Educational video game design by 8th graders: investigating processes and outcomes

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Abstract: Although there is evidence that game design can have a positive impact on learning and engagement, there are still few studies researching the creation of educational games by students, particularly in the context of Portuguese schools. This study examines the design of video games by 8th graders, to teach Mathematics, in a classroom setting, with the objective of investigating how designing educational video games affects learning and motivation to learn.
The research consists in a case study with twenty-eight 8th grade students. The students were given a preparatory session about educational game design, with a duration of three periods of 45 minutes, and then, a month later, eleven 45 minutes project sessions to create the games, over the course of a week, occurring during their class time. Participants worked in teams and designed video games to teach their colleagues about operations with bases and exponents (math powers). Multiple data sources were used in this qualitative research: participant observation; self-reported evaluation of engagement and learning outcomes; group interview with students; inquiry to participant teachers; games and game design documents. Data was analysed using descriptive statistics and thematic analysis.
The results showed that all teams were able to design video games that represented their understanding of content knowledge, with different game mechanics employed, with learning outcomes in terms of math contents, game design, technological skills and soft skills. Students were motivated by the project, working during their free time and showing their creations outside the classroom setting. Game design lead to knowledge-building and collaboration. At the end of the project there was a sense of competence and accomplishment with students reporting being positively surprised by their creations.
This paper discusses the effects of using educational game design by students as a pedagogical strategy, being particularly relevant to inform and guide teachers, school decision-makers, researchers and future research initiatives.

Keywords: Educational Video Games, Game Design, Student Authorship, Learning Outcomes, Motivational Outcomes

1. Introduction

Research has been, and continues to be, conducted on the benefits of using games for learning, with studies finding positive impacts on learning, motivation and engagement (Connolly *et al*., 2012).
There are several ways by which games can be used in education. Holmes and Gee categorize those practices into four main groups: action frame, structuring frame, bridging frame and design frame (Holmes & Gee, 2016). Most studies fall under the action frame, in which the focus is on the game, either by practices of gameplay activities or game analysis (Holmes & Gee, 2016). Our line of research addresses the design frame, in which the focus is on the creation process, with a constructionist perspective.
Game design is a pedagogical strategy that usually focus on teaching how to design and/or program games, with some of the following objectives: introduce programming concepts, promote design literacy or design thinking, increase cognitive skills such as critical thinking, systems thinking and problem-solving, raise interest in science and technology, or enhance understanding of subject concepts and ideas (Baytak & Land, 2010, Holmes & Gee, 2016).
The design of video games by students can be directed to incorporate specific contents of the curriculum. When introducing this extra layer, in addition to the advantages of learning by design, learners can also build knowledge of particular subject domains such as Mathematics, Science or Languages (Resnick & Cooke, 1998, Akcaoglu, 2014). In creating educational video games, students have the additional responsibility of designing an artefact that will be used to teach their peers, which can have a positive effect in the student-designer-teacher's learning outcomes, with the pedagogical strategy of learning-by-teaching being a good promoter of agency for deep learning (Hartman, 2001).

Although there is evidence that game design can have a positive impact on learning and engagement (Earp, 2015, Hava & Cakir, 2017), there is still a lot of work to be done concerning research of educational game-design by students (Hava & Cakir, 2017), particularly in the context of Portuguese schools (Pereira *et al.,* 2012). The current study examines the design of video games by 8th graders, to teach Mathematics, in a classroom setting, with the objective of investigating how designing educational video games affects learning and engagement.

2. Methodology

The research consists in a case study with twenty-eight 8th grade students. The students were given an initial preparatory session about educational game design (with the duration of three 45 minute blocks) and then, a month later, eleven 45 minutes project sessions, occurring during their class time. Participants worked in teams and designed video games to teach their colleagues about Mathematics powers (operations with bases and exponents).

2.1 Context

The first author is conducting a PhD in game-based learning with the second author as the advisor.

The research took place at a Secondary School in Vila Nova de Famalicão, a Portuguese city (33,000 inhabitants) located in the District of Braga, in the Northern Region of Portugal. The school is the largest secondary school in the region (1.800 students), and includes middle grades 7 to 9 (Agrupamento de Escolas D. Sancho I, Projeto Educativo, 2014).

The first contacts to gain access to the research site were made through the second author who had been a critical friend of the school in preceding years. During the previous school year the first author offered a teacher training development course on the creation of educational video games, which assisted in recruiting teachers to participate with their students in the research. Both the teacher of Portuguese (also the class director) and the Math teacher of the students that participated in the research attended the course. The focus of the games was Mathematics for this was a discipline previously identified by the school as one where students had extra difficulties.

2.2 Participants

A class of twenty-eight 8th graders, 17 girls and 11 boys (ages 12 to 13 years old), the class director (a teacher of Portuguese), and the Mathematics teacher, participated in the research. The class was divided in eight teams of 3 students plus two teams of 2 students.

Prior to the project sessions the class answered a questionnaire about their experiences with gaming and educational games (23 of the 28 students were present during the application of the questionnaire). 82.6% of the respondents played games at least once a week, with 17.4% stating that they played daily. 17.4% had never played an educational game and, of the ones that did play an educational game before, 55.6% said they had played it at school. 4 students had created games before, 2 of them using RPG Maker (the other two didn't know the name of the tool or didn't remember). On a 5-Point Likert Agreement Scale the average rate for "It is difficult to create an educational game" was 3.09 (standard deviation of 1.31) and the average rate for "I'm motivated to create an educational game" was 3.61 (standard deviation of 0.89).

2.3 Programme of activities

The math content was chosen by the Mathematics teacher that was asked to define a learning goal the students had not learned previously to this project. The teacher decided on powers, operations with bases and exponents. Each team had to create a video game, over the course of a week, using a structured map as a game design document containing twelve sections (1. Learning goal; 2. Concept or idea to teach; 3. Core game mechanics, 4. Additional game mechanics, 5. Game goal, 6. Obstacles, 7. Rules, 8. Space and components, 9. Story and Characters, 10. Aesthetics, 11. Score, and 12. Evaluation).

A preparatory session took place in December and served to present the project (objectives, process, schedule and expected final products) and to introduce the students to the game design process and tools. The session was carried out by the first author with the cooperation of the class director. The session happened over the course of three sequential 45 minutes classes, with one break in between. The following topics were discussed, with students' participation, and illustrated by examples and hands-on exercises: what is a game, what are the main elements of a game, examples of game mechanics, different phases of game design, introduction to the software for game creation, and how to fill the map created by the researchers to guide the process of educational game design during the project week.

In January, students worked for eleven sessions of 45 minutes, in turns, 5 teams each, due to access to the ICT classrooms, while the other teams were at their usual classes, and then switched shifts at the end of each 45 minutes. The first day, with three 45 minutes sessions, had the following structure: exposure to the basic game mechanics that the software supports, learning to use the software, exploring the mathematic concepts to teach and game mechanics that could support them. The second day had two sessions and each team had to work on: continuing to define game mechanics, rules, goals and obstacles, plan the space and components of the game, and think about aesthetics. Day three had one session in which teams had to think about story and characters, and keep on implementing the ideas previously defined. Day four had two sessions and teams had to think about the game's score and produce a playable prototype. They were also encouraged to think about ways to evaluate their own game's success. In the last day each team tested each other's games (within the same shift) and had the option to make corrections or improvements to their games.

2.4 Software

The software used for video game creation was BlockStudio (https://www.blockstud.io/bsp), an authoring environment developed at Center for Game Science, University of Washington, based on two central design principles: it is text-free and visually concrete (Banerjee *et al.,* 2016 & 2018). BlockStudio avoids using text in the coding interface, based on a programming-by-demonstration paradigm where users provide examples of behaviours they would like the system to execute, and then the software synthesizes a general rule from those examples (Banerjee *et al.,* 2016 & 2018). This makes it easy and fast to learn its basic functioning, allowing novices to quickly start creating simple artefacts.

2.5 Data collection

The methods used for data collection were participant observation, inquiry, documentation, and audio-visual materials. The first author facilitated the sessions, some with the collaboration of the class teachers, and kept a notebook with field notes of all sessions; some segments of the project sessions were audio recorded and then transcribed using oTranscribe (http://otranscribe.com/), an open source web app under the MIT license.

During the project week, at the end of the last session of each day, every student answered a questionnaire (with open and closed questions), about what he or she had accomplished and learned that day. During the project week, teachers evaluated the results and engagement of each team, through a questionnaire with closed questions. Approximately one month after the project week, there was a showcase of the video games created to the school community, where visitors tested and evaluated the games by responding to a questionnaire (with open and closed questions). After the showcase, a group interview was conducted with all the class, where students were questioned about their experiences in the project. Teachers were inquired about the project's outcomes and their evaluation of the games created, through a questionnaire with open and closed questions. All game design documents and all games created were collected for examination.

Data was analysed using descriptive statistics, with Microsoft Excel, and thematic analysis, with MAXqda.

3. Results

To facilitate comprehension and discussion, information from the several data sources is integrated and presented by categories of outcomes.

3.1 Learning

According to Schunk (Schunk, 2012) learning involves the acquisition or modification of knowledge, skills, strategies, beliefs, attitudes, or behaviours. There are many possible learning outcomes, categorized diversely according to different authors. We started out with several theoretical frameworks in mind (such as Bloom's Taxonomy of Learning Goals, 21st Century Skills, Unesco's 4 Pillars of Education, Technological and Pedagogical Content Knowledge - TPACK), but then decided to look at what emerged from the data with no fixed *a priori* categorization. Although there were almost certainly others, in this paper we highlight the following learning outcome categories: math contents, game design, technological skills, and soft skills.

3.1.1 Contents – Mathematics

Students had to understand rules of operations with bases and exponents in order to integrate them into their game, so the first learning outcome we investigated was this mathematic content (powers).
In terms of self-report, students didn't seem to perceive to have learned math contents. During the project week, in the open question (of the daily questionnaire) "What did I learn from today's activities?" no student stated math contents *per se*. The only references to math knowledge were tied to game creation, following under the category of educational game design, with three (out of 111) responses stating "I learned to create a math game", "I learned to relate themes with games and in the end to succeed", "I learned to create games and to relate knowledge (discipline, game) in a clear, objective and even fun way".
Nonetheless, in the same questionnaire, using a 4-Point Agreement Scale, the average value to "I was able to understand the concepts worked on today" was 3.66 (standard deviation of 0.47), with all students agreeing or strongly agreeing to that statement. One can argue, though, that since there were a lot of concepts they were working on, simultaneously, besides math (like game design and programming), this question is not measuring exclusively how much the students thought they understood of the math contents.
In the group interview at the end of the project, students didn't report to have learned math contents, however, through participant observation it was possible to see students discussing math while creating their games and while showing and explaining the games to other students and teachers. Table 1 depicts four examples of those observations.

Table 1: Observations of students discussing Math Contents

Observation 1	Observation 2	Observation 3	Observation 4
Teacher: How much is cube of two times cube of five? **Student 1:** Cube of ten. **Teacher:** Why? **Student 1:** Because you multiply... **Student 2:** You multiply the bases and give the same exponent.	**Teacher:** You have to know how much is eight raised to the power zero. How much is it? **Student 3:** One. **Teacher:** Are you sure? **Student 3:** Sure. **Teacher:** Why? **Student 3:** Any number raised to the power zero is equal to 1.	**Student 4:** We haven't put any with negative exponents yet, have we? **Student 5:** No, we did not ask a question, we put an answer with negative numbers... **Student 4:** I'm saying questions with negative exponents for people to have to invert... **Student 5:** Oh... yes.	**Researcher:** What is the rule to follow there? **Student 6:** It is the same base, and you add up the exponents... **Student 7:** And then here's as if you had an exponent of 1... **Researcher:** Hum, hum **Student 8:** So it gets three to the power of five.

Additionally, from his own observations, the Math teacher stated that, overall, students understood the math concepts in demand.
Another evidence of learning outcomes related to math contents is the concrete math students included in their games. Table 2 displays the rules of operations with powers each group incorporated into their game, as well as the scientific errors whenever present.

Table 2: Rules of operations with powers used in each video game

		Rules of operations with bases and exponents $[a \neq 0]$							
Group ID	Errors	$a^1 = a$	$a^0 = 1$	$a^m \times a^n = a^{m+n}$	$a^m : a^n = a^{m-n}$	$(a^m)^n = a^{m \times n}$	$a^m \times b^m = (a \times b)^m$	$a^m : b^m = (a : b)^m$	$\left(\frac{a}{b}\right)^{-m} = \left(\frac{b}{a}\right)^m$
G1	(*)	•	•	••	••	•	•		•
G2				•			••	•	
G3	†								••
G4			•	•••		•	••		••
G5	(*)		•	•				•	
G6	(*) (*) ×		••	•		•••	••		•
G7	(*) ×	•	•	•••	•	••	•	•	••
G8	×		•	•••	•	•	••	•	••••
G9			•	•	•		•		
G10								•	••••

Legend: (*) - missing brackets in one level; × - wrong answer in one level; † - unsolvable question / all answers are wrong; • - one rule present in the game

The analysis of the games' content reveals that all teams were able to incorporate the desired math concepts into their games. There were different levels of complexity in terms of types of rules used, ranging from group 3 that only used one type, to group 7 that used all of the eight types of rules, the average being 4.5 (standard deviation of 2.3). There were also different levels of complexity regarding number of rules used (ranging from two rules in group 3 to thirteen rules in group 8). On average, teams required players to use 7 rules (standard deviation of 3.9) in their calculations to finish the game (regardless of the type of rule).
Four teams (40% of the groups) didn't make any scientific errors in their games and two other groups had only minor errors (missing brackets in one level). In three cases (G6, G7 and G8) the answer the team considered

correct in one of the levels was wrong. Group 3’s game had a question where all options of answers were incorrect.

3.1.2 Game Design

Students reported to have learned game design, both in the interview, with statements such as “I learned to make a game in a week”, and in the open question of the daily questionnaire “What did I learn from today's activities?” with 27% of responses falling under the learning outcome category game design.
This is aligned with the evidence from participant observation, where during conversations students adopted vocabulary from the area of game design (e.g. level, rules, game screen, sprites), and were seen discussing and explaining game design decisions. Table 3 exemplifies some of those observations.

Table 3: Observations of students discussing Game Design

Observation 5	Observation 6	Observation 7	Observation 8
Student 1: When you miss, your sprite gets smaller, if you miss many times it disappears. (...) **Student 2:** We thought of always putting the same enemy and increasing his speed along the levels.	**Student 2:** In the first part begins with the two ships here and it has this calculation... and these two do not show. The options are these ones and the ball, in this case, will be the correct option, we have to hit the ball. **Student 3:** When we hit it, the projectile of the player who hits it... if the darker ship hits it, it earns a point, a star. And the question changes and the icons change so that the answer turns out to be different...	**Student 4:** It is a collaborative game, where in order to be able to pass the levels you have to... **Student 5:** They have to help each other. **Student 4:** Exactly. And you also have to know powers. (...) **Student 5:** See, the little one will now save them, when the little girl hits the right place the others can leave.	**Student 6:** For example having a heart you can pick up on some levels to give you an extra life. **Researcher:** How many wrong answers will you have? **Student 7:** Three, there is only one right. **Researcher:** So if you're giving him three lives, that means he can try them all? **Student 7:** No, no, three lives for the whole game.

All teams had to deliver game design maps defining their games in terms of learning goal, concept or idea to teach, game mechanics (core and additional), game goal, obstacles, rules, space and components, story and characters, aesthetics, score, and evaluation. In spite of a few mistakes, such as a team that used the game mechanics section to explain math rules, or another team that wrote that the game’s goal was “motivation”, it became clear, from the analysis of those documents, that overall students understood the main elements of a game and were able to correctly describe them. Only two teams included in the design document the description of story and/or characters for their games, being this the element less embraced. Table 4 shows an example of a game design map delivered by one of those teams.

Table 4: Game Design Map completed by one of the teams

1. Learning Goal	2. Concept or Idea to Teach	3. Core Game Mechanics	4. Additional Game Mechanis	5. Game Goal	6. Obstacles
"Know the rules of operations with powers."	"There are several rules, like: power with the same base or exponent; powers with negative integer exponent, and the power to power rule. While we are learning and doing exercises we are also having fun because we are playing."	"For the player to understand the concept to be reached, he should move towards the correct answer."	"To increase the fun and motivation, whenever the player reaches a correct answer, the speed of movement increases at the next level. If any player collides with the wrong answer, he loses and disappears from the game."	"The game consists of 7 levels, the goal is to get right as many questions as possible. The player with the highest number of correct answers wins."	"To make the game more difficult we have several wrong answers and only one correct, and as the levels go by the difficulty increases. There is also a sprite that blocks the way and if we touch it we lose."
7. Rules	**8. Space and Components**	**9. Story and Characters**	**10. Aesthetics**	**11. Score**	**12. Evaluation**
"In the game we have a calculation of powers in the center and several options of answers. Players will have to move to the correct option. If the player hits the correct answer, he moves to the next level and gets faster than the others. If the player misses, he loses and stops playing in that level."	"The game is digital, runs on the computer in a square grid. In the game we have 3 players (3 sprites), 5 text boxes with possible answers and 1 central text box with the powers."	"The ships that are lost in space have to answer the questions to get to Planet Earth. Power rules (concept to be taught) are directly related to the purpose of the game, to hit the highest number of correct answers to reach Earth. The characters are spaceships (that are in space)."	"The game is in digital format (on the computer). We want the player to have fun while playing and at the same time learn." 	"As the player hits the right answer, he gains a point. The game consists of 7 levels. The player with the most points at the end of all rounds win. There will be a grid with the score of each player."	"We will play once to see if there is something to improve and if the game is fun. Then we can ask the teacher's opinion to make sure everything is okay and we can show it to the other classes. We can do a brief questionnaire to see if the other classes liked our game."

The connection between game mechanics and learning outcomes was mostly superficial, in what Kafai would consider an extrinsic integration (Kafai, 1998). This is not surprising, since creating core mechanics that are well-aligned with the relevant learning mechanics is one of the most difficult aspects of educational game design, and the students didn’t have enough time to explore this more in depth. All teams applied the same four central core mechanics in their designs: movement, calculation, selection and avoidance. All games had levels, except group 10’s game that consisted of two mini-games. Twelve other game mechanics were used by at least one of the teams (see Table 5), indicating a diversity of approaches and an effort to create original games.

Table 5: Game mechanics applied in the video games

Group ID	Game Mechanics																
	Move	Calculate	Select	Avoid	Shoot	Eliminate	Race	Compare	Open doors	MP - Cooperate	MP - Compete	Levels	Points	Mini-games	Lives	Extra life (1-UP)	Easter eggs	Resizing of avatar
G1	•	•	•	•								•			•			
G2	•	•	•	•								•						
G3	•	•	•	•								•						•
G4	•	•	•	•	•				•			•						
G5	•	•	•	•								•			•	•		
G6	•	•	•	•			•	•			•	•						
G7	•	•	•	•								•						
G8	•	•	•	•								•						
G9	•	•	•	•					•	•		•					•	
G10	•	•	•	•	•	•	•				•		•	•				

Legend: MP - Multiplayer

During the video games' showcase, visitors (play testers) were asked to fill in a questionnaire to evaluate each game regarding how fun it was (from 1 - not at all fun to 5 - super fun!), how clear the rules were (from 1 - not clear at all to 5 - perfectly clear!), and how difficult the game was (too challenging – 1, nicely challenging – 2, too easy – 3). The average for fun was 4.68 (standard deviation of 0.8), the average for difficulty was 2.07 (very close to the optimal value of 2, with a standard deviation of 0.5) and the average for clarity of rules was 4.72 (standard deviation of 0.7). The games had a very positive evaluation, out of a total of 122 reviews, which can be considered an additional indicator that students learned game design.

3.1.3 Technological Skills

Students reported to have learned how to use BlockStudio and how to program, both in the interview, with statements such as "we learned to program", "programming with a kind of different application that most people might have never used", and in the open question of the daily questionnaire "What did I learn from today's activities?" with 30% of responses (the higher percentage) being related to the learning outcome category technological skills.

This is aligned with evidence from participant observation, not only by observing software usage, levels of autonomy and task completion, but also conversations in which students talked about rules they had created and showed signs of learning in this area. Table 6 illustrates some of those observations.

Table 6: Observations of students discussing Software Usage

Observation 9	Observation 10	Observation 11	Observation 12
Student 1: This alone... look at all the rules it has! And complex rules. **Student 2:** ha, ha **Student 1:** For example, when this happens, it replaces those all to green, the meteor goes to the trash, a star appears here, this one hides, this one reveals itself.	**Student 3:** No, but if we repeat a red cross it will have the same attributes as the other red cross of another level. **Researcher:** And which are those? **Student 4:** Breaking the wall... **Student 3:** Break off when the other hits the cross.	**Student 5:** If he then also fails they both disappear. We have this button here to restart the game. **Student 6:** Yes, to restart. **Researcher:** So if you both lose... **Student 5:** It doesn't restart completely, just puts the two ships at the start... **Student 6:** And comes the second question.	**Student 7:** In our game there were students who complained that the robot could walk faster, so that they didn't have to be pressing the arrow keys all the time. **Researcher:** And could you have done that with BlockStudio? **Student 7:** Yes, we can change it.

Another evidence of learning outcomes related to technological skills is the "code" students included in their games. To examine the digital artefacts created we used a similar model of analysis as the creators of the software in which they characterized the learning of coding concepts by examining the scope of learners' use of programming constructs (Banerjee *et al.,* 2018). All teams were able to create all rule types offered by the software (touch, key and collision), with most teams using at least one complex rule (*i.e.* affecting more than one block/sprite) in their games. All teams were capable of combining rules to create different patterns, with different levels of complexity (see Table 7).

As we can also perceive from Table 7, there is room for improvement, particularly in terms of polishing "code", *i.e.* deleting non-used or redundant rules, and creating simpler "programs" (e.g. by using loop patterns).

Table 7: Analysis of the games' code

Group ID	Rule Types			Pattern Types							Nr. Rules	Irrelevant
	Touch	Key	Collision	Collectible	Obstacle	Firing	Transition	Loop	Timer	Counter		
G1	S	S	S | C		•		•			•	23	0%
G2	S	S	S		•		•				31	35%
G3	S	S	S | C		•		•				38	24%
G4	S	S | C	S | C		•	•	•				42	12%
G5	S	S	S | C		•		•		•	•	24	13%
G6	S	S	S | C		•		•		•		78	5%
G7	S	S	S		•		•				75	27%
G8	S	S	S		•		•		•		59	37%
G9	S	S	S | C		•		•		•		156	27%
G10	S | C	S | C	S | C		•	•	•				85	8%

All teams were able to create a video game within the scheduled time, resulting the project week in 10 educational video games, some of which are shown in Figure 1.

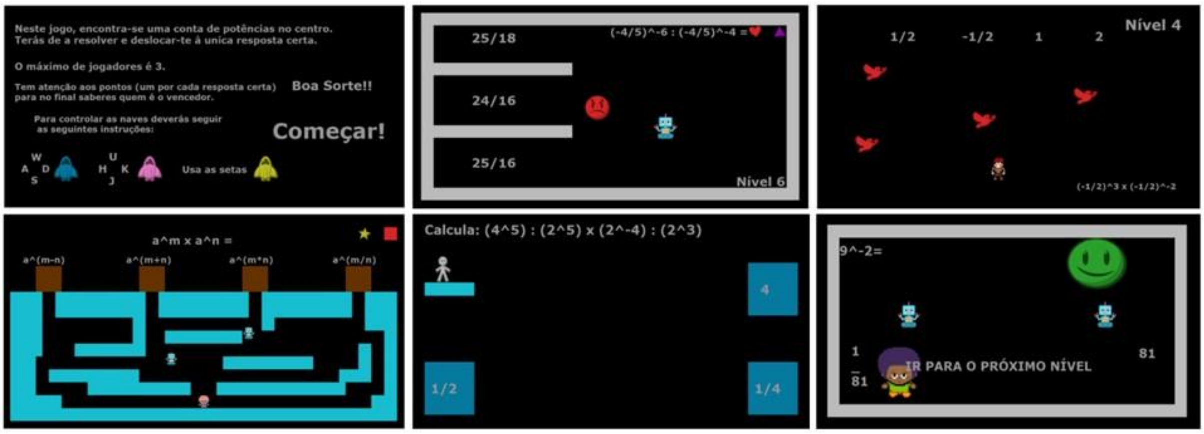

Figure 1: Screenshots of some of the video games created by the students

3.1.4 Soft Skills

Regarding soft skills, students reported having learned "to work faster", "to work better", "to explain myself better", "to organize my ideas", "to respect different opinions", "to work as a team" or "that teaching is difficult".

From the field notes we extracted a few observations coded as commitment, perseverance (usually associated with technological failures, e.g. work not saved that then needed to be redone) and curiosity, but mostly observations related to teamwork and "pedagogy" (learning to learn and learning to teach).

When asked about teamwork, all students stated they preferred working in groups, even the ones that usually don't: "Usually I do not really like working in a group, but I think in this case it helped more because the ideas were more fluid. And so each one gave his idea and we put the ideas together." This thought that working in teams facilitated the ideation process was common to several students.

Though this was not something that was taught during the project, since the participants had to better understand math contents (in a self-directed way) and then integrate them into a game that would serve to teach their colleagues, it is not strange that we observed learning in the areas of learning to learn and learning to teach. This was visible when students looked up school books or in the pedagogical choices some of the teams made in their games (e.g. having progression in terms of difficulty or creating easier intermediate levels for every time a player would fail a challenge). During the showcase students explained sometimes both rules and math contents, especially in the case of visitors from 7th grade. Some teams even made changes during the showcase to adjust the level of difficulty. The Math teacher said he would use the video games created, after the corrections (when needed) with other classes, for them to practice, indicating he thought the games were well-designed, and evaluated the games with an average of 3 out of 4 in terms of "The game is pedagogically well designed / suited to the defined learning objectives."

3.2 Motivation / Engagement

Students reported motivation to learn and to work on the project both in the interview, with statements such as "I really liked working during that week" or "I would like to do it again", and in a closed question of the daily questionnaire. By means of a 4-Point Agreement Scale, the average score to "I liked the sessions today" was 3.71 (standard deviation of 0.48), with almost all students agreeing or strongly agreeing (only one student disagreed on day 2).

This is aligned with evidence from participant observation, with teams continuing to work during breaks (four teams were observed in more than one occasion working in the classroom after the session ended), as well as students reporting meeting outside class to work on their games (see Table 8).

Table 8: Observations of students talking about working during their free time

Observation 13	Observation 14	Observation 15	Observation 16
Student 1: Last night I did it, I got this one to move. But the doll stays like this, I think it should go to this one and when you click you go to the first level.	**Student 2:** That's very difficult. **Student 3:** But we can do it. **Student 4:** Only if we go to the library in the afternoon to make the game, can we? **Student 2:** Yes.	**Student 5:** I'm going to have to finish the game at home today. **Student 6:** But I'de like to be present also.	**Researcher:** But are you going to do the game again? **Student 7:** Now we're going to do the math one. **Student 8:** Everything is already planned. **Reasearcher:** But I thought you had done enough ... **Student 8:** Yes, we had made a game like with a mouse and ... **Student 7:** But that was only for training.

During the project week it was visible the interest of the participants in sharing their creations with their class colleagues. Also, whenever there were barriers to technological access (such as a computer that wasn't working or a slow internet connection), students showed frustration with expressions such as "now we cannot advance in our game". Additionally, students displayed enthusiasm about showing the games to family, friends, colleagues and teachers from outside the class (see Table 9).

Table 9: Observations of students talking about showing their games outside school

Observation 17	Observation 18	Observation 19	Observation 20
Student 1: I showed in my house, and I showed it in my institute. Because ... this week ... Me and M. are from the same institute and we told the teacher there we were on a project. And the teacher asked if we could show the games. So we put it there on the computer and showed it to the class.	**Researcher:** Have you talked about the project at home? **Student 2:** Yes. **Student 3:** I showed it to my father. And he found it funny, BlockStudio.	**Student 4:** I showed the digital game to my family more and ... a lot of the people wondered ... how did he do it? But the platform is simple. BlockStudio is something simple, but a person out there does not know what it takes to get done (...) they were a little surprised.	**Student 5:** Even at home I sometimes showed how we were organizing the game and they found the idea interesting.

Prompted by the class director (the teacher of Portuguese), they organised a showcase for the school community with entries by invitation where each student could invite friends (also other 8th grade classes were invited). During the game display (see Figure 2), students served as hosts for the visitors.

Figure 2: Showcase of video games to the school community

During the group interview one of the students asked if they could organize a new showcase and invite their families, and most colleagues agreed with the suggestion.

The project raised interest not only in continuing similar activities next year but also in technology and programming, with six students creating a programming club (with an ICT teacher), as a student explained "Because of having started with this ... with that week of games, I also started wanting to program something more. So then I also went to that little programming club that started here in the class."

Teachers also scored highly the students' motivation, on a 4-Point Likert Scale the average was 3.5 (standard deviation of 0.3). One interesting comment was: "For the first time I was seeing some of the kids that have more difficulties discussing Math concepts. Even when the terminology wasn't the most correct, at least they were thinking and talking about it."

4. Conclusions

This study examined the design of video games by 8th graders, to teach Mathematics, in a classroom setting, with the objective of investigating how designing educational video games affects learning and motivation to learn.

The results showed that all teams were able to design video games that represented their understanding of content knowledge, with different game mechanics employed. Students were motivated by the project, working during their free time and showing their creations outside the classroom setting. Educational game design lead to knowledge-building and collaboration. Students learned simultaneously content, technology and pedagogy, which is well-aligned with the TPACK framework, usually associated with teacher training but that might be useful also to think about student learnings.

At the end of the project there was a sense of competence and accomplishment with students reporting being surprised by their creations. As one student explained "I think it surprised me because ... even on the day we were introduced to the project I thought it would not work... because, well, a group of twenty-eight people, divided in a computer room... with computers for us, to do a lot by ourselves… I thought it was not going to work. I bet even the teacher doubted that it would become such an elaborate thing."

This paper intends to contribute to the increase of the practice of educational game design by students as a pedagogical strategy, by teachers with the support of school decision-makers, and its study by academics, stimulating future research initiatives.

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