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Towards an Iterative Design for Serious Games

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Abstract: The design and development of Serious Games is a complex task, including a considerable risk of failure. Many attempts end up in non-fun, non-engaging games that fail to meet the purpose of improving education. Many different proposals have been published in the form of design frameworks, with the aim of helping practitioners succeed. Although these frameworks define and explain relevant concepts and guidelines, there is lack of focus in iterative methodologies. These methodologies have proven valuable in other areas on engineering and are also used by commercial game designers. This work proposes the introduction of iterative design for Serious Games and presents an early stage methodology, along with an example of the core mechanic of a game and a prototype for learning the concept of slope of a line.

Keywords: serious games; education; game design; games; iterative methodologies

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1. Introduction

This work proposes an iterative methodology to help practitioners in the design and development of Serious Games. It is intended mainly for educators, who usually need more knowledge and experience on game design. It focuses on short, iterative cycles of design, test, evaluation, and redesign. These cycles start from simple, clear, and direct game mechanics as basic building blocks. Game context design is delayed until core game mechanics have been tested and validated through measures of players enjoyment and educational meaning.

The aim is bringing the experience from commercial game designers. As they state in their works, the path to acquiring experience is by creating and evaluating many designs, and iterating over them repeatedly until the resulting games meet desired criteria [1–3]. Commercial game designers also acknowledge the usefulness of iterating over their designs to achieve high-quality products. Therefore, this work is a first proposal to bring this knowledge to educators, as well as helping them in gaining game design experience through iteration.

Since the first use of the term Serious Game by Clark Abt in 1970 [4], there have been cyclic ups and downs in the interest of using games for teaching and training purposes. However, the last two decades have shown a much greater rise in the interest in the field, parallel to the growth of commercial video games as one of the main forms of entertainment. This interest has attracted many educators. Commercial video games have shown a great potential for captivating student attention. However, this task has proven difficult in the educational environment. This difficulty comes from a similar nature to other kinds of intellectual content, be it movies, books, shows, or even classroom lessons and educative materials. There seems to be an intrinsic artistic and temporal component which is required to be high-quality modeled to obtain the pretended attractiveness.

Based on years of experience in game development, there are some important characteristics and design guidelines to produce a successful Serious Game [5]. However, experience also tells that this knowledge is not enough. Experience designing and evaluating Serious Games is necessary to create successful products. A high-quality Serious Game is mainly created after two important processes: the educational design, and the game design. Although they abstractly share many parts in common, they are sufficiently different to produce an important problem on Serious Game development: educators generally fail on designing games, and game designers fail on introducing proper educative content. Achieving an appropriate equilibrium requires enough experience on both fields.

To target this problem, many authors have proposed frameworks and methodologies for designing Serious Games [6–19]. Proposals focus on defining dimensions and characteristics to be designed, along with series of steps to follow. All these proposals are valuable and introduce practitioners into the view of the relevant parts and characteristics of games. However, there are two relevant aspects that require more consideration. First, practitioners often require a path to gain design experience. Acquiring experience requires creating several designs for different contexts. This is better achieved by designing small products, as they require less time and are easier to analyze and learn from. Therefore, it is important to guide practitioners to start designing as small as possible. Frameworks are generally focused on Serious Games as complete products that often require many months of development. Second, designing games requires rapid prototyping, testing and redesign. A high-quality product is generally the outcome of many iterations of the design-prototype-test-repeat cycle. Framework proposals generally lack enough focus on this part, which might be a reason for many important failures on Serious Game design. Starting very small helps performing many prototyping iterations, which is of great help for a better quality outcome.

Besides helping to overcome these problems, present proposal also encourages using the concept of core game mechanics. Since the work of Reference [6], many authors propose mechanics as building blocks for game design. However, they seldom discuss how many mechanics should a game include, or the difference in importance between them. This proposal encourages authors to start focusing on a single game mechanic, which will be called core game mechanic. This approach drives practitioners to focus their attention on the principal interaction between the user and the game, rather than on additional things, like points, badges, or leader boards.

Section 2 present a brief state of the art on frameworks for Serious Game Design and some considerations on education methods to use on games. Section 3 discusses all the details of this proposal. Section 4 presents Slope Shooter, an example game designed following the proposed iterative methodology. Section 5 shows the results of preliminary tests of Slope Shooter. Finally, Section 6 summarizes conclusions of this work.

2. State of the Art

Aligned with the main purpose of this paper, it seems reasonable to consider that modern frameworks and methodologies for designing and developing Serious Games. Therefore, this section focuses on a representative selection of papers describing most relevant modern frameworks on the field, from our perspective as authors. The works are presented in chronological order, to discuss their different proposals, ideas and innovations. For each presented work, we include our analysis on strengths and weaknesses, as well as its consideration or lack of iterative workflow.

In our consideration, modern frameworks started with Hunicke et al. [6]. Their work presented the classic Mechanics, Dynamics Aesthetics (MDA) framework. This framework is amongst the most influential in literature, establishing the separation between building blocks (Mechanics), composition of these blocks and interactions (Dynamics), and contextualization of resultant tasks for the players (Aesthetics). Although Hunicke et al. specifically mention the importance of iterative analyses and refinement of results, their proposal still focuses on products too big for rapid iteration (Babysitting game, Nickelodeon's Rugrats game, military simulation). Despite this fact, our proposal builds on these MDA components, as they have proven to be effective and useful concepts in many subsequent literature works.

Kiili [8] presented a framework called The Experiential Gaming Model (EGM). This framework owes his name to experiential learning theory and the flow theory [20]. This framework focuses on immediate feedback to the player, challenges, and the design of progression through difficulty matching between tasks and the learner. It also stresses the importance of Game Design and the impact of the limited size of the working memory of the brain on playing and learning [21]. This implies that usability is extremely relevant, and supports the idea that simpler game mechanics may be better, as they fit better in the working memory. Our proposal incorporates this knowledge in the concept of core game mechanics. The main weakness of this framework rely on its concepts being high-level mental constructs, which require previous knowledge and experience to be put into practice. There is no step-by-step path to start from small mechanics and grow designs to address these mental concepts. Moreover, the framework does not take into account iterative development.

de Freitas et al. [7,9,10,14,16,17] proposed and evaluated their four dimensional framework in several different projects. This framework summarizes on a high-level concepts representation on its four dimensions: Representation, Context, Pedagogy, and Learner. Although this has been a highly influential framework, similar to Hunicke et al., it may drive practitioners to think of Serious Games as big projects, due to its high-level conceptual focus. Moreover, although it mentions iterative development, it does not specifically address it, implicitly focusing practitioners on their Serious Games as whole products. A low-level step-by-step approach would be much desirable to complement this framework. Our proposal, centered on core game mechanics, could be used as low-level approach to complement this framework.

Amory [11] presented his Game Object Model (GOM) II, as an extension of his previous GOM [22]. This framework inherits from object-oriented programming proposing an engineering-driven approach. It relies on many individual concepts, emphasizing fun, drama, goals, competition, practice, critical thinking, play, exploration, challenges, and engagement, deriving from historic game designers' experience, like Crawford [1] or Lindley [23]. These concepts are categorized into spaces and sub-spaces. All concepts and spaces are formally defined, and the processes are systematized. Although the formal approach in this framework is valuable, it is difficult to understand and use, which has probably limited its expansion and use. Moreover, it also lacks an iterative development cycle and focuses on complete products rather than on small components and a step-by-step growing approach.

Ibrahim and Jaafar [13] relied on previous literature on good games firstly proposed by Gee [24,25] and advocated in favor of solid Game Design principles, supporting Hirumi and Staleton's argument [26]: "leaving Game Design tasks to educators and instructional designers may result in neither fun, nor engaging games". Based on this, they proposed their Educational Games (EG) design framework with three dimensions for Serious Game design: Pedagogy, Learning Content Modeling, and Game Design. Similar to other authors, they did not consider any iterative model of developing, nor the need for practitioners to repeat many designs to learn. The model also focused on high-level goals for the final product, but lacked low-level details on how to start from small steps, growing the product until it finally contains all desired learning content. However, our proposal considers their valuable advice on how to tackle Game Design. They stated that Game Design is difficult and usually underestimated by educators, leading to Serious Games that are not considered as Games by their target audience, nor played with the same interest, diluting their educative value. This implies a need for educators willing to design Serious Games to develop a solid ground base on Game Design, and our proposal aims to help in this need.

Aleven et al. [15] proposed a framework (ADEG) based on "heuristics" for guidance and three components: learning objectives, MDA [6], and Instructional Design Principles. They also referred to the concept of core-mechanic in a similar sense to the present proposal:

they designed a game called Zombie Division, in which the player has to defeat numbered zombies with numbered weapons. To defeat a Zombie, the weapon number used must be a divisor of the zombie number. This main mechanic (core) requires the player to constantly use the concept of divisor. Although this mechanic seems forced, and it might present difficulties for the user in terms of fun and engagement, it is the main interaction between the player and the game. This is the concept of core mechanic we propose in this work. Similar to previous frameworks, the proposal from Aleven et al. do not consider iterative development, nor give it steps for low-level mechanics design.

Ahmad et al. [27] reviewed many other frameworks with similar characteristics, including References [12,18,19,28]. Most of them rely on previously analyzed ones, with different variations. Some others are more broad or general proposals, or examples of use of previous ones. However, in all cases reviewed in literature, this work did not found a single framework directly focusing an iterative design cycle. Additionally, there was very little focus on how to start developing a game from scratch. Taking into account that a Serious Game could be a very big software product, it is highly relevant to provide series of small steps, iterative cycles, and a path to grow from small solid components development to greater parts and, finally, the whole game. Our proposal represents a first step towards providing all these knowledge to practitioners.

Table 1 summarizes all frameworks analyzed in this work, highlighting the strengths and weaknesses identified in relation to the aims of this proposal. This table helps in having a general big picture of this state of the art.

Table 1. Summary of considered frameworks. Strengths and weaknesses are relative to this proposal.

Authors	Model	Strengths	Weaknesess
Hunicke et al. (2004)	MDA	- Defines basic Game Design concepts - Mechanics, Dynamics, Aesthetics	- No step-by-step design path - Non-iterative
Kiili, K. (2005)	EGM	- Experiential Learning Theory-based - Considers brain's working memory	- High-level concepts only - No step-by-step design path - Non-iterative
de Freitas, S. et al. (2005, 2006, 2009)	4-dimensional	- Considers Pedagogy as a dimension - Human-Centered Design Theory-based	- High-level concepts only - Focus on commercial products - Non-iterative
Amory, Alan (2007)	GOM II	- Object-Oriented engineering approach - Based on renowed designers' experience - Formal approach: concepts and spaces	- Complex to understand/apply - Non-iterative
Ibrahim, R et al. (2009)	EG 3-dimensions	- Pedagogy and learning focus - Professional Game Design considerations - Considers how to train educators	- High-level concepts only - Non-iterative
Aleven V. et al. (2010)	ADEG	- Heuristics and guidance on Game Design - Based on Instructional Design Principles - Example with focus on Core Mechanics	- High-level concepts only - Non-iterative
Zin, N.A.M. et al. (2009) Malliarakis, C. et al. (2014) Lamprinou, D. et al. (2015)	Several proposals	- Rely on previous proposals - Similar strengths, depending on variations	- Mostly High-level only - Focus on commercial products - Non-iterative

3. Iterative Methodology for Serious Games Design

This methodology starts with the educational part, defining the concepts to be taught, and then using them as building blocks for the Game Design. As previously stated, the main aim is to bring commercial game designers' experience to educators. Therefore, this work focuses on the Game Design part right after the selection of the concepts to be taught. Figure 1 summarizes main educative parts at the top, and Game Design parts at the bottom. The Game Design part is divided in three stages: designing game mechanics, defining the game rules and interactions (Dynamics), and integrating all the elements in a gaming context (Aesthetics), following Hunicke et al. MDA concepts [6]. For this first step of our proposal, only the design of game mechanics is considered. This is the part where the basic, most important building blocks of the game should be produced: the core game mechanics.

This iterative model follows a design-and-testing cycle, where each step should ensure validity both from educative and ludic-playable perspective. Any element of the design that does not pass the validation should be re-designed until a desirable result is obtained. This follows a "fail hard, fail fast" philosophy for rapid prototyping and learning from design failures. The main advantage of this approach is that, when a stage of the game is being developed, the previous ones are already validated, so the development is being done on a solid basis. However, it requires to iteratively re-design or even discard failed prototypes. Therefore, to be acceptable, design and development steps have to be maintained small, to balance the complete development workload. This is exactly what commercial game designers propose, as stated before. The approach is based on designing as small as possible first, in order to produce as many prototypes in as less time as possible. Then, as the project evolves, confidence on previous designs rises, steps can become larger and the number of iterations reduced, accelerating development while maintaining an acceptable workload.

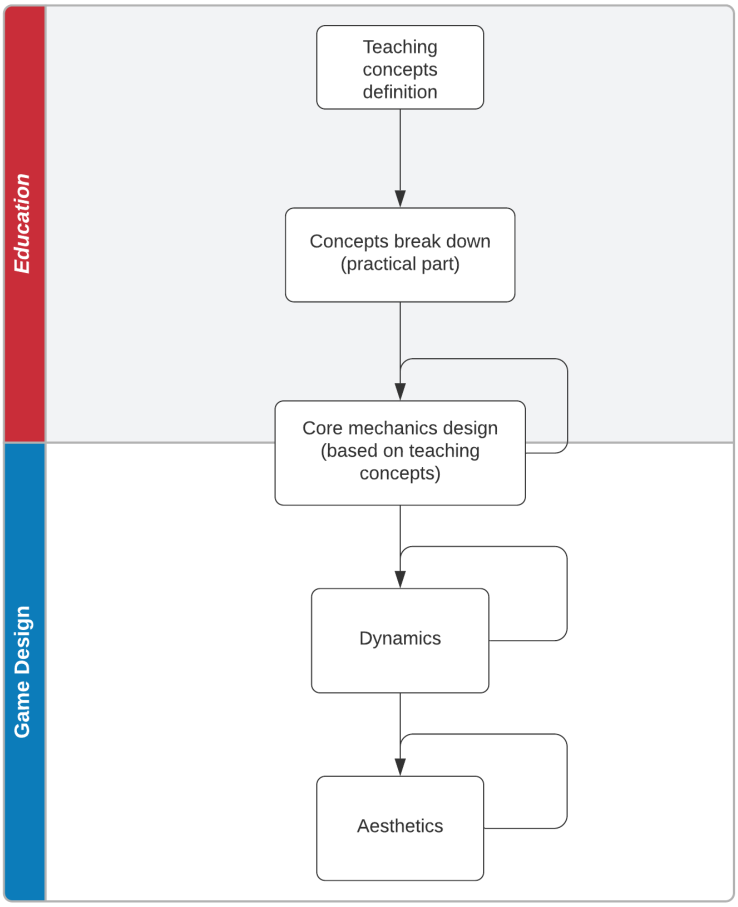

Figure 1. General iterative methodology diagram.

The first step in the educative part of the process consists in determining the pedagogical concepts that the game should teach, and focusing in their practical part. Video games are inherently practical, like sports, and so their main educative potential resides on developing skills. That is exactly how the practical part of a subject is taught: skills are developed by practicing. Henceforth, selected concepts to be taught should be considered or designed from the practical point of view, as a way to acquire and master them as skills. Once the concepts to be taught have been identified, they should be broken down as much as possible, and then converted into core game mechanics.

A core game mechanic is the essential form of interaction between a player and the game. This is, an activity that the player will be doing over and over again as a way to play the game. For instance, in a platformer game, like Super Mario Bros., jumping is a core game mechanic: the player needs perform and control jumping all over the game, from the first level to its end. As this is constantly performed by the player, mastering this core mechanic is needed to advance in the game. Therefore, core game mechanics define skills that the player will necessarily improve. This reasoning implies that converting selected concepts to be taught into core game mechanics is an effective way to enforce mastery of desired concepts by players willing to win the game.

After selecting and breaking down concepts to be taught, effectively defining these core game mechanics is the main focus of this proposal. The iterative process for these design phase is shown in Figure 2. Initially, the designing team produces a series of core game mechanic ideas on brainstorming sessions. From these ideas, those most suitable according to designing team's criteria are considered and the best of them is validated to start creating a prototype. For those teams lacking design experience, it is advisable to define some basic educative and ludic criteria to be met. However, it is important to take in mind that, at this early step in the design process, criteria should be broad and simple to let many different ideas be explored, as well as to account for the inherent uncertainty on their actual results until tested. After some brainstorming sessions, a game prototype is created based on the chosen mechanic. The prototype is exposed to teachers and students, along with a survey, so feedback can be obtained in order to have a preliminary evaluation on the potential of the mechanic. If the feedback determines that the mechanic is not fun enough or has no potential to develop skills related to its related educational concept, then the idea should return to brainstorming.

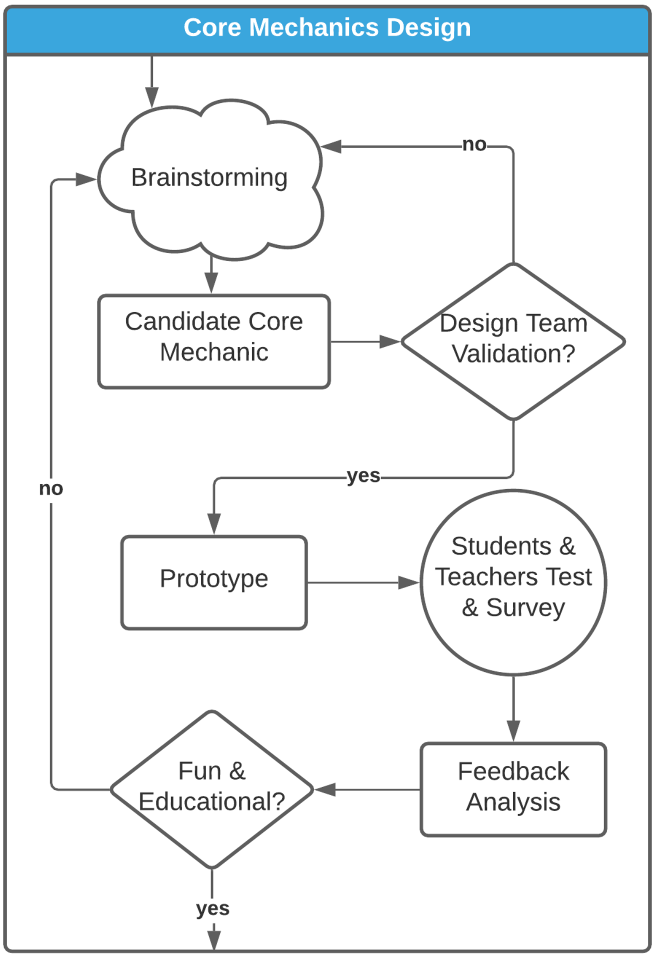

Figure 2. Mechanics design diagram.

In a second brainstorming pass, there are two possibilities: discarding the failed prototype and associated core mechanic design, or redesigning it. To choose between these two options, qualitative feedback in the survey might be useful. Potential new ideas or changes can be proposed by testers and should be taken into account. Additionally, the design team could use their intuition to explore if there is room for changes that could improve the idea enough. However, at this stage of the design process, the most valuable approach is to directly discard failed designs and start over again with different ideas. Practitioners should take into account that exploring different ideas helps gaining design experience and improving probability of designing better mechanics. Moreover, it is an advisable approach to escape from personal design biases that tend to appear. At this stage, the costs of abandoning ideas are very low, and the "fail hard, fail fast" approach usually yields better long-term outcomes.

The game design essentially consists in defining several game mechanics, then developing them to achieve more fun and variety, and finally integrate everything into a fantasy context. Following the Super Mario Bro example, with jumping as core mechanic, the game also includes some other mechanics, like walk, run, or shoot, and jumping is also used to kill enemies and breaking blocks (Dynamics). Finally, everything is integrated in a fantasy world, where the main character is a plumber that has to run and jump, over and over, in order to rescue a princess (Aesthetics).

When designing core game mechanics, it should be noted that it must allow players to improve their skills in a progressive way. For this purpose, it is advisable to think of the mechanic in terms of its performance dimensions. For instance, the jumping mechanic has a main spatial dimension which lets the player control the character on a continuous 2D movement space. This produces a virtually infinite space of possible movements and experiences associated. It makes this mechanic share similarities with hitting a soccer ball and controlling its trajectory. The player has a technically infinite learning space, in the sense that there is always new, different and potentially better ways of controlling the movement of the character. Designs meeting this continuous decision space criteria fall into the category of "simple to understand, but difficult to master", which is a recognized characteristic of good games [5,24,25,29].

Another common way to produce a continuous space for player outcomes is by adding a time dimension. This is seen in games, like awarded Nintendo's Brain Training, when they used a simple game mechanic such us solving basic maths operations (in which outputs are on the discrete space of success or failure), but they added the simple restriction of solving twenty operations in the minimum amount of time possible. This simple addition produces a virtually infinite space for outcomes, along with a new reality, where any result is potentially improvable. In our previous Super Mario Bros. example, the time constraint is also present, as the player can also compete to pass levels taking as less time as possible (in fact, this is the basis of a modern competition category called Speed Running).

Once the mechanics are defined, it is time to design the dynamics. Here, the different possibilities that the mechanics offer should be studied, as well as how they can interact with the player and other game elements. The dynamics should make the game more fun and engaging. Moreover, having several mechanics based on a teaching concept and presenting them in different ways will help students to abstract the knowledge that is being taught. If the same mechanic is presented over and over again to teach a concept, then the player may end up associating the concept with a the concrete use case of the mechanic. But, if one concept is presented within different mechanics, the student will need to develop a mental model based on the abstraction of the concept, which is common to all the mechanics.

The final step is to integrate the designed mechanics and dynamics into a fantasy context. As the MDA framework states: "aesthetics describes the desirable emotional responses evoked in the player, when she interacts with the game system". Here, elements that motivate the student to play the game, such as narrative, competition, challenge, expression, curiosity, sense-pleasure (like audio-visual effects), etc., should be included. Furthermore, similarly to previous discussion with mechanics, if the teaching concepts are presented within different contexts, players may develop a better abstraction of the concept, based on the need to associate it within all the contexts.

The iterative design-and-testing cycle has been followed at every phase of the game design described before. In addition to surveys, feedback can also be obtained by integrating analytical data collection in the prototypes, such as the time the user spent playing, the score they got, or where they have difficulties, along with many others. By following this model, the different iterations and validations proposed should increase the probability of a final product which is more entertaining, fun, and better suited to teach selected concepts.

In order to exemplify the application of this proposal, Section 4 shows an example core game mechanic designed following this iterative model.

4. Slope Shooter: Example Game on Learning the Slope Concept

To test and exemplify the proposed iterative methodology, the game Slope Shooter is presented. This Serious Game is currently being designed and developed along with the proposed methodology. This section explains the design and development process followed, along with the first three prototypes produced. These are prototypes centered on the core mechanic of the game: using the concept of slope of a line to aim and shot.

As proposed in Section 3, Figures 1 and 2, the first step is determining the teaching concepts. Basic Algebra has been selected for Slope Shooter because the development team teaches Maths in first year at the University, and the goal is testing and using the resulting game with students. Moreover, as suggested in the methodology, it is advisable to start with basic and small concepts to get simple, clear and testable prototypes.

Following Figure 1, the team started with several brainstorming sessions. In these sessions, distinct concepts such us matrix multiplication, steps from Gauss-Jordan reduction, linear equations manipulation or vector operations were considered. Similar ideas to Nintendo's brain training were considered with this concepts, along with other ideas, like magical combats based on arithmetic operations with proposed concepts. All of them were discarded in the first loop by the development team because they were either too complex, unclear, too broad, or too big for a staring core mechanic. Considered criteria were to start with a core mechanic that was simple, clear, easy to prototype and test and, most important, fast paced when played, focused on visualizing abstract concepts, and embedded on a continuous decision space defined by the outcome values of time and precision.

After some brainstorming sessions, selected core mechanic was using the slope of a line as a way to aim and shot. The player simply types-in a value for the slope and a line appears. When the player hits enter, a shot is produce following the slope line. This simple mechanic can be performed in seconds, repeated many times on a single game, and even used in different ways (the shot can be a laser, a ball, a bungee, etc.). Moreover, it helps associating a real value with a line, which could be used to develop intuition about slopes. As this met proposed criteria, the concept was considered enough to start designing core mechanic prototypes that can be further developed to obtain valuable dynamics for the game. Figure 2 shows the process of mechanics design using the presented iterative model.

The path that was followed to produce this slope game mechanic started by looking at the exercises students were already solving in the subject. They were given lines drawn in a Cartesian coordinate system, and they had to identify the number representing the slope. First mechanic ideas were as simple as reproducing this exercise in a virtual environment an playing around with it. The idea is to base design in actual exercises to maintain the educative value when designing the game mechanic. If the exercises are useful to teach the concept, then the core mechanic should be expected to be also useful.

Literally translating exercise mechanics into proposed core mechanic does not seem to constitute the basis for an entertaining game. So, there is the need to iterate on this idea, and to explore more possibilities to transform it into a challenging and entertaining mechanic. For example: lines do appear on a board one by one, in short periods of time, and the player has to identify their slope before they disappear. This simple twist increases dynamism and challenge, by introducing time and pressure. Moreover, precision can also be added assessing answers based on their proximity of to the correct solution. These changes exploit video game potential over classical exercises: failure is a natural part of the activity, and fast-paced trial and error with instant feedback help developing the skill of being better at approximating slopes.

Proposed changes represent an improvement but there still is a problem with this design: the player is not performing any purposeful action. The player is just identifying lines. A simple additional twist would be to use the line of the slope a aiming for shooting. For example, when the player writes a slope, a shot can be fired following the trajectory defined by its character's position and the slope. The goal can then change to shooting targets, which can be static or moving. In addition, the damage inflicted to targets hit, and the score the player gets, could be based on the accuracy, balancing time, and performance. This design opens up more possibilities:

- Several targets could be shown at the same time (and also several player characters).
- Targets could be enemies with the ability to shoot, so the player can see the slope of the line they will fire (the number), and then draw the line corresponding to such slope in order to neutralize the attack. So, reverse mechanics can be practiced in this way.
- The difficulty can be easily scaled by activating some visual helpers, like a grid for Cartesian coordinates, a laser pointer for previewing the line before shooting, or showing the exact coordinates of the targets.
- Different target types with varying sizes, velocities, strengths, and even capabilities can be designed.

This design was implemented as a prototype, and this step was iterated three times, producing three prototypes. The three prototypes are available for testing (at https://archive.org/details/ua-algebra-prototype, accessed on 8 March 2021). The prototypes show a Cartesian coordinate system and the main character at its origin. There is a text box to introduce slopes (as real numbers, ratios, or expressions). To help the user to understand the concept, the process is divided into aiming and shooting. When a slope is written, a laser pointer shown. When enter key is pressed, the shot is fired. Only one target is shown at a time, and targets do not move or fire. Figure 3 shows a screenshot of this prototype.

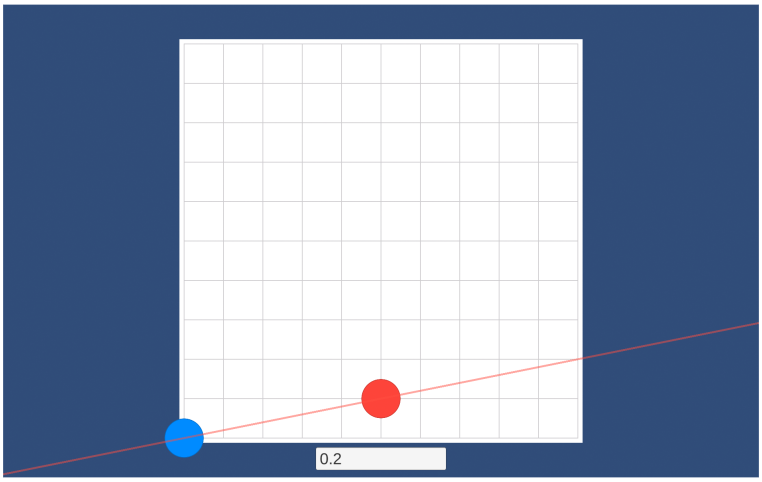

Figure 3. First prototype. Player is aiming at a target.

Two more versions of the prototype have been created in order to be tested: one giving feedback about the accuracy of each shot, and the other introducing a time limit. So, the final prototype is a mini-game, where the players can get a score after each play session. Figure 4 shows a screenshot of this third prototype. The three prototypes have been presented to the testers (teachers and students), so they can understand the mechanic with the first, improve their accuracy with the second, and, finally, try the mechanic in a challenging environment and get a score based on their skill with the third.

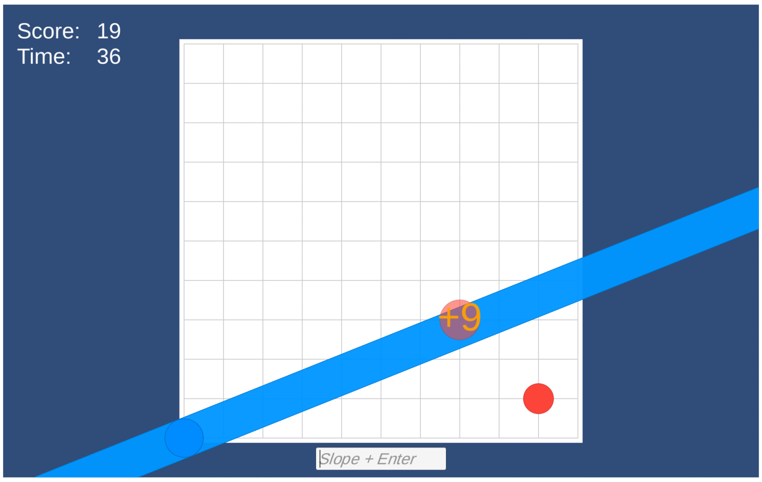

Figure 4. Third prototype. Player is shooting and hitting a target within 90% accuracy range.

Along with the prototype, the testers received pre- and post-surveys. Previous questions are about their affinity to playing games, and their familiarity with the concept of slope. Post-questions are about what they think of the prototype in terms of entertainment and educational potential. Results of this first test with the prototypes are shown an briefly analyzed in Section 5.

5. Experiments and Results

As described in Section 3, after iteratively defining core game mechanics and selecting one that meets development team criteria, the next step is to create and test the prototype. Section 4 describes the prototype based on selected slope shooting mechanic, of which three versions have also been iteratively implemented. These three versions have been made available publicly (Section 4) and given to 36 students for testing and feedback (see Figure 1). Along with the prototype for testing, students were also given pre- and post-surveys (Pre-/post-survey questions and anonymized answers are available at https://archive.org/details/ua-algebra-prototype-survey, accessed on 8 March 2021.) for this first-contact feedback. This evaluation part of the methodology is divided these 3 common steps:

1. Pre-play survey,
2. Prototype play session, and
3. Post-play survey.

It is important to notice that at this development stage it is more relevant to obtain fast, rather than accurate or detailed feedback. Most important part is to sketch a first impression on the possibilities of the proposed core game mechanic. Concretely, the mechanic should be perceived as entertaining. If participants do not perceive it as entertaining, it should be redesigned or discarded. Deeper or more detailed analyses will be done later on, if and only if the mechanic is perceived as entertaining. This is a first, rapid test to foster iterative design and to build ground support for the validity of proposed Game Design towards development of the future game based on the core game mechanic.

The pre-play survey asked students how much time they spent playing video games per week, and tried to reveal whether they knew/managed the concept of slope. The prototype play session consisted on 15–20 min of playing the three prototypes in order. Afterwards, the post-play survey aims to get evidence about the impressions and projections of the students with respect to the prototype, evaluating its playful and educational perspective. Moreover, this survey asked again about the concept of the line, to know if there were any changes in the understanding or performance of the participants.

The pre-play results (Figure 5) show that most of the students play video-games frequently. Almost all of them know the concept of slope, and 88.6% of them correctly answered the numerical questions on calculating some slopes. Based on these results, following opinions of students will be considered valid enough, as participants clearly show previous experience as game players, as well as previous knowledge and adequate skills on the concept of slope.

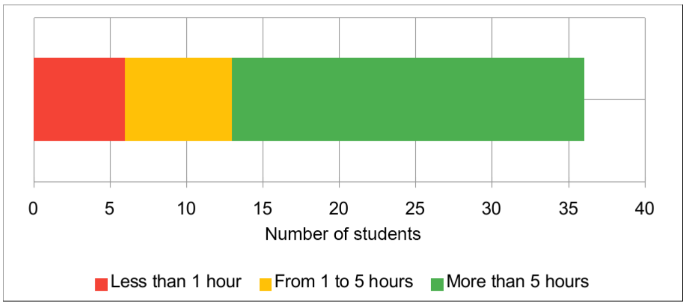

Figure 5. Number of reported hours playing video games per week.

As seen in Figure 6, the post-play results reveal that most of the students perceived the mechanic as entertaining (4 out of 5 points in mean and median). Moreover, most of them also think that it could fit in a good game, but depending on the context (median 3, mean 3.23). This is understandable, taking into account that students are only testing the first core game mechanic designed, but without game context at all. Moreover, they were not informed about this, so most of them could not project the use of this prototype as a basic mechanic in a greater game.

They were more optimistic about this prototype's learning potential (mean 3.83, median 4). This is an interesting result, as students clearly perceive that they could improve their skills related to the concept of slope. Moreover, some of them reported their perception on how having limited time and accuracy values can positively influence their skill development on this concept.

Regarding the questions on slope calculation, 93.3% of the students answered them correctly on the post-survey, which represents a 5% increase. Although this datum is anecdotal, it is also interesting because students were studying fourth year of an engineering degree, and they were only exposed to the prototype for a few minutes. Therefore, even being anecdotal, it is encouraging.

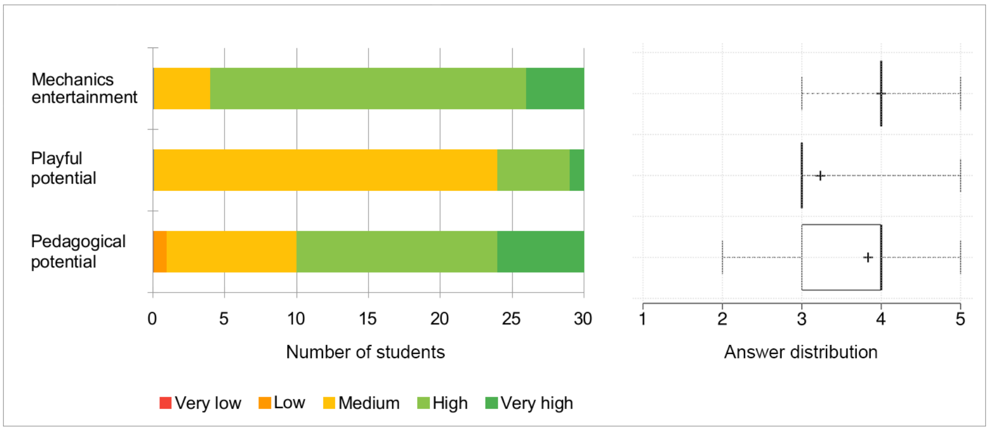

Figure 6. What the students think about the prototype.

In addition, the survey revealed some curious facts. For example, 3 students learnt from this game that the slope is a real number; they previously thought that the slope was always a ratio. This is in accordance to our previous discussion on single mechanics in concrete contexts: students had learnt that slopes were calculated as a ratio, and they seemed to have only practiced this form of calculating a slope. Therefore, they associated the way in which they calculated the slope with the concept of the slope. After practicing it in present prototype, and being able to use either ratios or real numbers, they challenged their mental model and learnt a new abstraction.

6. Conclusions and Future Work

This work is the first step towards providing a practical methodology for Serious Games design. The methodology is based on an iterative design-and-testing cycle and, despite being in an early stage of development, has been successfully used to create a playable prototype of a core game mechanic. The prototype has been tested by 36 students who answered two pre-/post-tests about it. Results of this survey initially support the idea that the designed prototype has potential, both from ludic-playable and from educational perspectives. As this is an early stage of development, there is no need for big tests or samples. This follows the philosophical rule "start small, grow progressively" that intrinsically supports all the design of this methodology. The smaller the prototype, the lighter the tests to validate pass to next steps. In the same sense, the next steps will require more design and development, as well as increasingly stricter tests and criteria.

Because the prototype and the survey results are positive for being at the first stage of the prototype, the game and the iterative model will be further developed. The presented methodology will continue being used for the next steps. Anything that will be designed will be tested to ensure its validity, so some features will need several iterations before they are considered valid, and others will be abandoned when proposed metrics and criteria are not met.

Along with the development of the game, the iterative model will be extended, completed and refined. Much more evidence is required to support the usefulness of either the presented game and the proposed methodology. Therefore, this paper aimed to present this initial development and drive interest in the proposal to gather evidence for the continuous process of refinement and improvement of this methodology. The main goal was to develop a complete complete iterative methodology up to its present expected potential to help practitioners improve their skills, as well as develop and deliver their best possible Serious Games.

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