# Liber Domus – Development of a Prototype RPG for 6th Grade Mathematics and Science Learning

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**Abstract.** Recent studies shed an unfavourable light on existing tools that support at-distance learning in pre-university students. Concerns revolve around motivation, focus, engagement as well as long-term knowledge retention rates. Multiple attempts were made to connect digital games with education, designated by Game-Based Learning, although educational outcomes have been mixed. Possibly due to ad-hoc experimentation, the effects seem related to relationships between specific game mechanisms and structural design. This research project focused on potential effects of a digital 3D role-playing game in learning. A multidisciplinary team built a prototype, named Liber Domus, using game developing techniques and mechanisms that have never been used or explored in the area on this scale. Preliminary results show the game presents students with a more dynamic approach to learning inside the classroom, increasing motivation and fun levels and allowing for a less repetitive revision of subjects, and the flexibility of the tool for both classroom and at-home learning. Further development is ongoing.

**Keywords:** Learning; Game-Based Learning; Role-Playing Games; Elementary Students, Storytelling

## 1  Introduction

For the past 30 years, the use of Role-Playing Games (RPG) or elements and parts of RPG in education, such as characters, scenarios, rules have been a subject of discussion [1; 2]. Either in physical or in digital format, its adaptation to the reality of the classroom appears to provide several benefits, even if there is still some debate as to which specific game genres, mechanisms or how the game itself is presented and/or played affects those benefits [3; 4].

To identify the utility and ability of RPG in education is, in fact, complex. There are a few considerations to be had and assumptions to comprehend how such a tool could be used. In the first place, the teacher or educational expert responsible for the development of such a tool must choose between using an existing RPG, either tabletop (TTRPG) or a Digital RPG (DRPG) and in which scenarios it should be used. Different RPGs have very different characteristics, stories, character development,

sets of rules, among other characteristics, which directly influence the subject being taught. One could argue that even the use of different learning objectives and contents will affect the experience of the student and therefore their outcomes [2; 5].

Afterwards, the teacher must create sets of rules to link the gameplay moments with educational goals and define how the educational contents are going to be connected to the narrative, either through characters, backstories, plots, storytelling, as well as related locations, items, etc., which are an integral part of the RPG and the type of connection, which could vary from introductory to complete. That will in its own affect the length of said RPG as well as which gameplay elements that will be required.

Another point of interest is how the teacher will use the RPG to choose which gameplay mechanisms will be used to demonstrate and create exercises for the students, which will also be affected by the demonstration capacities. A 3D engine in a DRPG will create different visualization and interaction experiences than a 2D engine. In a similar way a TTRPG gameplay with 3D objects and materials to interact with will have a different learning outcome when compared with a basic TTRPG experience.

Although it is not the intention of the authors to fully explore these subjects, it was considered ideal to have a starting point by evaluating the combination and implementation of RPG aspects that could be considered more impactful and educationally relevant, already done previously [6; 7; 8] and apply those through prototyping as to test it with students to evaluate and compare impact and outcomes.

For that purpose, a multidisciplinary team from ESMAD - School of Media, Arts and Design, and Schoolers & Scholars, a research group from inED - Centre for Research and Innovation in Education – School of Education, both from the IPP - Polytechnic Institute of Porto, developed a 3D DRPG, called Liber Domus, to support learning of Mathematics and Science for the 6th grade for the Portuguese educational system. The development of this prototype involved both the analysis and development of educational implementation throughout the narrative, game mechanisms and gameplay moments, as well as creation of specific game mechanisms to support comprehension and application of concepts by students, resulting in an innovative and structurally different Game-Based Learning experience (GBL).

## 2  Game Design

Digital or computer RPG have several game mechanisms and gameplay styles. Nevertheless, are characterised as relying heavily on characters (and its development), narrative and interactive fictional stories which are encompassed inside quests, representing calls to action (from a non-playable character or otherwise) for the player to perform one or several tasks, based on pre-selected or developed skills and/or traits. Upon completion, successful or unsuccessful, those will lead to consequences, and/or additional quests and/or rewards for the player and (potentially) the fictional world, characters, and their relationship between each other's and towards the player [9].

The structure of quests varies according to degrees of complexity, the number of narrative elements prior and the game mechanisms associated with it, being possible to connect tasks such as the destruction of enemies, puzzles, riddles, gathering/harvesting/mining or resources, trades, navigation towards a specific location, among many others. While not all of these are appropriate nor desirable for educational purposes, others will either be useful or hinder the performance of the student when applied [10; 11]. For that reason, we chose to develop a framework identifying the minimum narrative elements, the ideal game mechanisms, and positive and negative consequences to the player when said quests are completed. In addition, it also developed ethical and moral rules that guide game design and narrative design to assure those are acceptable to use in a 6th grade learning environment.
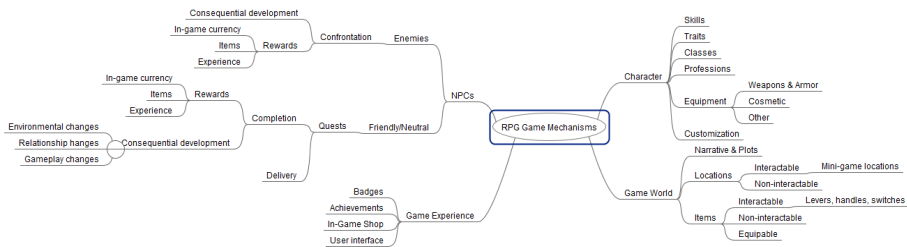


**Fig. 1.** RPG game elements and dimensions of play.

Based on the definitions and classification of game mechanisms as determined by Hitchens & Tychsen [12], RPG centre gameplay mainly on the existence of a fictional (with various degrees of realism and magic embedded into the world and related gameplay) game world, filled with locations (interactable and non-interactable), items and non-playable characters (NPC) (friends, neutral or enemies) who interact with the character. The game experience drives from the customization (initial and continuous of the character), the interactions and consequences of such interactions through quests or otherwise with NPC, which result, when successful (and sometimes even when unsuccessful), in rewards such as loot (dropped items and currency by enemies killed), chests and prizes. These rewards may or may not vary according to the complexity, degree of difficulty of the quest and/or enemies defeated (if existent). With the rewards obtained, the player can improve or change their character (usually by using experience points, which may also be used to level up a character), buy better equipment, items necessary for additional quests and overall improve gameplay outcomes and experience. To further expand the game experience, the player may receive badges and/or achievements, connected with the outcomes of quest and battles completion, that in turn may or may not affect the player gameplay by providing with rewards.

At first sight, some of the potential RPG mechanisms (Fig. 1) may be incompatible with educational games for 6th grade students in the Portuguese formal education system, in particular those that require of the player the use of violence and/or observing violence when defeating enemies and using weapons. Some of the quests usually required of the player is the destruction of buildings, items and enemies and may also include sabotage, stealing, lying, conspiring, and pushing the player to

engage in behaviour that may lead to moral or ethical issues, including engaging in risky actions and even virtual death of the player's character. Although an on-going discussion, there's the concern that long-term exposure to violence by K12 students may lead to reduction of empathy and desensitization [13]. At the same time, students of this age, considered early adolescence, are going through a formative process in terms of social and personal competencies and principles combined with increased autonomy, with the school and teachers having the additional responsibility of transmitting the educational contents in such a way that does not negatively affect their development [14]. In Portugal, the set of principles that guide the work of teachers and schools is established in several legislation published, with a few particular Decrees [15] [16] determining that schools and teachers: i) must promote pro-social behaviour; ii) include, inside their curricular activities, character enriching and ludic, formative and cultural activities and connect schools with real-life scenarios; iii) support the personal and social growth of students, with particular attention to civic, health, technology and financial education; and iv) provide the means of support for psychological growth of the students and promote healthy habits and prevent risk behaviour.

Furthermore, guidance was also drawn from the conceptual Dimensional Framework present in [17] that establish, for Digital Game-Based Learning (DGBL) solutions, standards regarding essential dimensions such as autonomy, play, affinity, and space. These authors consider that any DGBL solution should promote autonomy, allowing students to explore with autonomy in different degrees of complex environments and actions through open-ended gameplay. Play, on the other hand, should be specifically designed, removing certain rhetoric, such as fate, imaginary, frivolous and self.

The challenge was, therefore, the implementation of a structured educational and game experience that could draw from the positive benefits of RPG as discussed above and that can introduce several relevant taxonomies in comparison with other games and educational solutions [3], while removing gameplay, narrative and mechanisms that could negatively affect the student's development and educational objectives.

Two tables were produced to summarize the gameplay elements and mechanisms to be added (if possible) and removed from the prototype, as seen below. Some elements were designed but not implemented into the prototype due to time constraints:

**Table 1.** Allowed and encouraged RPG elements to implement in an educational game.

|  |  | In Prototype | In Full Development |
| --- | --- | --- | --- |
| **Mechanisms** | Interaction with 3d environment, items and characters, including exploration | Implemented | Implemented |
|  | Construction /modification in 3d environment, including customization | No | Partial |
|  | Performance of quests, including optional and non-linear progression | Partial | Full |

| | | | |
|---|---|---|---|
| | Energy or stamina levels as feedback mechanism | Implemented | Implemented |
| | Farming, mining and gathering with and without respawn | No | Full |
| | Development of relationships (positive or negative) with characters | Implemented | Implemented |
| | Crafting of items, including for consumption | No | Implemented |
| | Interaction with items for consumption | Implemented | Implemented |
| | In-game currency and usage | Implemented | Implemented |
| | 3D object manipulation, including changes in physical properties and scientific laws | No | Partial |
| | Note-taking | No | No |
| | Books | No | Implemented |
| **Gameplay** | Badges (with limitations) | No | No |
| | Achievements (with limitations) | Partial | Implemented |
| | In-game shop (for cosmetic and non-cosmetic character or game-related items/equipment) (with limitations) | No | Implemented |
| | Puzzles and puzzle-related mechanics | Implemented | Implemented |
| | Physical mechanics such as traps, doors, levers, buttons locks, etc. | Partial | Implemented |
| | Timing and time-related mechanics | Implemented | Implemented |
| | Rewards and reward chests (without random or probability related outcomes) | No | Implemented |
| | Physical and psychological mechanisms related to character | No | No |
| | Customization of character | No | Implemented |
| | Grab & drop, including attachment and release | Implemented | Implemented |
| | Skill development, including classes, professions, traits and skills | Partial | Implemented |
| **Narrative** | Positive and Negative Feedback from NPC | Implemented | Implemented |
| | Interference with narrative and plots including moral and ethical choices | Implemented | Implemented |
| | Real-life or similar to real-life scenarios, historical or otherwise | Implemented | Implemented |
| | Fictional or non-fictional plots and story, including lore | Implemented | Implemented |
| | Unhealthy items or that, when consumed, can hinder or negatively affect the mental of physical state of the character. | No | No |

**Table 2.** Not allowed or strongly discouraged RPG elements to include in educational games

| | |
|---|---|
| Mechanisms | Battle & battle equipment<br>Destruction of property / Vandalism<br>Stealing<br>Abuse of in-game currency mechanism<br>Cheating<br><br>Loot and loot boxes<br>Psychological manipulation of character or NPC |
| Gameplay and Narrative | Violence (execution or graphic), except directly related to curricular contents<br>Violence (graphic mention or dialogue, from player or NPC)<br>Nudity (any form)<br>Sexual content (any form, including implicit or indirect), except directly related to curricular contents<br>Lying (through dialogue)<br>Racism or intolerance towards an NPC (through dialogue)<br>Direct or indirect use of luck/chance to alter outcomes without explicit use of probabilities in age-appropriate settings<br>Excessive use of magic and fantastic elements |

## 2.1 Selected Game Elements and Narrative for the Prototype

**Story.** It was decided that, in line with the indications of the table above, the story of Liber Domus should not have certain negative aspects, but instead focus on the daily life of a fictional city and region, with traditions and typical conflicts and necessities, which will be the basis of most quests. As both a way to increase immersion and provide an emotional connection between the player, the NPC and the quests, and also to justify the location and scenarios, a backstory was created, which is also seen in an introductory video, showing the exodus of the Primi people, as they escape an empire in ruins looking for a new home, and find a safe location inside surrounding mountains and on top of a mesa, where they build a city called Liber Domus. There they also find, and connect with, a mysterious mystic animal, which they call Estimmo. Now an established, over 200-year-old meritocratic and democratic society, it's ruled over by a Concilio, a council of elected elders, which values knowledge, wisdom, and logic above all else.

Although these are the most relevant themes, we believe it would be wasteful to not take the opportunity to assess the potential impact of introducing ethical and moral dilemmas to the story and therefore decided to include plots related to ethnicity, tolerance, sustainability, and others. The prototype, for time constrains, only has a few interactions, which focus on ethnicity issues. The story background and origin took inspiration from classical civilizations as the Roman, Greek and Egyptian for language and as a source of relevant themes for learning of mathematics such as engineering, architecture and optimization issues, as well as societal organizations. As the students learned about these civilizations in the 5th grade [18], we believe these themes are age appropriate and spark interest.

Hence, when the player starts the game, it begins in the Dies Hospites day, a holiday that celebrates the bond between the citizens of Liber Domus and the Estimmos. Currently, two ethnic groups inhabit the city, the Primi and Secondo. Little

is known by the player about the Secondo, only that are very different, physically and culturally. As the player progresses through the quests, it will become clear that there is significant tension and conflicts between the two groups, which the player will try to mediate, all the while trying to solve other problems of the city.

**3D Environment**. The environment created was centred on the story themes. We opted by a regional and city environment due to higher dynamics compared to an outdoors or countryside location as the story would be centred in human interaction and conflict. The climate was taken into consideration as it is a part of the 6th grade Science curriculum and mimics the Portuguese climate and flora. For story and development simplification, the only animals seen in the prototype are the Estimmo. We also believe that the educational contents that are being taught are more relevant inside an urban scenario. Several scenarios were designed inside the city, of which only three are visible and implemented in the prototype. The character's house, which is used for tutorial purposes, Doma, the residential district, and the Forum, where the main quests take place. These scenarios are built with similar traits, architectural features and logical construction and items, as to provide the player with the feeling as if the location could exist.

**Companion**. The companion, in the form of Estimmo is an NPC that always accompanies the player. In the story of Liber Domus, Estimmos are magical creatures that "bond" to every citizen. If a new citizen is born, the parents' Estimmos create a new Estimmo which will have traits of both. To keep the game environment with reduced magical components, it was decided that the only magical abilities the Estimmo have are the perfect memory and ability to speak.

**Quests**. The quest system was implemented alongside the remaining systems and is embedded into the dialogue system. For the prototype, it was considered a simple delivery mechanism if conditions are met for it to be delivered. These conditions are the existence of enough stamina as the required for the specific quest, the existence of previous quests that should be completed before or other tasks, the existence of a certain rank, skill level or elements, including equipment. Each quest also has consequences when completed with success, such as rewards, praise, and continuity to other quests, or without success, as dialogues to restart the quest and motivate the player, and additional hints.

There are four types of quests: i) Main quests, linked to the main story line, and that, through the actions of the player, will allow the character to progress; ii) Secondary or optional quests, used by the player for a number of reasons, not required to move forward in the story and finish the game. These can be used for the player to improve skills and elements or obtain additional in-game currency or rewards. iii) Society quests, which were not implemented in the prototype but crucial to the game, inserted into societies which focus on engineering, medicine, artisanship, and nutrition. The player must perform these quests to progress in rank (necessary to progress in the main quests) but can choose which ones to play in order to reach that goal. iv) Lore quests. These are non-educational quests but with educational outcomes and present different structure to the traditional quests. Quest givers are not NPC but

events and items, when found by the player, give way to information complementary both in terms of story and education.

**Stamina**. Stamina is seen as a method to incorporate failure in-game. As the quests are related to the educational contents and objectives, to complete a quest without the minimum knowledge deemed necessary would be contrary to the purpose of the game. On the other hand, failure in absolute terms cannot be implemented in the game for two reasons: continuity and purpose. The game structure requires the completion of certain quests to proceed with the general direction of the narrative, giving room to additional required quests. Failure without the option of repetition by replenishing stamina would defeat that goal. And, naturally, the purpose of the game is to support learning by students. Each failure should be met with the option to try again. If the player fails to have enough stamina to continue with quests, the quest is put on hold until they can recover stamina through the consumption of apples or other food items. If the player does not have any food items or in-game currency to purchase more, the game provides small optional quests that require no stamina to start or complete. As these quests provide educational revisional contents, we believe it is a good opportunity for students to review subjects to be best prepared for the other quests.

**Skills**. Three skills were associated with the player, Charisma, Strength, and Agility. These are typical RPG skills. Charisma is a skill which usually affects how well a character does in dialogues (or if they can talk to a NPC). Strength refers to the capacity of the player to move or destroy certain items (e.g. a large boulder). Agility is a skill that can be used to affect how the player performs in certain situations such as climbing a wall, dodging perils, balance, etc. Although these skills are not connected to the educational contents being delivered in the game, it was intentional to provide the player with a well-known mechanism and exclusively game-related (other skills that could have been implemented were for example "mathematical thought", "logic", "reasoning", "calculus", etc.), as to not overbear the educational references. At the same time, it is believed to be important to provide the player with contexts in which the ability to have a certain positive skill would help in overcoming certain situations. For the prototype, as it didn't reach a more advanced part of the story, there's no interaction between skills and gameplay.

**Elements**. Two additional elements were created, additional to the skills, symbiosis and reputation. Symbiosis signifies the connection between the player's character, their Estimmo and nature. Estimmos, as magical wolf-like creatures, have a mysterious past, connected to nature and a forest inside the region, to be revealed later in the game. The better the player treats their companion and other Estimmos, the better the relationship, affecting the ability of the player to proceed in the narrative. The second element is Reputation, referring to the reputation the character has towards the ethnic group Secondo. The better the dialogue choices, as well as the number of quests related to Secondo issues completed, the higher this indicator. To advance to certain main and secondary quests, the player needs to reach a minimum level.

**Societies**. The city has, available to the player, three societies. Each is focused on specific professions: SoMe (Society of Medicine), SES (Society of Herbs and Culinary arts) and SEM (Society of Engineering and Maintenance). These societies, not available in the prototype, provide the players with a system built to connect educational content with real life problem solving. Each society has different quests that pose challenges related to professions and allow the player to rise in the ranks as a citizen.

**Rank**. The citizens of Liber Domus have a class system, which affects the privileges which they are bestowed upon. A citizen, at the age of eleven-years-old, becomes an Apprentice (Level 1). By proving enough knowledge, they can reach the rank of Cita Juni (Level 2), which gives access to Societies. Following ranks provide additional changes to skills and allow for further advancement of the narrative.

**Equipment.** The player can equip six different types of equipment on the character, one for each part of the body (head, torso, legs, feet, hands, and shoulders). As in the remaining mechanisms, information and characteristics about equipment is always connected to the story, assuring continuity. Equipment helps to provide a game feature that can assist the player with immersive feel and connection to the character. It also provides additional skills and impacts other aspects of the game, including quests. In the prototype the player can equip one specific piece of equipment, the "Laço", which is a piece of fabric that symbolises the connection between citizen and Estimmo and increases Charisma skill by 5 points.

## 3 Educational Structure and Development Plan for Prototyping

Having established the goal and the general structure including the game dimensions and mechanisms to be applied, it was defined the structure of the team that would work on the several technical and educational objectives established, as well as the tools to be used for implementation of a prototype.

Discussion between all parties involved lead to the conclusion that the prototype would require a game designer, an educational expert, and programmers, with coordination being shared between both Schools (ESE and ESMAD).

For technical development, it was determined that the tool to be used for such implementation was Unity 3D, which uses the C# object-oriented programming language and a game engine which enables a faster and more practical implementation of 3D elements and game development. Using the guidelines established previously, the group determined that the prototype should be developed until July 2021.

## 2.1 Educational Contents & Objectives

As the prototype focused on the development of all systems necessary for the implementation of the game mechanisms considered necessary, the quests focused on the initial, early stages of the game. As the game is meant to follow a curricular year-long learning of Mathematics and Science, it was considered ideal to concentrate on four initial topics of mathematics according to the Essential Learning Objectives [19]. These are:

- To add, subtract, multiply and divide rational non-negative numbers by using mental calculus and algorithms as well as plausible estimations;
- Describe shapes in a 2D plane and in space, based on their properties and the relationships between their elements, including classification;
- Calculate perimeters and areas of 2D shapes, including circle.

Inside these three learning objectives, four specific topics were selected: Angles, 2D shapes identification and basic perimeters and area calculations, mental calculus to calculate mathematical expressions and division.

To support the learning of the student and their ability to complete quests related to these subjects, three support or help systems were designed, through the companion (providing small explanations of the subjects and hints), a question mark button next to each game interface providing full explanation, and through dialogue prior to the quest, including encouragement.

## 4   Current Outcomes and Further Development

A prototype was successfully built and delivered on the 30th of June, 2021. Despite the novel characteristics and innovative framework for the educational context, it was possible to create a large-scale 3D environment, a user interface with character portraits, gameplay mechanisms such as skills, equipment, items, three game scenes and five initial quests, including 4 different game interfaces, related to the tutorial and the initial part of the mathematics curriculum for the 6th grade for the Portuguese Education System, successfully creating a RPG with educational purposes and content. The project's outcomes can be summarized as follows.

### 4.1   Introductory Stage

The first quest is presented to the player after an initial three-minute-long video using several drawings in a montage informing about the backstory of the game. The intention of this video, which was accompanied by music, was to introduce the player to the narrative setting and game world which would be presented afterwards. The montage of images (example in Fig.2) depicts a city and a group of people, appearing to be arguing, concerned about an army in their doorstep. Some of those people appear to be able to escape by boat, carrying books, right before the city is seen burning. This unknown group of people go through an exodus of sorts, facing several terrains and adversities. One night, camping during heavy snowfall, a child is seen

being held by the mother near a campfire. The child looks at a light and leaves the mother, deciding to follow the light. The entire group follows the child and find him sleeping cuddled with a wolf-like creature under an oak. The group makes camp near the inside of a clearing and explore the newfound location, eventually settling on top of the central mesa structure and building the city of Liber Domus, where a child is born alongside a newborn wolf creature similar to the initial one and several others inside a room.



**Fig. 2.** One of the 49 Illustrations in the initial backstory

The game then shows a small ten second cutscene showing the house and zooms in a character standing next to a bed. A message appears explaining that the player's character woke up late from playing the day before and is late to go celebrate a festival that's ongoing in the city's forum.

The game starts with a dialogue between the Estimmo and the player. The companion warns the player that he/she needs to hurry. Several notifications, timed between 3-5 seconds explain how the player can move through the 3D environment as well as interact with objects and characters. Further information is provided when the player accesses the user interface (UI) using the keyboard key "I" (Fig.3).



**Fig. 3.** User Interface (UI)

**Tutorial Quest – "Primeiros Passos".** As observed in Fig. 4, When the player moves to the ground floor a waypoint becomes visible, pointing to a character. As the player interacts with that character (the character's mother), they engage in dialogue, each leading to different dialogue options and consequences. The second interaction provides the quest "Primeiros Passos" (player is also notified), being instructed by the mother to find an item "Laço", which is required for the player to equip. The quests objectives can be seen by accessing the UI.



**Fig. 4.** Arrow in grey next to the character "waypoint" and quest name indication above it. Dialogue then determines delivery of quest, the player then receiving a quest notification. Quest details including objectives and rewards can be observed.

The player is also informed of the existence of a mini-map object that will help guide in the correct direction. The player then finds the "Laço" and equips it as instructed. All the steps in this quest are identified in Fig. 5 and supported by indications through arrows and notifications to get the player familiar with the functionalities of the gameplay.



**Fig. 5.** Mini-map object with icons to identify locations of interest, location of the item in the 3D environment and instructions to the player.

Once the quest is completed, the player is allowed to exit the house, now accompanied by his companion. As soon as the player leaves the house, instructed to head to the city Forum, a final instruction appears, informing that, if the player selects the companion, can receive information about any active quest, including educational information.

**User Interface (UI).** The player has access to, at any point, a series of support and information systems for gameplay. In specific, as seen in Fig.6, the player can observe and, regarding inventory, interact with this component for certain purposes.

**Fig. 6.** User Interface details

Quest Information menu (1) – Each quest delivered and accepted by the player (acceptance is not always an option) has specific information which is provided inside this section, such as quest objectives and rewards available. Inside this sub-menu it's also possible to access the Achievement menu. This menu allows for observation of completed quests.

Inventory Menu (2) – All items that can be gathered by, gifted to or bought by the player are placed inside this menu. Equipment items can be placed in the equipment slots (5). Fast consumption items, which are used to recover energy, can be placed inside the three available slots (6). Inside it there are also stored books and other temporary or permanent items gifted to the player.

Map Menu (3). Each location has a specific map associated so that the player can understand the general locations inside the game as well as their position.

Skills Menu (4). This menu provides a summarized view of all the character's skill points as well as the name, rank and two additional gameplay elements (reputation and symbiosis). At the bottom of the menu the energy levels can be seen.

Inside the 3D environment (also referred to as "game world"), the UI assumes a different format, as seen in Fig.7, with the mini-map (7) in constant display and updated as the player moves.



**Fig. 7.** User Interface details

Below the fast-consumption items the player can find the Stamina bar (8) – Stamina is used every time a player starts (or restarts) a quest, removing two points

for main quests (the exception being the first four quests in the game after the tutorial which only require one point), one point for optional quests and no stamina required for recovery quests. It's removed automatically as soon as a quest is given or accepted by the player, and also when the player loses a quest which will be forced to restart (regarding optional quests the stamina will be removed even if the player does not try again. However, it won't be removed again if, and when, the player decides to try. Stamina can be recovered by consumption of one of three fast-consumption items (only one was implemented as the remaining two are expected to be introduced into the game later in the narrative), which resemble or mimic food, in specific apples. Consumption of an apple allows the player to recover two points of stamina. These items are received as rewards when quests are completed and can also be bought by the player in an in-game store, exchanging currency (also a reward) for these items.

The player's portrait (9) is accompanied by the rank (10), on the bottom left side of the screen. The player portrait changes expression, as well as the NPC portraits, according to the emotion they want to transmit.

**Companion System.** The companion system, delivered through the Estimmo as seen in Fig.8, allows the player to have an NPC to which an emotional attachment is to be expected and also a help system since, if the player selects it when there's an active quest ongoing, the companion can provide full information about the related educational contents.



**Fig. 8.** The Estimmo. The player companion.

**Dialogue Interaction with the "Katua brothers".** As the player makes its way to the city's forum, there's an unavoidable interaction between the main character and two young brothers, both with a different appearance and clothing. The interaction was designed to give, in each player interaction, three dialogue choices, with correspondent answers by the NPC. It's quickly identified by the player that these brothers are from a different group or ethnicity (at that stage it is purportedly unclear). At the end of all the dialogue interactions, which do not affect the player's following quests directly, a notification appears discussing how the player's dialogue choices affect the "Reputation".

**Forum Quests.** As the player arrives at the Forum, an NPC informs there is four games to be played as part of the celebrations, each delivered by a Master of Mathematics. The four locations are spread around the forum. It is up to the player which quest they want to do first. The quests are not repeatable at this point, but all the questions placed to the player inside the quest are randomized from a pool of potential questions, making each game iteration different.

**Quest "Rings".** This quest, as seen in the Fig.9 gives the player the chance to get 5 answers right by tossing the ring to the right log if they get the angle and strength levels correctly. Three wrong answers force the player to restart.
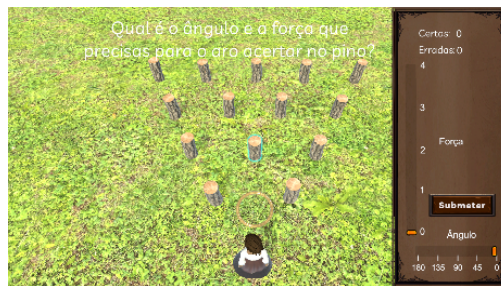


**Fig. 9.** Rings Game Environment

**Quest "Bridge".** This quest (Fig.10) was designed to motivate players to quickly learn how to identify which numbers, when divided by three, result in a whole number. If the player tries to cross the bridge by stepping in a slab with the wrong number, they fall and if they fall three times they must restart.



**Fig. 10.** Bridge Game Environment

**Quest "Balloons".** The quest seen in (Fig. 11) shows several 2D geometric figures by using lines and balloons placed on top of those. The player needs to use darts to shoot at the right balloons according to the name of the figure placed above the board. If they fail one or more balloons, it is considered a wrong answer and if they fail three times, are forced to restart.
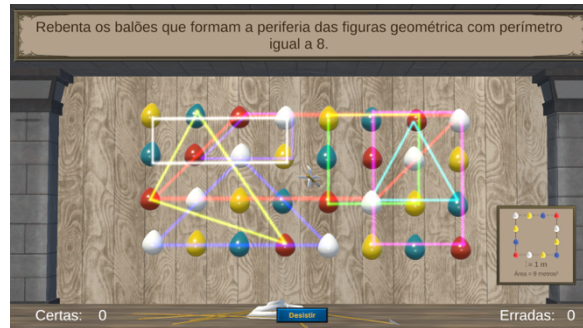
**Fig. 11.** Balloons Game Environment

**Quest "Vases".** This quest challenges the player to pick up and deliver 12 vases, spread around the forum (Fig. 12). Each time the player delivers a vase, they must answer a question regarding mathematical expressions. If they fail, the vase goes back to the same location. This quest has a time limit of 15 minutes. There is no limit to the number of times a player can fail an answer.



**Fig. 12.** Delivery of vase and consequent question.

## 4.2 Preliminary Results

Exploratory research was conducted, during the months of May and June of 2022, in three different classrooms of an elementary (2nd basic level of education) school in the Porto district of Portugal, with, among those, 30 randomly selected students participating as active players and divided into focus groups. The players had access to a beta version, allowing them to experience the game as it was displayed in this article, and were asked to complete the four initial quests of the game, including the mathematical challenges it included.

Preliminary results indicate that children enjoy the opportunity to learn mathematics through a game and that it was fun to do revisions through the game. Comments were particularly focused on the "play" aspect of learning and the higher levels of interaction, dynamics and challenging they can obtain from the game, rather than doing traditional exercises. There was some indication of frustration when the player couldn't finish the quest, but most were eager to try again, giving some indication that motivation levels remain high even in failure. It was detected some difficulty in usage by students with less game experience, mainly in regard to controls and gameplay. There were comments to gameplay aspects deemed relevant such as the inability, inside the quest system, to repeat certain tasks to reinforce a certain topic.

These results were obtained in classroom environment and students indicated they feel like these games should be played in this context, to maintain the support and help from teachers in case they can't progress, with students and teachers alike voicing that classroom dynamics were substantially different, more positive, and interactive, than in traditional lessons. Although these results are still in early stages and quantitative outcomes must be identified, it appears as the use of this type of role-playing game might have a place in the students learning process.

## 5 Discussion & Conclusions

The prototype delivered represents the work possible in the time proposed. In total, consists of a game-like environment, with tutorial and four initial quests, inside an open explorable fantasy-like 3D environment which is enveloped inside a narrative that permeates into all aspects of the game. There were multiple objectives to this development, such as to create an educational game that did not provide students with the notion of it being simply a new way of studying but instead a game where they would learn useful, practical and game-related contents. It was also aimed to provide students with a tool that could increase intrinsic motivation to study and while studying, as to hopefully improve their learning outcomes from autonomous study sessions. We believe that, although certain outcomes can only be identified later one, the main objective was successful and presents an interesting opportunity to focus on the development of such GBL solutions resembling typical digital games and that, as such, might provide an alternative to current solutions.

Development has continued after the prototype delivery, through the formation of a private legal entity consisting of the team that worked during the prototype as initial feedback from students and teachers has been very positive. At the date of this paper, although there are no quantitative studies delivered on the outcomes, focus groups have been implemented in three different classrooms with preliminary outcomes pointing to positive feedback regarding the usefulness of the game as both a way of improving motivation and fun levels but also to assist with revisions and studying. Additionally, more than 600 current users playing beta versions of the game. Full game delivery is expected by September of 2022.

Further testing should be done to identify if there are long-term positive outcomes of playing Liber Domus as it was designed as a full-curricular educational support for Mathematics and Science for the student to play throughout the school year. There are active concerns regarding possible repetition of mechanisms creating negative effects on motivation, as well as the number of quests necessary to provide the students with enough content for such a long period of time. The usefulness of the game as a learning support tool will also be tested, as the quest system means the player cannot repeat quests unless a new game is started, and the helps provided along the quest execution might not be enough both in terms of repetition and memorization necessary. To prevent that, the full game will feature books, the option to repeat certain quests and the access to all previous educational content through the companion.

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