W-STEAM card game to develop computational thinking

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Abstract. Involving girls in playful activities about STEAM (Science, Technology, Engineering, Mathematics) content, that exercise their logical reasoning skills by developing what has now been termed as computational thinking is an ongoing challenge. Therefore, this article discusses aspects of the development and application of a card game that works with elements from Brazilian women STEAM projects, Amazonian culture, and STEAM content in general. Called "ParPow", the game is based on math-computational theory, mainly Euclids principle which indicates that two lines in the plane intersect at just one point, being similar in structure and playability to a well-known card game: Dobble, also known as Spot it. This work discusses the mixed team and the game development process, involving concepts of geometry and mathematical combinatorics, and culminating in an algorithm for automatic generation of the cards in order to satisfy the theory. The game, played individually, in pairs or in groups, works on visual perception and agility, and also working on the four pillars of the computational thinking - abstraction, pattern recognition, decomposition, and algorithm - both for the development of the game and for the understanding of its gameplay. The exposure and application of the game at scientific and technological fairs demonstrated how engaging, fun, and integrating the ParPow W-STEAM card game is, attracting a diverse audience, from children in early childhood to professional adults.

Keywords: card game · gender equality · mixed teams · software development · steam · women in computing.

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1 Introduction

Increasingly, the creation of new teaching and learning methodologies are launched with the purpose of bringing a relaxed atmosphere to the classroom and leisure. Math-based courses are the most complicated for children and adolescents, in the western hemisphere of the world, to understand. The teaching of mathematics is fundamental in our lives, and if it is not worked well from an early age, it can lead to complications in the future [1]. One of the ways to alleviate the difficulty with this discipline is to innovate teaching with playful mathematical concepts and activities that can enable the student to have logical reasoning, creativity, and the ability to solve problems. In early childhood education, the fun of teaching mathematics is not only dynamic, but it also makes students feel more pleasant to learn because they are very interested in playing and games. The first contact with the playful makes the students actively participate in the class.

The purpose of this article is to present the involvement of women in a process of obtaining steam knowledge in its multiple dimensions, through a card game, which works with various aspects and dimensions of steam content, whether in the process of game development or for to applications of dynamics explaining its gameplay, and also to the act of playing itself. The elements included games, regional culture, projects to encourage women in computing, science, and figures representing technologies. Throughout the initiative, we will obtain various aspects of skills and knowledge according to the age group. This work is organized as follows. Section 2 addresses the Theoretical Foundation. Section 3 presents the related works. Section 4 reports the development of the ParPow w-steam card game, describing the math-computational that underlie the w-steam card game, and its characteristics. Section 5 presents the experiments and analysis of the results. In Section 6 we have the final considerations.

2 Theoretical Foundation

Most games to date make it necessary to have reasoning mechanisms for problem-solving, the same goes for computational thinking that is based on the fundamental concepts of computer science where it involves logical reasoning and problem-solving. problems.

Computational thinking [2], is supported by four pillars: (1) **decomposition** - is the ability to decompose a big problem into smaller and simpler problems to solve; (2) **pattern recognition** - is the ability to perceive similarities between different situations; (3) **abstraction** - is the ability to filter only the important parts of the process, ignoring irrelevant things; and, (4) **algorithm** - is the ability to join the three previous pillars, in an attempt to develop a set of steps to solve the problem.

With a wide range of games, it becomes increasingly difficult not to be faced with a game that does not require one of the four pillars for solving problems presented in order for the user to go ahead. Games with the intention of requiring logical reasoning from players are known as Puzzles, where a logical organization of events and actions is required that often include a mathematical experience, quick logical reasoning in their resolution, and computational thinking.

Jeannete Wing [3] defined some characteristics for computational thinking such as:

- conceptualize, not code (what many understand to be the act of programming). He believes that thinking like a computer scientist is more than coding and requires thinking on multiple levels;
- fundamental and innate ability, not mechanical;
- a way that humans, not computers, think. Emphasizes that computational thinking is the way to solve problems by humans, we are the ones who make computers exciting and it is from our intelligence that we are able to deal with problems that we would not even have to deal with;
- complements and combines mathematical and engineering thinking. Computer science is based on both mathematical and engineering thinking since systems interact with the real world;
- ideas, not artifacts. What will always be important will be how and the computational concepts we use to solve problems on a daily basis and not the products themselves developed; and,
- for everyone, everywhere. Computational thinking must be available to everyone, seeing the great collaboration that can arise in any area.

Wing [3] also addresses that computational thinking involves solving problems, designing systems, and understanding human behavior, based on the fundamental concepts of computer science,being widely used in several games, mainly those considered puzzles, which require thought to solve a specific problem, where we always seek to raise the difficulty and the best way to solve it.

A theme of many games that explore the pillars of computational thinking in gameplay is STEAM (Science, Technology, Engineering, Arts, Mathematics). This is used for the learning of multiple math-based contents in order to have access points for students' research, dialogue, and critical thinking. This approach started to be used in educational games to promote interaction with children based on fun. Furthermore, in the board games industry, computational thinking is inserted in such a way that a lay player exercises one or more of the four pillars without realizing it, making the game more thought-provoking.

Feminist-themed games, as well as the other elements of W-STEAM, are gaining more and more space in schools and attracting both genders with increasingly worked gameplay and consequently causing a positive impact on the dissemination of content about women in several knowledge fields.

3 Related works

We can also find games that cover as much as W-STEAM with an emphasis on games that empower women, as well as games that have computational mathematical aspects. Some games can be seen in Table 1.

Table 1. Feminist and math-computational aspects of different board games.

Games logo	Board Game	Description	Feminist aspects	Computational and mathematical aspects
	Flanx	Players face each other trying to match their cards to form the path that will block the other player.	Null	Geometric shapes, pattern recognition and algorithmic strategy.
	Set	Players must identify sets of three same or different symbols in four categories: color, number, shape and shading.	Null	Set notions, geometric shapes and pattern recognition.
	Feminaipes	Feminist deck that is illustrated only with female figures that have been successful in Argentina.	Promote gender equality and empower women and girls.	Null
	Wonder Women - a Feminist Card Game	Informative card game about 44 women scientists in a real strategy game with narrative pulse in the center.	Promote gender equality and empower women and girls.	Null
	Dobble - Spot It	Speed and observation game in which players must identify among eight elements on the card, the only element that is repeated on the card of two or more players.	Null.	Classification by set, abstraction, algorithm in the construction of the game and pattern recognition.

Most of the games listed in Table 1 are known, but we can analyze above that games with a feminist theme, Feminaipes [4] and Wonder Women [5], do not cover computational mathematical aspects, differently of some agility games and with the main characteristic is the recognition of patterns like the games Flanx [6] and Set [7]

One of the games that stand out is the one called Dobble cite asmodee, also known as Spot It, which besides having several computational mathematical aspects, is a world-famous game that attracts several players of different age groups and genres. In contrast, the Dobble game has no feminist aspect and does not cover the areas of W-STEAM, but it has an extremely strong mathematical bias starting from the construction of the game until the act of playing.

In 1976, Jacques Cottereau solved Kirkman's Schoolgirl's mathematical problem described as follows: *Fifteen young maidens from one school walk side by side, in groups of three, for seven successive days; order them daily, so that two of them never walk side by side more than once* [9].

This is a combinatorial problem, a branch of logic that deals with combinations of objects under specified criteria. To represent the students' problem, Cottereau designed an "insect game" with a set of 31 cards with six images of insects, containing exactly one image shared between each of them.

Denis Blanchot found letters from Cotterau's "insect games" and based on the same principle he created the card game known in the world as Dobble, and only in the United States as Spot It.

The Dobble - Spot It contains 55 cards, each containing 8 symbols, where, like the game of insects, the dynamics of the game are summed up that there will always be a common element between two cards. Therefore, for the realization of the game proposed in this article, the gameplay and computational theory behind the Dobble game was chosen, however, the theme turned to W-STEAM for the development of ParPow.

4 ParPow W-STEAM card game

The ParPow W-STEAM card game is a reinterpretation of the commercial card game Dobble (with a version called Spot It) where the objective is to find the symbol in common between two cards. The name ParPow refers to the popular slang denoted as *Pá-Pow* that alludes to something that comes and goes, replacing the *Pá* with *Par*, since the game has the purpose of finding the same symbol on two different cards (forming a pair of the symbol). This game allows the possibility of working with mathematical content involving the four pillars of computational thinking [13] (pattern recognition, abstraction, decomposition, and algorithm). This section will present the mathematical-computational principles on which ParPow is based on. This section will present the mathematical-computational principles on which ParPow is based on. Then, it presents aspects of the game construction of the proposed version.

4.1 Euclid's principle and combinatorial geometry games

The ParPow game that has the same mathematical principles and theoretical foundation as the commercial card game Dobble (and its American version Spot it). In this section, the main geometric and combinatorial concepts are presented to understand how to create the game and how to play it. The reference material used is based on scientific dissemination articles from online magazines or even on structured texts on the topic on Internet sites. This section is based on some literature texts [10], [11], [12].

The game can be modeled using a mathematical structure called a finite projective plane. A projective plane is a set of points and lines with the following axioms:

- two distinct points define a single line;
- two distinct lines have a single point in common;
- there are four points such that no line passes through more than two of them.

A finite projective plane is nothing more than a projective plane with a finite amount of points and lines. It can be demonstrated from the axioms that, on a finite projective plane, all lines have the same number of points and there are as many lines as points. More specifically, for every finite projective plane, there is N such that there are N^2+N+1 lines, N^2+N+1 points, $N+1$ lines per point and $N+1$ points per line. The N value is called the plan order.

Thus, it is possible to create an equivalence between the game and a finite projective plane. To do this, just consider points equivalent to symbols and lines equivalent to cards. The plan's properties ensure that all cards have the same number of symbols and every two cards have exactly one symbol in common. Figure 1 shows how a deck of 3 symbols per card could be generated in this way.

Due to the properties of a finite projective plane, this equivalence only generates complete decks. That is, any other deck with the same number of symbols per card can be obtained by eliminating cards or changing the symbols associated with each point.

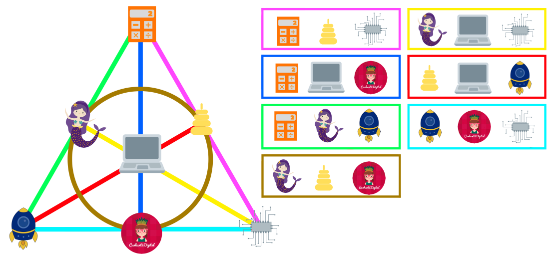


Fig. 1. Finite projective plane of order 2, and deck generated from the plane. Authors' source.

Since projective plans must have at least four points, decks with up to three symbols cannot be constructed in this way. There are two possible complete decks with less than four symbols. The first consists of just one card with a single symbol. The second is composed of three cards: AB, BC, and CA.

If N is the power of a prime number, then there is a finite projective plane with order N. For some values, like 6, it has been proved that it does not exist. Other values remain open.

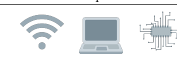
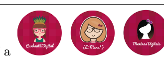
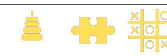
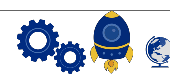
During the study of the game Dobble - Spot It, it is noticed that there are categories separating the icons implicitly to improve the gameplay and increase the level of difficulty, confusing the player when he must identify the symbol that appears on both cards. However, in the original game, these groups are formed by simple elements and are differentiated only by shades of color.

In contrast, ParPow also has categories to make the player's experience more interesting, however, in addition to also using color, these groups were separated into themes.

The development of the card game and its thematic categories was through *Design Thinking* process, involving the phases of immersion, ideation, and prototyping.

In the immersion phase, the team was composed of students from the Cunhatã Digital project [14], which aims to encourage girls to take science and technology undergraduate courses. The team was formed by students from the area of computing and design, with mostly female members. In this way, questioning was carried out among group members and university students about which thematic categories would be addressed in the game. It was determined that the game categories would be divided into the W-STEAM theme, and that they were defined as: computing; women's projects in exact sciences; games in STEAM; Amazonian culture - legends, folklore, fauna, flora; education; science. In the ideation phase, activities were promoted to generate innovative ideas such as *brainstorming*, in which the colors that each group would be represented were defined, and which elements would be part of the game categories, which can be identified in Table 2.

Table 2. Table with the definition of the ParPow thematic groups, colors, and symbols belonging to each category.

Game categories	Simbols	Color set for category	Simbols examples
CS - informatics	Notebook, Cloud, Circuit, Mouse, Wifi Signal, USB Signal, Pen Drive, Binary, Printer, Tablet.	Grey.	
W-STEAM projects	Cunhatã Digital (Digital Cunhantã), Meninas Digitais (Digital Girls), Py Ladies Manaus, LAWC, Manauara Tech, Ei Mana, Bit Girls, Ada Code, Caboclas Kirimbaua Aueté in Science, Mulheres na P.O. (Women in O.R.).	The color of the project's logo was maintained with the addition of a pink background for standardization.	
STEAM games	Chess (Pawn), Domino, Tower of Hanoi, Sudoku, Magic Cube, Puzzle, Abacus, Tic-Tac-Toe, Deck (ACE), Tetris.	Yellow.	
Amazonian culture	Curupira (folklore), Vitória-régia (Victoria amazonica), Boto (porpoise), Garantido e caprichoso ("boi bumbá", folklore), Yara (folklore), Guaraná (fruit), Canoe, Cocar (Indian headdress), Jaraqui (fish), Sauim de Coleira (monkey).	Purple.	
Education	Pencil, Ruler, Book, Colored pencil, Eraser, Scissor, Backpack, Calculator, Whiteboard,	Orange.	
Science	Test tube, Molecule, Graph, Globe Terrestrial, Gears, Microscope, Rocket.	Blue.	

During the prototyping phase, the team was divided into two parts: creating the algorithm and creating the icons. The creation of the algorithm was responsible for one participant of the project while for the creation of the icons, each participant of the team was in charge of producing and searching in free image banks the symbols of each category seen in the Table 2. After that, there was a new division for making the cards and the *logo* of the game which can be seen in Figure 2(a).

In this way, ParPow has a total of 57 symbols listed in Table 2, which are distributed in 55 cards where each has 8 of these elements. These symbols are not repeated on the same card, but the same element may appear on another card in the future. The icons also vary in size over the course of the cards, which can be seen as small or large, and distributed at random in the assembly of the cards. The dynamics of the game is that there is only one element in common between any two cards, as in Figure 2(b).

(a) (b)

Fig. 2. ParPow game cards: (a) back of the card with the game logo; (b) pair of playing cards, with the identification of the element in common. Author's source.

In Figure 2(b), the "Cunhantã Digital" belongs to the category of women's projects in STEAM and is the element that is repeated in both letters. In ParPow as well as in Dobble - Spot It, there are several mini-games that consist of the same principle of finding the equivalent figure, and the player can invent new dynamics as he prefers.

The importance of bringing regional elements, projects of women in exact sciences, educational games, objects of science, computing, and education aims at the formation of the individual in several areas of knowledge while practicing a playful activity.

Knowledge of local culture promotes regional appreciation, as well as understanding the existence of projects with women active and focused on STEAM provides empowerment, inspiration, and motivation. Knowing more about computing, science and education stimulates technological transformation and instigates curiosity as well as the other categories of the game.

5 Experiments and Analysis of Results

The four pillars of computational thinking can be observed from the Design Thinking software process of development the game, until the act of playing the game. During the prototyping phase of the game, the students responsible for building the algorithm up to the design of the cards sharpened their logical reasoning skills, and the four pillars of the computational thinking could be observed, as follows in Table 3:

Table 3. Pillars of Computational Thinking during the phases of the Design Thinking game development process.

Imersion	**Ideation**	**Prototyping**	
		litando o trabalho. **Card game modelling**	**Combinatorial algorithm**
Abstraction: analyze elements with relevance to the theme, differentiating from those that can be left aside. Decomposition: Division of categories, delimiting the scenario.	Abstraction: to identify the elements that would be part of each category.	Decomposition: division between participants to create cards and join each card and join each card forming the game. Algorithm: creation of a group of rules to ensure that two letters always have only one symbol in common.	Decomposition: division of categories, delimiting the scenario. Pattern recognition: identification of common aspects in the process of creating the cards.

After that, training was given to the volunteer team of the Digital Cunhantã Project, with the purpose of providing an understanding of the game creation process seen in the Table 3 along with the gameplay, and thus be put into practice and spread the knowledge acquired at events and fairs.

The importance of explaining the game to the volunteers was defined in disseminating the computational and mathematical subject, ensuring that they knew the importance of dealing with W-STEAM issues in the game, focusing on women's projects in exact sciences, in addition to generating curiosity, empower women and girls, since many would see it as an example and a career possibility.

In addition, the volunteers themselves were able to acquire the necessary knowledge, due to the need to expose and explain the game, and had positive impacts by learning the game's development from the lines of code to the printing. In addition, they have perfected or developed the ability to speak, and have more security when exposing themselves to an unknown audience. A large part of these volunteers are girls from the Cunhatã Digital project who, throughout the process, acquired the knowledge proposed by the game and became more confident by expressing themselves to others taking some knowledge, and thus, consequently inspiring other young girls.

ParPow was exhibited at several fairs and events for students of different age groups. In addition, the game also caught the attention of parents, educators and professionals in the computing and STEAM fields.

Table 4. List of educational and technological Fairs and Events showing the game, with the age group of the participants.

EducTech Fairs	Age range	Objectives
16th INPA National Science and Technology Week	from 6 years-old	To expose to children and adolescents the importance of science and technology.
1st Science, Robotics , Environmental Education, Technology and Innovation Exhibition (Expocreati), and 4th Programming and Robotics Contest	04-15 years-old	Expose the projects carried out by students of municipal schools in Manaus
North Student Fair	14-18 years-old	Expose careers and professions to high school students, assisting in choosing the course undergraduate.
2sd Digital Pole Fair	from 18 years-old	Exhibiting universities and companies for students and professionals in the field of science and technology.

When looking at the several groups playing the ParPow W-STEAM card game during the events (Table 4), it is possible to see in Table 5 where the pillars of computational thinking are identified in the act of playing.

Table 5. Chart relating aspects of the pillars of computational thinking in the act of playing ParPow.

Abstraction	Abstract the color of a symbol or category and identify the identical figure on another card.
Decomposition	Identify a group pattern, color or size to solve the problem as quickly as possible.
Algorithm	Set of steps to find the identical picture (analyze colors first, identify by group or eliminate a player).
Pattern Recognition	Search for the same symbol and recognize the identical figure on another card.

During the exhibits shown in Table 4, the groups of each age group presented different perceptions according to the four pillars of computational thinking. Children between 6 to 8 years old showed difficulty in abstraction to recognize the figures because the colors are characterized by theme and an object known in everyday life did not have its usual color. However, children aged between 8 and 12 years old, found it easier to abstract the images, however, they had difficulty in recognizing patterns, that is, recognizing the identical figure in the opponent's card. Students over the age of 12 found no impediments during the game and showed more competitiveness than younger children. Figure 3 shows students and participants in technological and scientific fairs playing ParPow.

Fig. 3. Some pictures about the experiments carried out at science and technology fairs. Author's source.

It is noticed that the students concentrated on larger figures and sought the combination in their colleague's letter, being characterized by the Algorithm pillar previously seen in Table 5. However, the minor elements were recognized last, only in cases where the player has identified the major element in his card and was looking for the combination in the cards of the other players.

Some difficulties in the gameplay were also noticeable, such as the fact that some elements are unknown to some players, such as test tube, graph, Hanoi tower, and the abacus. On the other hand, after playing a few times, it was noticeable that at each game the students understood and learned more about the elements according to which they exercised the pillars of computational thinking. Besides, most of the students wished to learn about women's projects in the exact sciences exhibited at ParPow and to learn a little about the mathematical theory behind the game. Besides, a portion of the students and parents who knew the game asked for the possibility of purchasing or samples. Some educators also attended one of the exhibitions and were interested in using the game in schools with the purpose of teaching geometry and combination.

The category of women STEAM projects provided greater knowledge for the Cunhantã Digital project volunteer team, as many of them did not know about other projects related to the STEAM purpose. At one of the game's exhibits, volunteers from other projects felt represented in the game. With this representation, the game was publicized on the social networks of the projects present in the cards, as an incentive to know the gameplay and the understanding of the computational geometry and combinatorial theory.

6 Concluding Remarks

The card game ParPow addressed aspects of Women in STEAM (Science, Technology, Engineering, Arts, and Mathematics), exploring several dimensions. The proposal for thematic categories made it possible to revisit: W (Women) STEAM projects; W-STEAM card and other board games; Amazonian culture; education; and science in general. The game is based on math-computational theoretical concepts, such as computational geometry and combinatorics, being an intersection game, and having commercial versions called Dobble and Spot it.

In this way, ParPow was accepted in the community and promoted STEAM knowledge in computational geometry, combinatorial games, computational thinking, and program coding for the students responsible for the development of this game, but also for those that promote the exhibition at the educational and technological fairs, and who those to receive the information and played the ParPow w-steam card game, allowing different people of different age groups to contact with W-STEAM contents, stimulating the computational thinking of those who teach and whose plays, in addition to providing space for girls to be heard by several different audiences talking about the importance of more women in STEAM.

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