

# Voxar Puzzle Motion: An Innovative AR Application Proposed Using Design Techniques

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## ABSTRACT

This work presents and discusses the creation of an application to the Voxar Puzzle, an AR platform that has been built in order to promote children's education in a fun and lively way. The application was conceived using a well-structured methodology named Create Innovation Pack that is based on the design thinking theory. This method aims at helping to exploit the potential of a technology to deliver value to the user of a field, which in this case is children education. It applies the use of interdisciplinary teams with complementary skills, in which the technology developers are key members. The goal is to conceive solutions that are both innovative and with high impact potential. Thus, the application presented in this work was generated by teachers, educational researchers, a designer, AR researchers and an entrepreneur whose solutions proposed aimed to meet three criteria: desirability, viability and feasibility. The application conceived, the Voxar Puzzle Motion, therefore, combines knowledge from different areas: education, design, computer science and entrepreneurship. It is aimed at children aged 3 to 8 years old and intends to foster their motor skills as well as their logic-mathematical and logic reasoning cognitive abilities.

**Index Terms:** K.3.m [Computing Milieux]: Computers and Education—Miscellaneous

## 1 INTRODUCTION

It is well known that children learn differently from adults. Thus, a reasonable understanding of how they develop is a great tool for teachers and researchers. Many theories have been developed over time in order to explain and understand such complex phenomena. Many authors agree that children must learn from real experiences. Another important aspect is that children must work independently and that they learn through sensory experiences [19]. Piaget states that children's intellectual growth is based partly on physical development [21]. According to him, children build their understanding through things they do. This author, along with Vygotsky, argued that much learning takes place during

play. Vygotsky, on his turn, advocates that children not only learn by doing, but also by talking, working with peers and persisting in a task [19]. He emphasizes the importance of language and interaction among children.

Taking this scenario into account, it is noticeable that Augmented Reality (AR) is a promising technology concerning education and it has the potential to enhance children's learning. The coexistence of virtual and real information allows learners to visualize complex spatial relationships and abstract concepts. It also offers different learning experiences due to a number of reasons such as support for seamless interaction between real and virtual environments, use of tangible interface metaphor and ability to transition smoothly between reality and virtuality [29]. Many of these characteristics provide interesting opportunities for children. The tangible interface metaphor, for instance, allows children to deal with real world objects while expanding these interactions to a whole new level. Additionally, AR may provide the use of different senses which is argued to enhance learning experiences.

Although there are many educational AR applications being developed, only a few of them are created by interdisciplinary groups and based on learning theory [24]. Interdisciplinary teams are more likely to generate ideas that will lead to higher impact solutions since in these groups people usually have complementary backgrounds. Each participant usually contributes with his/her personal view of the issue and when all the views are combined together, better ideas are likely to come up. This is critical with technology researchers because the focus on the technology itself leads to complicated solutions that deliver a poor user experience and low impact on improving education. Nevertheless, a well-structured process is necessary to guarantee that participants will be engaged and converging on the best ideas. Additionally, these methodologies may help participants to give better feedback and have insights on how to combine the different points of view found during the discussions.

This work discusses the use of a well-structured methodology named Create Innovation Pack, which is based on the design thinking theory. It aims to put together interdisciplinary teams to conceive innovative solutions for education using AR technology that meets three criteria: desirability, viability and feasibility. It also presents an application created to the Voxar Puzzle, an AR platform that has been built in order to promote children's education in a fun and lively way. The application conceived, named Voxar Puzzle Motion, combines knowledge from different areas, which in this case were education, design, computer science and entrepreneurship. The goal was to enhance the potential impact of this application in the educational setting. It uses plastic blocks as a tangible interface and a portable setup in order to allow children to play games.

The present document is divided as follows: Section 2 presents the related works, Section 3 describes the Voxar Puzzle platform

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and Section 4 explains the Create Innovation Pack process. The proposed application is detailed and discussed in Sections 5 and 6, respectively. Finally, Section 7 concludes the paper.

## 2 RELATED WORK

There are a lot of applications available for educational purposes. They are aimed at different age ranges [11, 18], school subjects [27, 28] and platforms [2]. There are also educational applications that use AR [1]. However, only a few of them combine these characteristics with tangible interfaces. One example is Elements 4D [9], which uses cubes that have one periodic table symbol on each side. When the student points the camera to a specific element, additional content overlays the cube, such as an animation showing the real form of the element in nature or the chemical reaction when it is combined with a cube of another element.

One school area that has several applications is the one dedicated to developing the child motor skills. There is software aiming gross motor skill [6] but the majority is dedicated to the fine abilities. For instance, in [4] the child uses his/her fingers to drag animals to different places following a determined path. Others develop the motor skills combined with other school areas, such as Math [3].

However, almost all of them are mobile and use the touch interface to interact with the application. Thus, they do not use any tangible interface, which is a key element to develop the fine motor skill. It is so important that the vast majority of the activities applied by teachers in the classroom to develop this ability uses tangible objects. Examples are the pencil used to draw lines to connect points in a paper or colored marbles that have to be sorted into bottles by their color.

## 3 VOXAR PUZZLE

The Voxar Puzzle is a prototype platform created to validate the development of a hardware/software solution for educational AR activities. The hardware uses Osmo's structure, which is a tablet support and a mirror for the front camera [26]. Additionally, it uses 3D-printed blocks specially designed for children, which allows them to interact with the software [23]. The software consists of a frame marker tracker, which tracks the blocks to insert AR content registered with this interface. Therefore, it is possible to create several applications that can use this platform. One example is an AR jigsaw game, in which the player has to assemble an image divided into nine parts while having feedback regarding his/her progress, as shown in Figure 1.

It is possible to see that the tablet support is designed so that the screen is facing the user and the camera points to his/her hands through the mirror. Each block has a frame marker that allows the software to recognize and locate them using a barcode encoding scheme. This code represents the block's identification and orientation [23]. Figure 2 shows that a generic picture is used inside the marker in order to help children to distinguish one block from the other.

Voxar Puzzle was originally developed as a desktop application using projective AR. However, the camera-projector setup was not easy to configure and this concept was adapted to run on a mobile device. This version was developed for iOS platform. Therefore, it is possible to interact with the blocks and see the result on the device's screen. The system can be controlled by both the touch interface and the blocks itself. Thus, it provides two important elements that can be explored for educational activities: interaction with real elements and virtual feedback in real time. These characteristics were praised by teachers and students on evaluations of previous versions of this tool [25].

## 4 CREATE INNOVATION PACK

As described in the previous section, the Voxar Puzzle has been an evolution of a set of AR and design techniques that were well



Figure 1: AR jigsaw running on Voxar Puzzle. Note that the iPad is on the Osmo's tablet support and the mirror is the red object covering the frontal camera.

received by children and professors alike. Despite that, it is clear that further work is necessary to develop and test teaching/learning practices as well as features that could have a higher impact on education.

We have applied a session of Create Innovation Pack, which is based on the design thinking process, being an instance of product conception developed in order to put together researchers that developed the technology, users and business people to conceive and select innovative ideas. Based on Brown's criteria for successful ideas, the process is focused in harmonizing three constraints: viability, desirability and feasibility [5].

The initial briefing of this project was to combine the tangible AR capabilities of the Voxar Puzzle to the needs of the teachers in order to create new and more effective ways of guiding children on the learning experiences. According to Damanpour [8], teams with different and complementary skills are more likely to innovate than groups with similar ones. Therefore, teachers, educational researchers, a designer, AR researchers and an entrepreneur were put together in this effort. A total of seven professionals participated in the session. Participants were chosen for their expertise and complementary background. Their profiles are summarized in Table 1.

To deeply understand the problems of the teachers and to generate the first ideas, this team participated in a brainstorming session. Every team member works or studies at the same university and they are used to interact with each other. The two invited teachers are the only exception. They teach in the same school and they used to work with one of the education researcher, which is the only person they are familiar with. An interesting aspect of the

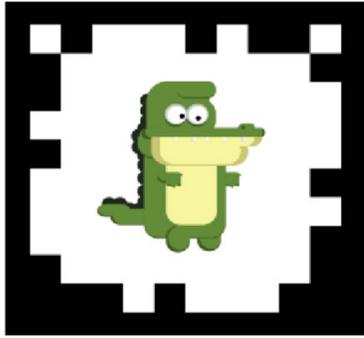


Figure 2: In the Voxar Puzzle marker, the white and black squares on the board indicate block identification and orientation.

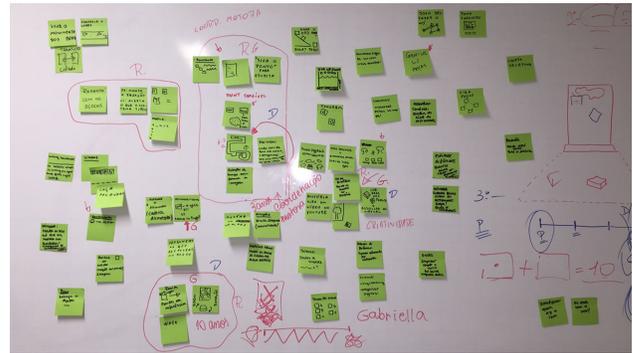


Figure 3: Sticky notes with ideas on how to use Voxar Puzzle Tools. In this image, similar ideas are grouped together.

Table 1: Profile of the Create Innovation Pack participants.

Participant	Background	Expertise
Designer	Bachelor degree in Design	UX design
Education Researcher	Teachers with bachelor degree in Education and Computer Science postgraduate students	Use of IT technologies for education of young children
AR Researcher	Ph.D. candidate in Computer Science	Tracking of objects and use of AR technologies for education
Developer	Computer Science B.Sc. student	Development of the Voxar Puzzle
Teachers	Teachers with bachelor degree in Education	Teaching children. They are familiar with technology use in the classroom
Entrepreneurship Teacher	Ph.D. in Computer Science and teacher of entrepreneurship courses	Conception of a business model based on technology solutions

process is that the two invited teachers had never interacted with this technology before. At the initial stage of the creative phase, they were presented to the Voxar Puzzle and were able to use it for about twenty minutes, while asked questions about its possibilities of use. The fact that this was their first contact with the tool did not act as a barrier for these participants on the ideation process.

After this introductory moment, each participant was invited to think about how the new tool could be used in class and present their ideas through sketches on the board, as seen in Figure 3. This session lasted about one hour and a half and teachers became used with the brainstorming dynamics very fast. The other members are familiar with this type of creativity technique. After all participants had presented their sketches, they were requested to group the ideas with similar characteristics. Based on grouping similar ideas, it was clear that some specific domains represented potential problems to be solved, such as motor skills, storytelling and basic mathematical operations. Also, it was presented some initial possibilities on how to solve these issues.

In early childhood, children should be pushed to develop different kinds of knowledge and skills. It's known that motor skill has a great impact on their personal development. According

to Magalhães [17], issues regarding this ability are common in childhood and can influence not only academic achievement but children's self-esteem. The lack of coordination capacity is usually linked to the quantity and quality of activities experienced by the child [15]. This failure can and must be resolved by appropriate actions, which include physical activities that can be related to games and puzzles.

Taking into account the importance that the development of motor skills has for children, this issue was selected as the main skill to be addressed. Therefore, a small group composed by the designer, the AR and the education researchers analyzed the ideas that were proposed concerning this topic. The goal was to review them taking into consideration the viability, desirability and feasibility of all ideas. After that, the ideas were combined to create the sketch of an application, which was sent to the teachers to collect their feedback. Finally, the same group composed by the designer, the AR and the education researchers met in another creativity session to consolidate the application. This session was mainly based on the application sketch and the teachers' feedbacks. The final solution developed through this process will be described in the next section.

The general process of the Create Innovation Pack is illustrated on Figure 4. For this work, the problem was how to use Voxar Puzzle in order to empower the children's learning experiences. In this sense, the multidisciplinary team summarized on Table 1 was assembled. The brainstorming session with most of the team, the idea selection phase and the creation of the application sketch composes the creation session. The outcome was then sent to the teachers so they could validate this initial idea. Finally, the concept was defined using the initial as starting point and taking the teacher's feedbacks into consideration. Each step was executed only once on this instance of the Create Innovation Pack. This was possible because a member of the team that created the final concept has experience with education. Therefore, she was constantly validating the application during its creation. However, when there is no one that is used with the domain area, it is highly recommended to validate the concept with experts and improve it until it reaches the desired quality.

## 5 VOXAR PUZZLE MOTION

The application proposed in the Create session aims to use the Voxar Puzzle features to improve motor skills, an important ability to children's overall development. Additionally, the application also intends to develop the logic-mathematical and logic reasoning cognitive abilities. Voxar Puzzle Motion is a playful application which intends to help children develop these competencies and also provides a detailed evaluation to teachers and parents on how the young apprentices are evolving.



Figure 4: Create Innovation Pack process.

The Voxar Puzzle Motion was designed to have two interaction methods. One is the touch interface of the tablet that gives access to all management options, such as configuration and evaluation data. The other is using the blocks to select and control all educational activities. Therefore, children will only interact with the application through the tangible interface.

The application starts displaying the option of three games for the child to choose Travel, Pickup and Maze:

- **Travel:** This game focus on developing the child’s motor skills. The player has to use the block to guide his/her avatar to some place following a determined path. The tablet screen displays a virtual scenario while the road is represented by the camera image. The child must place the block inside this path and his/her character will appear using AR. While manipulating the block through the road, the child develops his/her motor skills. The path will grow sideways to be easier to hold the block without occluding the marker. That allows the game to be easy to use regardless each dominant hand the child have. In order to evaluate his/her performance, the distance between the center of the block to the correct path will be measured. Several paths with different levels will be available and it will be chosen the most suitable one according to the child level in the moment he/she starts to play.
- **Pickup:** This game is similar to the previous one. The player uses the block to guide his/her avatar to some place following a specific path. The difference is that there are multiple ways to get to the destination and the child must guide the avatar into the paths to collect something related to the character before getting to the destination. The path is determined by some type of sequence, such as following the numbers in increasing order, as illustrated in Figure 5. Therefore, it helps the child to practice the mathematical concept of sorting along with his/her motor skills. The gameplay is very similar to the previous one, which is to manipulate a virtual avatar using the block as interface. Evaluation is performed by observing how many moves the child did before finishing the game or the time is up. Several paths and sequences with different levels will also be available to be chosen according to the child level in the moment he/she plays.
- **Maze:** In this game, the child has to take his/her avatar from one place to another as well. However, the story will tell him/her that the character does not know how to get there. The aim is to go through the virtual labyrinth, which represents the several options the child has to complete his/her journey. Thus, it develops the child’s motor skills and logical thinking since he/she has to find a way to complete the task. Different from the other two, this game does not use AR. All elements are virtual and they are manipulated through the tangible interface.

After choosing the game, the child has to select the character he/she will play with, such as a car, a spaceship, a horse, a monster among others. In the following screen, the application displays an ludic animation to tell the story of the selected character and relate



Figure 5: Illustration of the Pickup game in which the player must guide the dog to its final destination while picking up the books in the correct order. The road is the image captured by the camera and the character overlays the block.

it to the activity context. This is important to improve motivation and narrative skills because it provides a specific story related to the child preferred character, which creates a stronger relationship between him/her and the game. Additionally, the target audience to use these games are children that are still learning to read. Therefore, this animation is also important to provide instructions for them. Finally, the child will play. Each game will finish when he/she completes the task or the time is up. During the interaction with the teachers, they mentioned that time is an important element to have on these activities to stimulate quick thinking. Once the game ends, it collects all evaluation data and stores it for further analysis. Additionally, this data is converted into a simplified score for the players and is displayed on the screen. At this point, the child is able to decide if he/she wants to play another level of this game or change to a new one.

## 6 DISCUSSION

Playfulness is well known and used as a method or educational resource in early childhood education. The literature on education admits it as an important aspect of life and development, which is presented in all human trajectory [12]. Therefore, it is understood that games should be seen “as a way of stimulating cognitive, social,

emotional, language and psychomotor development, and provide specific learning” [22].

According to Kishimoto [14], playfulness is justified in education for several reasons:

1. For being a teaching resource;
2. Encourage student’s interest (making them the active subject of the teaching-learning process);
3. Because games and jokes allow teachers to observe activities and student’s interests.

Lopes [7] says that playfulness in the school context allows children to treat issues related to anxiety, work on their limitations, deal with rules and rule-based systems, extend their own abilities, develop autonomy, improve coordination, increase concentration and attention, develop anticipation and strategy, and, at last, expand logical thinking and creativity. It is also pointed out that playfulness provides ways to develop emotional control, enhancing the student self-confidence and a better understanding of possibilities and personal limits. It also allows the individual learning by playing a cathartic role, which relieves stress [22, 10, 16]. Thus, Voxar Puzzle Motion has many playful elements such as the storytelling to involve the students in the context and the game itself, which was meant to allow children to have fun while practicing different cognitive and motor skills.

Considering the Create Innovation Pack process experienced, it was possible to develop the aforementioned application. With this application, it is expected to stimulate not only motor skills development but also cognitive abilities, especially in logical-mathematical and logic reasoning fields. This development will, particularly, happen through the manipulation of a tangible object, which is an important aspect for younger pupils who benefit greatly from the interaction and manipulation of real objects [19]. Additionally, the Voxar Puzzle Motion uses different kinds of puzzles and activities, which require a set of skills, such as attention, concentration and wits.

The importance of the use of a structured design process becomes clear with this final result. This creativity and interdisciplinarity based process creates connections between what before was segregated and tacit knowledge. Only through the application of this process, it was possible to collectively think about a powerful concept of an application using different knowledge areas. In this case, education, design, computer science and entrepreneurship. Opposing to the common belief that only rare creative born minds can generate useful ideas, [13] argues that anyone can be creative with the right stimuli. The brainstorming sessions reinforced this thesis, where all participants contributed with valuable ideas, even though some of them had never participated in a similar creativity technique. Another important aspect was that a sophisticated technology could be exploited and used in the final solution by small children.

## 7 CONCLUSION

This work showed the process of creating applications to the Voxar Puzzle by using a well-structured design thinking process, the Create Innovation Pack. This process enabled the creation of Voxar Puzzle Motion combining knowledge from different areas in a creative and innovative way. The application created aims to develop children’s motor skills along with logic-mathematical and logic reasoning cognitive abilities. This content was proposed taking into account the technical and interaction potential of the Voxar Puzzle. This combination was fostered by the use of the Create Innovation Pack methodology. The ideas were developed and validated by all the participants involved.

As future works, this concept will be carried on a new phase in which it will be prototyped, tested and evolved through the participation of potential users. Some characteristics of the product will need to be improved in order to fit the needs and expectations of its specific target audience. The applications will also be tested aiming to align and empower their impact on children regarding education. The interaction with the application will also be the focus of future tests and improvements, such as the way users will move and interact with the blocks along with the consequences of having a screen with limited size.

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