floor. In order to program the car to move from the start to the end of the trajectory using CodeCubes, the users needed to place the cubes with the respective instruction (face) facing the devices' camera. However, the camera sometimes captured two faces of the cubes, which generated some confusion among the users. To avoid this, we have replaced the paper cubes by paper squares with the same dimensions as each face of the physical paper cubes (Fig. 4).

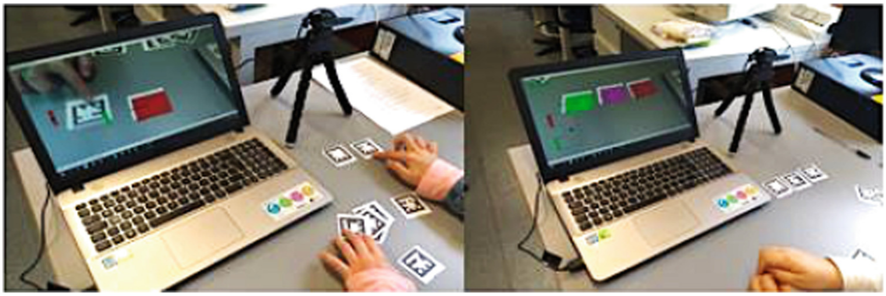

Fig. 4. A participant testing and running the program (top).

Similarly, to program with Scratch the participants had to use the visual blocks (using drag and drop) to program the car to move from start to the end of the trajectory.

The first session was dedicated to the presentation of the activities and the collection of demographic data. In session two and three the participants freely explored CodeCubes and carried out the tasks for each of the three levels. In session four and five each participant carried out following tasks individually (i) programming with CodeCubes; (ii) programming the car to follow the track using Scratch; (iii) programming the Lego WeDo® robot to walk the same track as the car. In session six each participant was interviewed individually.

In summary, in order to compare and evaluate children’s preferences towards each of the programming methods the participants carried out the same task using three different approaches. The final task was carried out in the Code.Org [3] platform for playing Angry Birds - Classic Maze [4].

4.3 Data Collection

In order to understand children’s engagement and interest, the data collection was carried out through direct observation, field notes, photographs and video recordings. The demographic data was collected through questionnaires. In order to assess children’s preferences and experience with the different programming modalities, a questionnaire was applied before the intervention, after using CodeCubes and at the end of the intervention.

The questionnaire was composed of four sections. Section one collected demographic data, section two collected children’s opinion about CodeCubes, section three concerned children’s opinion about using AR in class, and section four asked the children to evaluate the activities carried out during the intervention using a five-pointsLikert scale. In the last session each participant was interviewed individually. This interview aimed to clarify and confirm some of the information collected through direct observation.

4.4 Observations and Discussion

We observed that the participants did not show difficulties using the physical AR markers to program the proposed tasks. They followed an exploratory approach, by trial and error being able to carry out the proposed tasks. To accomplish the first level most participants executed the code instruction by instruction instead of using the ordered sequence of instructions. However, in the following levels they programmed the whole sequence.

We observed that the participants were engaged and motivated to carry out the proposed tasks, actively solving them. This was confirmed by their answers to the questionnaire and the interviews. Table 1 displays section two of the questionnaire (ease of use).

Table 1. Section two of the questionnaire - CodeCubes, ease of use.

Question	Yes	No	Some
Did you need help to use CodeCubes?		8	1
Does CodeCubes require long to learn how to use it?		9	
Did you enjoy using CodeCubes?	9		

Concerning the level of difficulty, eight participants considered CodeCubes easy to use and did not need help to use it. All referred that it did not take long to learn it. All the participants enjoyed using CodeCubes.

After accomplishing the four tasks, the participants evaluated the activities developed using a five-points Likert scale with following classification 1-not like; 2-like a little; 3- no opinion; 4-like; 5-like very much). The results are presented on Table 2.

Table 2. Section 4 of the questionnaire displaying the rating of the activities

Activity	Ratings (five- points Likert Scale)				
	1	**2**	**3**	**4**	**5**
Programming the robot		1	1	2	5
Programming with scratch	1	1		2	5
Programming with AR (CodeCubes)				2	7
Programming with Code.org	1		2	1	5

Seven participants rated CodeCubes with 5 (like very much), and two rated it with 4 (like). Most of the participants, also liked to program the robot, scratch and code.org, rating these activities with a five, (like very much). Since the results for all the activities were very similar, we applied another questionnaire to the participants asking them which activities they preferred most. We used a 4 points scale with following classification: 1-not like; 2-like a little; 3-like; 4-like very much). The results showed that eight out of nine participants preferred the programming with AR (CodeCubes) activity, see Table 3.

Table 3. Section 4 of the questionnaire representing the preferred activities.

Activity	Ratings			
	1	**2**	**3**	**4**
Programming the robot		2	4	3
Programming with scratch	1	1	5	2
Programming with AR (CodeCubes)		1		8
Programming with Code.org	1	2	4	2

In the interview the students referred that they like to assemble the robot and to program it, as well as to see if it carries out the programmed instructions. Most of them said that they gave the robot a nickname and that they gave it orders while programming it (as if they were communicating with the robots). This "communication" did not happen when they were programming with Scratch or using the Code.org platform. Regarding the CodeCubes, the students referred that it was new for them and that they enjoyed manipulating the paper markers and simultaneously see their hands while programming. They especially liked to see the virtual elements overlay the real and to be able to control the visual elements through the physical manipulation of objects.

In the interviews we also asked the participants to tell us which changes they would apply to CodeCubes. They referred that they would like to have more characters and audio. A girl suggested that the challenge could be to have a character that would collect trash, which would increase in higher levels. The aim of the game would be to collect as much trash as possible to fill a trash bin. A boy mentioned that he would like to have scores. All the participants expressed their wish to use CodeCubes in class, and that it could also be integrated in schoolbooks.

5 Conclusions

We have described an intervention carried out with nine students in a robotics club. The intervention aimed at assessing the potential of CodeCubes for motivating the students, as well as possible interaction difficulties. CodeCubes was easy to start with for all the participants, they have enjoyed all the activities and CodeCubes above all.

The participants were very engaged and carried out the proposed tasks enthusiastically. The results confirmed previous research about the potential of tangibles and AR as a pedagogical tool that potentially promotes the student's motivation and engagement, which may lead to increased learning [13, 17, 18].

6 Limitations and Future Work

The results presented in this study are confined to a very restricted universe, therefore they are merely indicative. The participation of a larger number of students, in a long-term study, would be needed to further confirm the results presented here.

Due to usability issues, instead of using the physical paper cubes the students preferred to use paper pieces. In future work we will explore different possibilities in order to find a better solution for the detection of the cubes' faces by the camera. The suggestions provided by the participants, e.g., to add audio, a range of different characters as well as a punctuation system will help to improve the system. We will also create more levels and a new set of instructions using structures, loops and selection.

Another interesting possibility that we are considering is to implement a multi-player version to extend the group interaction. This would potentially allow investigating to which extent the AR technology may contribute to develop prosocial behavior.

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