

Logos, the Dragon Slayer: A Serious Game to Develop Algorithmic and Logic Thinking

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Abstract

Serious games exploit the immersion and motivation promoted by games to facilitate the achievement of predefined educational goals. The aim of this work was precisely to design, create and validate such a game that could engage and help younger generations developing an algorithmic and logic thinking once this is an identified cognitive gap. The game consisted in a series of logic puzzles directly connected to the expected cognitive aspects to be improved, embedded in a dungeons and dragons' narrative to provide extra motivation for students. The preliminary evaluation results showed that the solution served well its purpose and revealed itself as a good tool for the cognitive stimulation to kids.

1 Introduction

Today's society goes hand in hand with technology and practically everyone owns a multimedia device. However, most people only know how to use those devices and are not really aware on how they work. For the younger generations it is more and more relevant that they develop algorithmic and logic thinking as that ensures, besides a fuller understanding of the operation of the digital devices, the availability of a wider range of potential professional careers. According to Crow[Cro14], the technological advance is so fast that in a very near future coding will be the language of the world and those who do not know it will have the same difficulties as an illiterate and, as a consequence, will have more difficulties in the labor market. Games represent a major part of the multimedia content available in those devices and almost everyone enjoys the thrills, challenges and fun that games provide. Serious games exploit the motivation and immersion promoted by games to focus the user/player in educational (or other serious) objectives. Playing games is a process that enhances interaction, exploration and learning. A good game motivates the player through challenges carefully adjusted to his/her abilities promoting the development of his/her skills and competences. Game-based learning has shown clear advantages in terms of student motivation in comparison to the traditional learning approaches. As such, it makes sense to think that, through games, it is possible to create cognitive development processes. So the aim of this study was precisely to design, create and validate a solution (serious game) that would engage and help younger generations in the development of logic and algorithmic thinking. The game consisted in different logic

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puzzles related to the cognitive development purposes in a dungeons and dragons' narrative style. In this article we present the concept, design and development of that game and the initial results of its use with children.

2 Context

"A game is a system where players enter into an artificial conflict, defined by rules, which ends with a quantifiable result." [Sal03]. For these authors the main concepts related to this definition are the following:

- System: A system is a set of parts that interrelate to generate something more complex. For instance, in football we have players, the ball, the goals which interact together to form a more complex operation.
- Players: A game must have one or more participants. The players interact with the other system elements to experience the game.
- Artificial: The games provide a simulated view of "real-life", both in time and in space.
- Conflict: There must be conflict in all games. The conflict may appear in competition or cooperation scenarios, and may be between the user and the game system or in social multiplayer contexts.
- Rules: Rules are a crucial part of games. The rules delimit the structure where players will immerse themselves and define what they may or may not do.
- Quantifiable Result: The game must have a quantifiable result / objective. At the end of the game, the player either won or lost or, at least, received some kind of numerical result.

Playing games is related to human needs. Abraham Maslow, summarized these needs in a pyramid where the first level, the base, corresponds to physiological needs (e.g. food, water, rest); the second level corresponds to security; the third level addresses relationships (friendships, love relationships); the fourth level is directly linked to respect and the feeling of achievement; and finally, the last level, "self-realization" [Man14]. Maslow argued that as long as the lower levels were not met, it would not be possible to progress to higher levels, for example: someone who is hungry, does not think in improving his/her self-confidence or in gaining the respect of others but is rather just worried about finding food. Games relate to this taxonomy as players try to answer those needs in the actual game context as if they were doing it in real life. That creates a very high level of involvement in the game context.

Serious games are games that have as main purpose something other than entertainment. They can be used in education, health, engineering, politics, training, among others. Sawyer and Smith developed a taxonomy of serious games, thus categorizing games according to their area of application and objective [Saw08]. The use of games in education has many advantages, such as:

- Motivating effect - the game captivates users by being a source of fun and challenges. With a motivated player, it becomes easier to develop knowledge and competences;
- Development of cognitive abilities - the player constantly applying and improving his/her cognitive abilities, trying to devise strategies to beat the opponent, or trying to find a solution to the "challenge" that the game presents.
- Learning with errors - a game employs this method of teaching / training practically on all occasions, due to their almost immediate feedback to each action of the user and by providing a risk-free environment, where the player can risk and explore at will.

2.1 Serious games for algorithmic and logic thinking

Next, we present a few examples of games dedicated to the development of algorithmic and logic thinking.

- Machinarium is a 2D point-and-click adventure game available for PC, Android and iOS. It was released in 2009 and developed by the Studio Amanita Design. The game follows the story of the main personage, the robot Josef, and its adventures to save his girlfriend robot, Berta, from the boss of the city. To do this, the player has to solve logical puzzles. The game stimulates logical thinking insofar as the puzzles are not something obvious, but rather something that often does not match a first guess. The characters and scenarios have a good level of detail but the dialogues are quite minimalist, with the characters communicating

through speech bubbles with simple animations and symbols, avoiding thus the long and common dialogues common in some adventure games [Sapsd].

- Limbo is a platform game with several puzzles for PC, PS4, PSVita, Xbox One, Android and iOS. It was released in 2011 by independent studio Playdead. The game features a 2D monochromatic environment, full of dangerous traps where the main character, a young boy, looks for his sister, trying to get her out of the limbo where she is trapped. To do this, the player must solve various jigsaw puzzles using the surrounding information. There is no other type of interaction other than the control of the character. Limbo offers good puzzles that are often solved with elements of the surrounding scenery, not being obvious what has to be done and what has to be used. For example, one of the obstacles is to pass through a spider and to achieve that it is necessary to use traps that previously prevented the character's progress.
- Mekorama is a logical puzzles game, released in May 2016 for Android and iOS. The game consists in transporting "B", a small robot, to a point of extraction. To do this, the user has to solve logical and mechanical puzzles. Using an existing concept, this game succeeds due to its intriguing mechanics and clean and simple design with a difficulty that is increased at each level.
- Unblock Me is a simple and addictive puzzle game released in 2009 for Android and iOS. The objective of the game is to move the red block off the board. For this, the player has to drag all the blocks (with different sizes and positions) to create a passage for the red block. There are several ways to complete each level but the maximum classification is only achieved when doing the fewest movements possible.
- Can You Escape is a puzzle game for mobile devices (Android and iOS), developed by the MobiGrow studio in March 2017. The objective of the game is to escape from several different rooms. To achieve this, it is necessary to search and investigate which objects exist and which ones are possible to use to find a key which will open the door. Sometimes objects are not used as tools but as a source of information about something, from codes to color combinations necessary to open boxes or doors.
- Flow Free is a puzzles game released by Big Duck Games LLC available as a web application in HTML5, Android, iOS and Windows Phone. The game consists in connecting with a line all the points of the same color existing in one level, without any intersection. Players drag the line from one point to the other taking in mind that it must be continuous and cannot be superimposed. The gameplay of Flow Free implies a previous planning of the routes of the lines so it requires some strategy and problem-solving, such as in the beginning, the player should create more straightforward and simple connections, followed afterwards by more complex connections, thus dividing the problem in several smaller problems.
- Room Escape is a puzzles game available for mobile devices developed by Javelin Mobile. The game unfolds in an atmosphere of drama and suspense, where the player embodies a character that was kidnapped and is stuck in a room without any kind of memory. The goal is to escape the room before the time runs out. For this, the player must investigate the entire room to obtain the necessary tools and clues to implement a logical plan of escape. During gameplay, the player is constantly being challenged by alphanumeric puzzles that serve, for example, to open locks.
- Adventure Tom is a game of logic, oriented to sequential and spatial reasoning, for children from 9 to 12 years. The game aims to guide the main character, Tom, to find a treasure chest and to achieve this, the player has to logically place his limited set of blocks to form a path. These blocks have their own actions, such as move right, down, left, among others. As levels progress blocks with new options appear, such as the possibility to pave parts of the map. Once the path is logically planned, the player presses the ("GO") and checks if the solution is correct.
- Humble Jungle Puzzle is a logical puzzle game, recommended for children between the ages of 7 and 9 years. This game stimulates computational thinking and the sequential reasoning through puzzles. These puzzles consist of discovering the correct way to unite all the "fruits" in one to be delivered to the main character of the game. For this it is necessary to predict what position the "fruit" will have after the merger in order to become available for another possible merger. The game features a friendly and catchy interface for children, using bright colors and elements of play appealing to them, such as talking animals.

- Need a Hero is a logic game that develops logical / computational thinking, suitable for children between the ages of 8 and 11. The game unfolds in a board-like environment where Bob the mouse has to save his friends from Dr. Badd Cat's traps. The character can only do horizontal and vertical movements, movements that are only stopped by other objects. These objects can be boxes, which serve also to Bob being able to stop and change direction. Dishes can be moved to board boundaries or against a motionless object, gaining the same function as a normal box. In addition to these tools, there are portals that transport Bob between the two extremities of the board. Using all these tools, the player needs to find a solution to release all Bob's friends and finally, use the trap-like catapult to move to the next level.
- A Good Snowman Is Hard To Build is a puzzle game, released in 2015 by Alan Hazelden and Benjamin Davis. It is available for PC, Mac OS and mobile devices (iOS and Android). In this game, the user controls a monster and helps him to create snowmen. A snowman is formed with 3 snowballs, a large, an average and a small one. Sometimes snowballs already exist and are already in the right size, being only necessary to push them in order to create the snowman. Pushing the balls across the snow-covered terrain, causes it to be removed from the ground and make the ball bigger, i.e. by moving a small ball on the snow will make it become a medium-sized ball. There are also situations where there are only 3 balls of small size or even situations where it is necessary to build 3 snowmen from 9 snowballs. In addition to these there may be different objects such as garden benches, lamps, among others. The presence of these objects influences the motion of the snowballs, since they act as obstacles.
- 1Line is a puzzle game, available for mobile devices (Android and iOS). The game consists in connecting all the points with only one line, not being able to cross the lines already formed. Initially simple forms are presented, but each time the level increases, the number of rows increases and the complexity of the figure also increases.

2.2 Coding platforms for algorithmic and logic thinking

In addition to the games, there are some platforms that try to get programming and coding ability to the children. Not being as motivating as the games, they still achieve good results in teaching kids so they've become widely used. For instance, Scratch is used in the discipline of information technologies of a good part of secondary schools in Portugal.

- Scratch is a visual programming language developed by the Lifelong Kindergarten Group of the MIT Media Lab, a project led by Mitch Resnick. It is available for Windows, macOS and Linux. This language was designed for ages 8 to 16 in order to help these younger generations to think creatively, to reason systematically and to take the first steps in programming. However, it ended up being used by people of all ages, to create presentations, games and animations. (Scratch, s.d.). The visual mechanism used is that of blocks, that is, the user programs the actions as if they were a puzzle, connecting the blocks (actions) so that in the end they achieve the desired function. It is a very successful approach because it is very simple and intuitive for any age.
- Tynker is an educational programming platform, with its own Integrated Development Environment (IDE) that uses an interface based on drag and drop mechanism such as Scratch. The goal of this platform is the teaching of programming to children over 5 years. The children find an interface identical to that of the Scratch with draggable blocks that have different functions. It is possible to visualize the blocks in JavaScript code which allows the learner to perceive what corresponds to the action of a block in a programming language. It is also possible to use the blocks directly in JavaScript.
- CodeCombat is a browser game that teaches and encourages the practice of programming. It has a retro style in the form of a Role-Playing Game (RPG). The game has two strands, one aimed at children over 9 years of age and another dedicated to programmers and / or more advanced users. CodeCombat is widely spread throughout the world, being used in more than 200 countries and translated to over 50 languages. It has a player base of more than 5,000,000. (CodeCombat, s.d.). The interface is appealing and the objectives are well defined. The levels are divided by modules and follow a strict order, that means that it is not possible to go to level 3 without passing through level 2. The modules cover all the programming tasks from syntax and logic to the development of games, web development, artificial intelligence, among others.

3 Logos, the Dragon Slayer

According to Jean Piaget's theory, human cognitive development is divided into 4 stages [Tei15]:

- Sensory-motor - from birth to 2 years.
- Preoperative - from 2 years of age to 7.
- Operative-Concrete - from 7 years to 11 or 12.
- Operative-Formal - approximately from 11 or 12 years onwards.

This globally accepted and recognized theory holds that it is in the fourth and last stage that children gain and develop abstract thinking. Then the child becomes capable of adopting other perspectives beyond their own. At this stage, in addition to many aspects of deductive and inductive reasoning, the ability to use formal logic and mathematical reasoning also grows. The child learns to create concepts and ideas, and to use logical and systematic reasoning [Che17]. Following this cognitive development theory, Logos, the Dragon Slayer game has, as target audience, children from 11/12 years, once they are at a stage where logical and mathematical reasoning emerge. So the game will try to captivate and guide them in that process responding to the need to stimulate computational/logical analysis of these pre-adolescents and, eventually, fostering their interest in programming and/or computer science. The style of the game is based on logical puzzles that promote the cognitive development algorithmic. The puzzles will be of a spatial nature solved, mostly, with the movements of the character, Sokoban style. The puzzles and underlying narrative are adapted to the target audience by being based on a dragon world fantasy model quite common for these ages. The narrative of the game is as follows: "In an oppressed world, dominated by terror, agony and destruction, a dragon reigned, Duvnoss, the supreme dragon lord of darkness. It all started when Rivalon, one of the top 5 nations, led by Alabaster Rivalon, invoked Duvnoss since these creatures were considered the creators of the whole universe, beings of immeasurable power. Alabaster thought that he could master such a source of power, however, when invoked, Duvnoss easily took control of the entire royal family and subsequently of the whole nation, beginning his reign of terror. Rivalon, now led by Duvnoss, began its expansion conquering neighboring lands. Numerous dragons were resurrected such as his 4 generals: Maekid, Ogor, Chodam and Urre. With such military power, the annexation of its neighbor and longtime ally, Veobia, was quite simple and quick. The expansion of the terror continued and reached the continent of Obone, where its inhabitants were known as tireless fighters. In fact, they fought persistently, but the Dragons' power was too much for their strength and technology. However, some of them managed to survive and take refuge in the nation of Lehia. Only two nations did not fall before the power of Duvnoss, the empire of Clanand and Lehia. Both were known as nations of peace, for many years had the function of regulators of relations among all 5 nations. It is said that Rivalon has not yet succeeded invade them due to its wall, which according to history, was built by the white dragons Lehiathan and Clanandoss. There are those who believe that the peoples of these nations are descendants of these dragons. The player as an inhabitant of Clanand, was chosen as a hero in this fight against the darkness. Its function will be to explore numerous dungeons, thus trying to know more about the history of their ancestors, finding fighting mechanisms against dragons, their weaknesses, etc."



Figure 1: Logos, the Dragon Slayer narrative as presented initially to the player

The player will have to explore dungeons scattered all over the world, some even in hostile territory. The locks inform the player that those levels are still unavailable, waiting for the completion of other challenges. When unlocked they can be repeated as many times as the user wants to get a better solution and a higher score. Aesthetically, the puzzles are adapted to the part of the world they represent, for example, in a desert the puzzle shows a sandy environment.

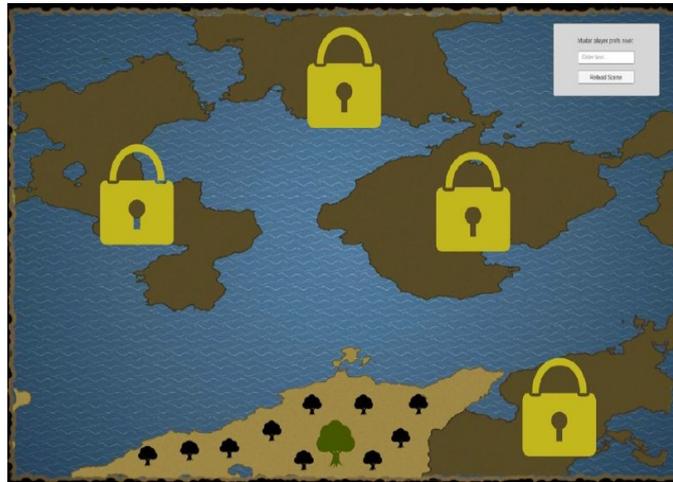


Figure 2: Rivalon world when starting the game

The dungeons have different difficulty levels and represent puzzles. The puzzles challenges can be due to limitations in the number of movements, to the manipulation of objects, to move elements to create a path, etc. In each level the aim of the player is to find a solution to escape the dungeon. He/she has to go through an open door, which sometimes is closed and the user has to perceive the mechanisms necessary to open it. In some levels the user can manipulate several objects and the objective is to pass a precious, cube-shaped mineral through the door. At this set of levels, the handling process is slightly different. In terms of difficulty, the game was implemented with a growing level of difficulty per succeeded dungeon. Each new level is harder than the previous one. However, in each new country which includes the introduction of new mechanisms, the first level is simpler to allow the understanding of the logic mechanism. From then on, the levels are getting more and more complicated. This difficulty management is done with the reduction of the useful playing space and the introduction of new variables necessary for the completion of the level.



Figure 3: Dungeon in the initial country

The game was thought to provide a pleasant experience to its users, be it on a mobile device or on a computer. For this, a fundamental aspect that was in its design was to make navigation fluid, regardless of the device where it was played. The game features a 2D environment, with traces of medieval style. Simplicity is a crucial feature of this goal. The colors were also chosen according to the style of play. The map was designed according to

history, divided into five continents/countries and with the climatic elements that characterize them. The game was developed using Unity, a game editor/engine developed by Unity Technologies, which is used mainly for the development of video games and simulations for mobile devices, consoles and computers. A game engine consists of a grouping of libraries that includes several features, 2D and 3D render, physics systems, collision detection, sounds, and more. Unity also features an integrated development environment with C# as the main language.

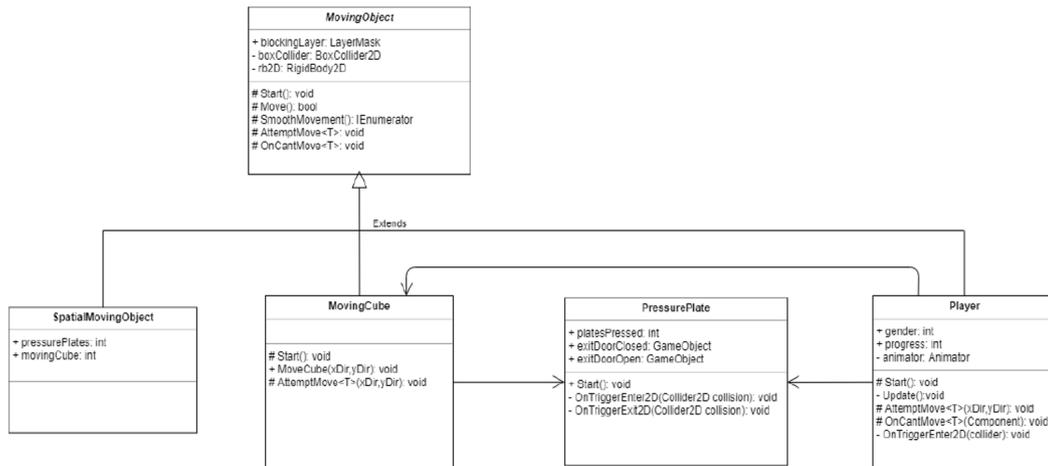


Figure 4: Class diagram for the game

3.1 Results and discussion

To assess the game as an educational tool, a study was carried out with 22 primary and secondary school teachers with experience in the use of educational technologies. The choice of these participants was due to their experience with the students of the target age group and their expertise and know-how on the use of other computer applications for teaching and learning which allowed them to have an informed view about the game.

For the study purposes the game was adapted to run in browsers and was freely made available online, so that the teachers could test it on their own. After a small briefing session, teachers test the game autonomously for a week. Subsequently they answered a questionnaire, divided into three sections: usability, gameplay and cognitive development. Each closed question used a Likert scale, with scores from 1 to 5, where 1 corresponds to "strongly disagree" and 5 to "agree completely". Teachers also had the chance to answer questions with open comments and suggestions, thus providing a qualitative appreciation of the game. The questionnaire was made available online with the help of the google forms platform.

Starting with the usability aspects, 81.8% of the teachers considered that it was easy to start a new game. Curiously, only 72.7% of the teachers considered that it was easy to move from level to level which might indicate some software problem appearing from time to time. In relation to the game controls are easy, 54.6% of the teachers thought that it was easy to play the game. Some teachers had some problems probably due to some browser issues. 72.7% of people agree or fully agree that the interface is simple and appealing, 63.6% consider menus easy to access and understandable and 54.6% consider the navigation simple and appropriate. Regarding the game instructions only 43.5% considered them to be clear which implies that this must be reviewed

In relation to gameplay, it was tried to assess if the game was motivating and pleasant for the target group. 63.6% of the teachers considered the game fun and the same number considered the game challenging which is very good. The narrative of the game and its connection to the puzzles was enjoyed by 72.7% of the teachers which indicates that there is coherence and consistency in that aspect. 91.8% of the teachers considered that the audio was relevant to the game context which was clearly the most positive aspect. Only 54.6% of teachers liked the graphics which implies that more work has to be done in that aspect.

The assessment of the potential cognitive development was the most important reason for choosing the teachers to test the game as it would be difficult to have good answers from the children. Here we will analyze if the game complies with the that he had coveted. 72.7% of the teachers considered that the game would develop self-learning abilities. More importantly, 90.1% of the teachers considered that game allows pattern recognition, encourages reflection and develops logic and algorithmic thinking. This result is very important as it helps to prove the solution work and that the game is on the right track. 63.6% of the teachers consider that the game environment and the gameplay are adjusted to the learning context and to the learning objectives. 81.8%

consider that the game allows cognitive development that can be used in other contexts, which was also one of the crucial points of the game and was successfully fulfilled. 63.6% of the teachers would recommend the game to their students.

In terms of the qualitative comments, they were very much focused on the usability and gameplay aspects. One of the opinions was that the game took a long time to load and that it was not easy to complete a level. The first part is justified by the fact that the game has been tested in a free online platform where the speed and access are limited, while it was thought and developed as a desktop/native mobile app for Android and Windows. As for the difficulty, it is possible that the game is a bit difficult initially without a full set of instructions. Another respondent stated that the movement could be more fluid and in fact would be a good improvement to implement in this project. Another suggestion is that the graphics should be improved which also corresponds to the closed questionnaire results. It was also suggested to have more levels to allow a more regular use. In fact, regular updates are planned with more puzzles.

4 Conclusions

With the current technological advance, digital devices are increasingly present, particularly with the younger generations. There is more and more information and training about how to use these devices but very little to explain how they work, that is, the logic and computational processes. The devices increasingly have games as a growing digital content. Games have proved to be a powerful tool for entertainment but they have many other benefits which can be useful for education, such as: motivation, stimulation of cognitive abilities, learning by "trial and error" (trial and error), etc.

This study aimed to combine the previous ideas by developing a serious game with the intention of stimulating the logical and algorithmic reasoning of children between 11 and 13 years. A study was also made on the characteristics of the target audience and it was decided to elaborate a serious puzzle game, with a captivating story to help keep the player motivated. The game is based on spatial puzzles of sokoban style, where the player has to manipulate certain objects. The game was tested by a group of teachers of primary and secondary schools which helped assess the usability, gameplay and cognitive development features of the game. In short, it was proven that Logos: The Dragon Slayer game can contribute to the stimulation of the logical and algorithmic reasoning of the players, providing them with a good and fun educational experience.

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