

Action Research applied to design of environmental educational games

Renato Berlim Fonseca

Brazilian Agricultural Research Corporation - Embrapa

Brasilia, DF

renato.berlim@embrapa.br

ABSTRACT— This paper intends to describe the development of an Educational Board Game. It was designed to raise awareness of and teach some punctual topics of an important Brazilian environment called Cerrado. As the theme of a dissertation, prototypes were developed through the convergence of action research, a model of research in education and the playcentric approach proposed by Fullerton [1]. This convergence was employed to support game development and avoid some typical pitfalls of educational games. Firstly a brief literature review about action research and some game design pitfalls are presented. After that, the research structure: claims, participants' profile, data collection methods, data analysis. Then some of the most important points collected from game sessions and further discussions are presented, followed by conclusion and suggestions for further research.

Keywords— *game design; education; playcentric; action research*

I. INTRODUCTION

This article describes the development of a board game aligning action research and Fullerton's [1] playcentric approach in order to develop a board game about Brazilian Cerrado. This research is part of a MSc. dissertation presented at University of Southampton by Fonseca [2], the illustration process was described at another paper [3].

The proposal was designed through a framework of game design according to the principles of instructional design as suggested by Becker [4, p.6]. The prototype evolved from action research where opinions, beliefs and expertise of participants about their experience playing the prototype were employed to support its development, which agrees with Fullerton's [1, p.249] proposal of game testing as one of the most important activity in game design and McNiff et al [5, p.19] views of action research as a way of improving practice. This model of research was employed to improve the game; through qualified game player's insights, the discussions after each game highlighted problems and possible solutions for further prototypes. Game features shaped by participants' intervention are alleged able to avoid some pitfalls commonly found in educational game design.

Buckingham [6, p.143] observes a variety of basic formulas to make learning engaging through a mix of education and entertainment. Becker [4, p.10] considers some of these educational solutions deficient in the features that make commercial games so appealing. Thus, much of these ineffective educational games can be considered a result of this shallow understanding of games by teachers and instructional designers; a trend also pointed out by Mattar [7, p. 47, who observes a conceptual conflict between instructional design and

game design, concerning the nature of educational games. In his book, Mattar presents a literature review describing the argument between game and instructional design. According to him, these highly structured approaches are too objective and do not make room for creative work. The outcome is the "cookie-cutter" traditional instructional systems which hinder some game features such as motivation and engagement.

A possible solution lies in Fullerton's [1] playcentric approach. As games are systems based on interaction, their dynamics can be understood and developed under the players's input. The author[1, p.78] considers play-testing as one of the most important activity within a game project. More than a mere validation, testing the systematic practice of play is part of the game's conception. Under an educational perspective, the experience of play allows insights and improvements needed to underpin game design because players must easily learn the game goals and targeted knowledge, skills and attitudes required to win. However, a research model was also needed to offer a systematic tool to develop the game. This model should be exploratory, as the problems related to designing a game about Cerrado were not clearly defined; as well as qualitative, as most data were not numbers.

II. RESEARCH MODEL: ACTION RESEARCH

McNiff et al [5, p.19] define action research as an intervention in personal practice in order to improve it, driven by educational values. Thus, action research requires a constant process of action, reflection and reaction based on previous findings. "It is an enquiry by the self into the self, undertaken in company with others" [5, p.15]. It is a systematic study intended to improve practice and planned to fill the gap between research and practice [6, p.297-298].

Action research is largely employed by educators as a way to allow them to improve their practice [9]. Differently from other methods, it aims at intervention and change, encouraging people to take action. Some authors [8 p.298] argued that action research is more than mere problem-solving. According to them, this model involves political and social dimensions, which is close to the definition of problem-posing as presented by Freire [10, p.70], which assist some requirements of Environmental Education (EE) [11], [12]. In action research, research definition, aims and methodology may eventually be altered during the process, as a result of participant's intervention. It seeks to improve the quality of human action.

This model is peculiar to the relationship between researcher and participants, because the player is not a sample

or object of research but an active agent. Researcher intervention also shapes the object of research. The researcher role is similar to the teacher in interactive learning techniques, as a facilitator rather than a controller.

A. Claims

Is it possible to improve an educational game applied to environmental education through action research? Which advantages, problems and improvements were observed by participants based on their experience of play game prototypes?

B. Participants

The players, as research participants, are chosen by their knowledge, mind-set and skills to build up the intended game. So, participants with specific profiles were needed.

Two different profiles of participants were originally defined: first, environment experts with specific knowledge of Cerrado, to define technically correct content and to observe if the game would be a proper simulation of the Cerrado ecosystem; the second profile is composed by experienced players with a view of different board games and videogames, brought to analyze and offer findings of the game play. However, as the project advanced, a third profile was included: people with expertise in environmental education. This profile was essential to validate content and offer an educational perspective [3].

Although these groups are not the target population for the game, which is intended to involve students from elementary school, their views offer some advantages, such as detailed and qualified guidance based on their expertise. Thus, three different aspects can be triangulated from this action research: content about Cerrado, learning and game features. Nevertheless, tests with the actual target population are strongly recommended for further research and game improvement.

C. Data Collection Method and Ethics

The intended data was collected during and after the game sessions, with further group discussions. The data collected, their speeches and notes were recorded and converted into written text or images [3].

The use of audio/video records may raise ethical questions about confidentiality among participants. In order to fulfil ethical issues, all participants have been warned about the recording and have signed authorizations when requested. Confidentiality was maintained as the recording was not shared beyond research purposes or publicly disclosed. The participants were advised that their real names would have been changed to maintain their anonymity; results would be published as part of the dissertation and the final report would be made available electronically to any participant who requested one.

D. Data Analysis

The analysis of collected data, their speeches and notes taken during game sessions and interviews were based on Bardin's method of content analysis. This method is indicated due to its efficiency to get data from qualitative methods, such as interviews or discussion groups, with rich and complex speeches [13, p.89]. This method splits the speech in elementary context units (ECU) as indicators and groups them in categories

to support inferences about the subject. Bardin recommends this model to observe the beliefs of participants through their speech. Under the current content, it aims to raise possible game improvements and problems from participants' view. The data was obtained essentially from answers, questions were dropped from corpus and it can be analysed under three different units: lexical, where words are the basic unit; semantic, focused in the way of combining words and classifying them within sentences; pragmatics, which involves contextual meanings of sentences and paragraphs, where interviewed intentions can also be observed. These units are important to define any bias and support content categorization which can be done before (*a priori*) or after (*a posteriori*). As this is an exploratory study, categorization *a posteriori* was employed in order to avoid eventual loss of meaningful data. Most data collected from discussions were classified according to topics defined a posteriori and split in elementary context units (ECU) as presented on further tables. Nonetheless, Bardin's method was subsidiary to analyse data. ECU's and further categorization was employed to isolate and define the most discussed topics during sessions. Categorized data were also read and analyzed under a qualitative perspective in order to define their application on subsequent prototypes. Tables 2 to 5 present samples of such analysis. The last column focused on problems and suggestions as the objective was to support game improvements.

III. GAME DESIGN FRAMEWORK

This project followed a framework based on an overlap between game design and instructional design. So, the game was framed as if it was intended to teach, observing it under an instructional design perspective, which was a solution to bridge participants (educators, experts and game designers).

The basic curriculum needs have been observed; Cerrado, its threats and EE have been defined, followed by a definition of content needs. This was performed among Cerrado specialists from Embrapa, in order to observe learning needs and outline objectives. These learning objectives are based on Bloom's taxonomy. Although there are other options and this taxonomy is not originally designed to games, Becker [4, p.5] recommends it because it is well known, largely accepted and reasonably comprehensive as it includes knowledge, skills and attitudes. Borges et al. [14, p.286] recognize empirical investigations to support this taxonomy and its use to assist instruction's planning.

A. Initial Conception

In order to suit game narrative needs and support a further game design phase, a commercial game was chosen as reference to support the development of rules. In this case the choice fell over a German game called "Carcassonne: Hunters and Gatherers" (CHG) -a tile-based game of construction designed by Klaus-Jürgen Wrede. The choice was made due to its specific features, such as: cooperative moments, which enhance cooperation among participants, and mainly because players get points assembling a map according to the terrain and occupy it; this game addresses some

TABLE 1: EXAMPLE OF LEARNING SITUATIONS, GAME RULES AND EVALUATION STRATEGY UNDER THE PERSPECTIVE OF INSTRUCTIONAL DESIGN [2].

Educational media: Table board game			
General objectives <ul style="list-style-type: none"> To list different kinds of vegetation found during the game, highlighting their differences To describe the impact of floods and fire over different kinds of vegetation To explain the importance of watershed vegetation comparing with areas without vegetation 		Domains (Boom's taxonomy): <ul style="list-style-type: none"> Cognitive domain, objectives linked to knowledge, understanding and analysis. Affective domain, objectives related to the receptivity and appreciation of the Biome 	
<i>Specific objective</i>	<i>Strategy, instructional procedures</i>	<i>Instructional tools: game rules</i>	<i>Learning assessment: During the game the player should be able to:</i>
show impact of fire	show fire as a natural feature with different impacts over the environment	fires expel the follower of its terrain. This abandoned terrain may be occupied by any other player as soon that fire ends. A headwater or river protects the player from fire effects	recognize fire as temporary and its impact
show impact of rain and flood	show rain as a natural feature with different impact over the environment	occupied slopes suffer landslides, -2 points for each area of hillside occupied in case of rain. To avoid it the player must occupy the area but not use it. The player must mark the slopes and these points will not count for the player	recognize the diverse impact of rain over Cerrado
describe ecologic corridors as positive	create situations to show ecologic corridors	If there are forests at a distance equal to or smaller than 1 tile, both forests get +2 points.	create ecologic corridors on their own or collaboratively
describe cooperative moves during game	offer options of collaborative strategies as a win-win situation	woods and fields can be occupied by more than one player. In which case both have the same negative and positive points	create collaborative situations

issues about occupation and use of soil as observed by Ratter et al [15, p.229].

The game Carcassonne can be considered a mix of puzzle and strategy game. Based on game definitions and their possibilities in terms of education suggested by Frazer et al [16, p.893], as a puzzle it offers a clear provision of goals, opportunity to contextualize information well and it is deep immersive; as a strategy game it is good to express information clearly, working well alongside classroom teaching and allowing space to improve reflection. According to BoardGameGeek [16] the reference game is a game of area control and influence made by tile-laying; as it involves area control and influence, it is possible to suggest an affordance with a strategy game. Players get more points as soon as their understanding of rules and terrain improves. Based on this idea, it was possible to propose a hypothesis: if terrain types could be changed to match an ecosystem's behaviour, it could be possible to engage students to understand a simplified version of its behaviour. Thus, participants can achieve desired learning objectives through game.

After choosing CHG as reference, there was a meeting involving designers and ecosystem experts. After a short presentation about educational games, some findings drawn from literature review and the desired learning objectives were presented and discussed. Some changes to fit the game and some curriculum needs were observed by specialists. After that, the game CHG was played and some reflections about its suitability to attend

to environmental and learning needs were discussed.

Regardless the first proposal to start the action research in the play-test phase, the research actually started in these early meetings. Correlating with the frameworks presented by McNiff et al [4, p.58], it was possible to observe some features pointed by them happening there, such as: identification of the objective of review, in this case learning about the environment; a search for aspects to improve, questions to be solved and the planning changing according to the findings; and it happened through constant dialogue and evaluation. Thus, more than a model, action research is a path of collaborative learning through practice. Even if detached from play at this phase. McNiff et al [5, p.59] observe the need of identifying problems and taking action through the empowerment of participants. This agrees with Hale [11] and Dias [12] approaches about environmental education.

So, based on that game session, the environmental specialists proposed a lecture to brief the designer about the ecosystem in order to include the content within the game narrative. This lecture converges with those specialists who have different backgrounds: biology, soils, ecology, sustainable development etc. During that lecture, some of the most common misunderstandings about the Cerrado were presented and possible in-game strategies were discussed. Those meetings became essential to establish the dialogue practice needed and their first outcome became the design of the first version of rules.

However, addressing the content about Cerrado within the game has soon become a difficult task. There were more

than twelve different kinds of vegetation, influenced by soil, weather and human action; to insert all these factors as rules was risky because they increased game's complexity and timeframe, possibly out of the target public profile. Soon it became clear the difficulty to define how the content would be presented in-game. Therefore, the solution relied on mapping different learning situations, based on Becker's [4, p.6] proposal of game analysis under the lens of instructional design. The content, composed of background studies and the expert's proposals, was presented in form of learning needs and aligned as clear goals, a formal element of games as demonstrated by Fullerton [1, p.256]. Subsequently these learning objectives were converted into learning strategies to facilitate the development of learning procedures presented as game rules and tools. Those were added by other forms of assessment designed to work in the game's context. This map of learning situations became an instrument to manage the project in initial phase, allowing participants to share their views over the same construct, a place where information and contradictions were observed and the overall game's internal cohesion constructed (Table 1).

B. Prototype Interface

As observed by Fonseca [2] a game is a system based on interaction, so an interface to let participants interact is essential; this interface should be environmentally correct enough to describe content, as well as beautiful and interesting enough to motivate and involve participants. But in the present case an interface was still to be developed based on participants' remarks. Thus, a basic interface based on polygons and colors was designed to allow players to interact and offer data to underpin progress to advanced illustrations. Final illustrations were separately designed supported by environmental experts and validated by experienced players group. Later on, these illustrations were incorporated in advanced prototypes [3, p.83].

IV. PROTOTYPES

Fullerton [1, p.248] recommends play-testing as a practice throughout the design process to gain insights about how the game works and evolves. Thus, the first tests were informal, in order to produce a first workable prototype. The designer "runs" the game system in order to make the first prototype workable; this is recommended in the foundation stage to experiment the game fundamental concepts. As a practice following the whole process, self-testing or testing with confidants were frequently run to experiment or tune specific features. These tests were run informally due to time and resources constraints, but all changes were tested at formal game test sessions. The following items describe the most representative game-test sessions of 10 game teste sessions [3] following the structure presented at item II.

A. First Game Session with Cerrado experts

The first session involved the group of environmental specialists from Embrapa, Brazilian Agricultural Research

Corporation, to analyse content embedded in the game. Gathering this group in one occasion was something difficult, due to participants' tasks and priorities in life. Based on previous meetings with them, it was possible to infer a trend to overanalyse interface and visual aspects rather than observe game rules. Therefore, the prototyped basic interface was useful to keep focus on rules and game dynamics. At that moment, the main goal was to examine if the game rules behave as an acceptable simulation of the referred ecosystem.

The session started with a briefing: research background was presented and objectives and authorizations were signed. Followed by a description of how the session was organized and the game rules. They were advised to play and only after the game discuss about their experience and how the game could be improved. During the presentation, a few questions about rules were asked and a bit of over excitement to play the game was shown. As the game started, more questions arouse, which required more facilitation; thus, there was higher researcher participation during this session. After some time the need of facilitation decreased as participants became more familiar with the game interface and rules.

However, this session ended suddenly as most players simply considered themselves satisfied. Despite having been asked to finish the game or proceed to discussion phase, they simply denied it, claiming lack of time. At the same time, all of them praised the experience and, despite criticism, considered the game a very promising proposal. Thus, the discussion was cancelled by their unwillingness to continue the meeting and later interviews were proposed to get their views about the experience. Due to the difficulty to gather participants, they were individually interviewed days later, which hindered findings due to distance from the game session. Based on the absence of an after-game discussion, the researcher opted not to employ Bardin's analysis. However, based on the observation of their experience of play and comments, some common points were observed, such as: complaints about river tiles. According to them they were closer to European forests rather than Brazilian Cerrado; lack of similarity between the proposed scenario, a farm, and the real version; unbalance of different vegetation and disagreement about the scoring system.

In general, this group presented itself as meticulous, critic and very focused on Cerrado details. They tried new tile combinations, correct according to rules, but totally different from what was originally expected, a pattern observed in further sessions. The early ending of the session could be linked to the participants' difficulty to allow time to join this research but also suggested lack of motivation to play or a need to simplify rules and make the game dynamics more interesting, which can be related to their delay to score points when game started.

In terms of learning, observation suggested that the first phase was instruction, with few participants' response. This phase was followed by imitation; their moves mimic instructional examples presented during briefing and a lot of questions about what would be the best move were asked. Soon they assimilated rules and developed their own moves. It is possible to infer that they

learned reflexively from different sources such as their own experiences, observation of other players' moves, communication among players and questions to facilitator. Soon they were doing cooperative learning, explaining rules or discussing the impact of some moves and their experience playing. The experience of play appeared to work as a "cognitive catalyst" to participants; despite instructions of only playing, leaving criticism and discussion to the after-game, some participants started to discuss about the experience of play during game, as a consequence of feeling excited about playing it, slowing game dynamics at some moments but offering rich information for further discussion.

This session also worked to test researcher skills as facilitator and help him reflect about his own experience. The constant need of facilitation during game highlighted the importance of presenting rules carefully. Even worse, excessive facilitation could hinder learning, so a space to allow participants to comment during game was necessary.

B. First Game Test with education experts

The second session happened on the same day of the first and involved a group with experience in EE. Participants were a multidisciplinary group, selected from members of the Conservation and Sustainable Use of Brazilian Biodiversity Project (PROBIO) run by the Ecology Institute of University of Brasilia and sponsored by the Brazilian Government. The project aim is to produce educational materials about Brazilian Environment and one of these materials was an educational game. Thus, this group is experienced to develop and employ EE learning tools.

The session followed the same structure as the previous one, composed by briefing, play and discussion. Some questions arose during the briefing phase, regarding game narrative and if the objective to be achieved in game was proper under an educational perspective, followed by questions about what is allowed in game. One of the participants argued strongly about the story because, according to her, it did not make much sense and it was not a good reason to encourage participants to play. After some explanations and an invitation

to the group to think about how to improve the story, the session followed to the game phase. Based on the first session experience, participants received a sheet of paper to note their comments down during the game and share them in the discussion phase. Thus, it was possible to keep their comments during the game without affecting collective game play. These notes became another source of information, some participants even made illustrated notes. However, as observed in the first session, people commented and discussed during game simply because they were excited about the subject or were discussing how to play. This game session was played without interruptions and participants played it until the end. As in the first group, features of collaborative learning were observed, as well as different learning curves among participants. The amount of required moderation reduced after some minutes, but they asked for facilitation during the whole game, most times to arbitrate about rules. Despite some participants' requests about the strategy to follow, direct answers were avoided.

After the game, there were 35 minutes of discussion, the main topics proposed were: what they considered good during their experience; what they considered bad and how to improve it. This discussion was recorded and changed into written text and translated to form a corpus of information.

The content analysis got a total of 261 ECU divided in two main categories: one is the environment and its reflects in the game, including participants' opinions about different elements in game and how the environment was shown; another is the game, discussing mainly about rules, game balance and narrative. During this session, the topics about problems and possible improvements were much interlaced: generally, a participant presented a problem; then, there would be a discussion on how to solve it and proposal of improvements. After the first categorization, there was a second one based on the same categories to define what participants considered problems or weak points during game play, with 37.1% of ECU and their suggestions to solve them, with 36% of ECU, a surprising balance of issues and proposed solutions.

TABLE 2: SUMMARIZED VERSION OF CONTENT ANALYSIS, ITEM B, GAME SESSION WITH EDUCATION EXPERTS [2].

Main Categories	Primary subcategories	Secondary subcategories	Example of ECU	Problems and Hints	
Nature and its reflects in game 144 ECU (53,9%)	Weather events	-	This dynamic (related to) rain was very good	Problems: 2 ECU Suggestions: 13 ECU	
	Rivers	-	(at Cerrado) there isn't a great amount of water	Problems: 2 ECU Suggestions: 10 ECU	
	Area recovering	-	What is the advantage of recovery (in game)?	Problems: 12 ECU Suggestions: 11 ECU	
	Ecological corridors	-	Put this (ecological corridor) in advanced rules	Problems: 2 ECU Suggestions: 6 ECU	
	Flora and fauna	Cattle		Yes, to use cattle was a bit 'complicated'	Problems: 20 ECU Suggestions: 4 ECU
		Elements with economic value		Breeding of ostriches?	Problems 3 ECU Suggestions: 16 ECU
Cerrado's representation	-		The Cerrado is well illustrated	-	
The game 43 ECU (16,1%)	Rules, its presentation and scoring system	-	The game seems to need a master.	Problems: 16 ECU Suggestion: 18 ECU	

Participants pointed the Cerrado description as a good trait, and frequently mentioned about the fragmented feature of the vegetation, a typical trait of Cerrado; the final “mosaic” [3, p. 85] composed by tiles was a good description of the biodiversity. For example, rain and fire in game was considered quite interesting due to their impact, good for players with preserved areas and bad to players with degraded areas. Their dynamics represent quite well fire and rain’s behaviour in this ecosystem and add interest to game play.

Concerning problems, participants frequently argued about discrepancies between story and rules. According to them, it was difficult to understand rules and the learning potential was hindered by the lack of contextualized learning. They also considered difficult to play without a moderator. Moreover, some animals presented in game can bring mixed messages to students: cattle, for example, are a well-know intruder and degradation factor. Thus, presenting cattle as a source of points looks confusing at best or controversial and wrong at worst, on their perspective. This discussion took 15.8% at its main category. According to them, the lack of context between elements of ecosystem and rules hindered participants’ perception of rules and affected their scores. For instance, the connection of anteaters as source of bonus points to recover degraded areas or protect areas from wildfire was considered meaningless, devoid of content to learn about and ineffective to understand rules. The outcome was few recovered degraded areas, described by a participant as “an important educational resource which was undervalued”. Less practice of recovery means fewer chances to observe the importance of recovering degraded areas or protecting environment from wildfire, an important topic to learn about. They also considered the game too complex and long to its proposed target public, and recommended to increase the minimum age to play and to group rules in order to make them easier to understand.

Comparing both meetings, environmental experts tended to see the game by its parts, looking to obtain fidelity to the original ecosystem. Alternatively, the second group members observed the game as a whole and under the light of educational purposes, considering the ways this game could be employed.

Based on comments from both groups and observation of game sessions it was possible to arise some points to design a second prototype. The balance between game elements was regarded as inappropriate due to many rivers and lack of savannahs; if the proposal was to present the importance of all kinds of vegetation, all of them should have the same values in points rather than different values, i.e. forests were worth more than savannah. Moreover, both game sessions were too long: the first session was suddenly finished after forty-eight minutes and second session took almost two hours in a game intended to take one hour at maximum. Therefore, these remarks were suggested to simplify the game, which was done by gathering similar specific rules in more generic ones, contextualizing rules through story, creating more story references in game and reducing the number of tiles. These changes required a second prototype to be tested in next sessions. This new version involved: a new balance of terrain, with less rivers; initial tiles and the biggest river were discarded, with the total of tiles reduced from 106

to 94 tiles; bonus points were changed and bounded to creation of ecologic corridors in a way to link rules and game narrative, the bonus was described as a resource to recover vegetation, and offered due to creation of ecologic corridors; thus, content was transformed in rules and contextualized in the game’s story.

C. *Second Game Test with Cerrado experts*

This session involved environmental experts from Embrapa. They were presented to session’s structure, with presentation, game session and discussion and advised not to leave the session before the discussion. This time a report about the last sessions and new rules were presented, based on participants’ comments. The instruction phase was shorter due to their previous experience. However, new rules were highlighted and a more exhaustive presentation of rules was made. As tried in the second session, a sheet of paper was offered to participants to preserve their insights to discussion phase without affecting game play. Participants required moderation in game, usually to arbitrate rules application. Some participants shown willingness to explore new rules and the use of events such as rain and fire caused a strong impression on them. On one hand, they liked the representation of rain due to its positive and negative impacts according to players’ behaviour. On the other hand, there was uncertainty about how to apply rain effects and participants complained about the difficulty to count scored points. The score was undefined until the end, which motivated players.

Following supervisor’s advice, this time the researcher, acting as facilitator, avoided to control the session trying to pigeonhole the experience, letting the discussion flow a bit more loose. According to the supervisor, a session of action research has a little of unpredictable; over-control may obstruct participation. It has also been recommended that the researcher joined the participants during the discussion phase, as he also has points to enrich the discussion. The first proposed topic to discussion was about what participants liked and considered effective in the game, which was done briefly. But participants rapidly changed to the problems, mentioning an issue on rivers presentation in game. According to them, differently from the European environment, where the reference game was based, there were too many lakes in the game, which does not fit Cerrado’s features. Thus, they agreed on the use of falls instead of lakes, which agrees with the idea proposed in the second meeting to employ falls as source of points attributable to their potential to tourism. This similarity reinforced the proposal. Table 3 describes content analysis of the after-game discussion.

The role played by fire started a controversy among participants. According to them, the rules allowed an offensive use of fire in game because a player can put it on a terrain and expel other players and take their terrain. They pointed this as a mixed message to future players as it encourages people to use wildfires or consider them convenient; in fact, fire is employed by farmers to clean areas and frequently it turns into uncontrollable wildfires. Therefore, fire should be presented as a “bad” thing and its use should be punished, never rewarded. The researcher answered that the fire in game was shaped to be difficult to predict and frequently it worked against the player who puts it; secondly, under this model of learning, the proposal

TABLE 3: SUMMARIZED VERSION OF CONTENT ANALYSIS, ITEM C, GAME SESSION WITH CERRADO EXPERTS [2].

Main Categories	Primary subcategories	Secondary subcategories	Example of ECU	Problems and Hints
The environment and its reflexes on game 199 ECU (47,2%)	The rivers and its connections: issues about lakes and river's connectors	-	The lakes do not represent the Cerrado ecosystem well, I think.	Problems: 7 ECU Suggestions: 34 ECU
	Issues about savannah and meadow	-	The savannah should be green and the meadows yellow	Problems:19 ECU Suggestions: 40 ECU
	Suggestions about shared terrain between players	-	I would share responsibility with him towards that bigger fragment (of terrain)	Suggestions: 18 ECU
	Farm's description	-	A degraded area could show tire and plowing marks	Problems: 6 ECU Suggestions: 17 ECU
	Features of flora and fauna	Problems about flora and fauna in game		The buriti (tree) does not make sense in a savannah
scored points based on flora and fauna			It is possible to include the deer (to score points)	Suggestions:14 ECU
Game 63 ECU (14,9%)	Understanding, presentation, rule's learning and game's interface	-	It (support material) helps, but it is not enough	Problems:13 ECU Suggestions: 18 ECU
	Educational aspects	-	Because it (the player) should associate what is outside with what is here (on game)	Problems: 1 ECU Suggestions:2 ECU

was not to define fire as good or bad, this moral point would come from participants performance in game and could be addressed by further reflection; even a mistake could be used as a good source of reflection. The proposal of this model was let them play, observe consequences and reflect about them. That discussion raised two questions: firstly about the paradigm of learning applied to the game; on a behaviourist approach, the use of fire was reinforced by possible convenient consequences, but under an interactive learning approach, the mistaken action of setting on fire was an opportunity to learn. There was also a question about the role of the researcher as game designer: should he follow all participants' suggestions or use their comments as support to game development, keeping the last word to himself?

D. Second Game Session with education experts

This session involved EE experts of PROBIO project again and, as in the last session, findings and their outcomes were presented as changed rules. Due to Christmas break, there were less participants, being one of them absent from the previous meeting. At this time, the facilitator changed his approach subtly: at the first ten minutes, players were supported in game as a tutorial phase, but participants were highly encouraged to do all actions by themselves and soon they were monitoring themselves without the need of facilitation. This approach followed supervisor's advice: the facilitator avoided to control the session excessively. Thus, the discussion flowed more loosely. As anticipated by the supervisor, too much facilitation may obstruct participation and limit findings.

Having learned from previous session, this time participants were more confident about rules and relied more on other participants than on the facilitator to manage the game. Thus,

the participants' discussion about the play, which indicated cooperative learning, was more visible and the discussion about the need of a facilitator to play the game was not repeated. Some questions about rules applications came, most of them were answered with advice to read the reference card and discuss them with other players. Anyway, from this point, the facilitator frequently kept himself silent, even when they ignored rules or played against rules without noticing it. This resulted in a better view of game dynamics and choke points to be fixed on next prototypes. As example of choke points, the rule of ecological corridors and bonus points was ignored and there were no recovered areas; two hypotheses were inferred to explain this: poor rules presentation or limitation of interface.

At the discussion phase participants considered this version easier to play, due to simpler rules and a different balance of terrain, which resulted in tiles easier to connect. The starting point with a house was considered important to contextualize the idea of a farm, reinforcing game narrative, which was tagged along suggestion from previous sessions. The previously observed problem of ecological corridor was also commented by participants. Despite their agreement about the importance of teaching it, they also noticed they have not used ecological corridors; even after game there were doubts on how to create them. The participants highlighted the need of a post-game phase to analyse the mosaic created during game.

E. First Game Session with experienced players

This session involved experienced players and the illustrated version was presented, which was appreciated by players. This group was the most demanding about rules presentation, with various questions about them and their possible consequences in game. Since the beginning they have shown willing-

TABLE 4: SUMMARIZED CONTENT ANALYSIS, ITEM D, EDUCATION EXPERTS [2].

Main Categories	Primary subcategories	Secondary subcategories	Example of ECU	Problems and Hints	
The Game 228 ECU (84,4%)	Game evaluation and comments about the new prototype	-	conceptually you can identify various things (environmental elements)	Problems: 7 ECU Suggestions: 34 ECU	
	Game's learning objectives	-	The savannah should be green and the meadows yellow	Problems: 19 ECU Suggestions: 40 ECU	
	Post game reflection and its application in classroom	-	I did not recognize (the rule of close areas)	Suggestions: 18 ECU	
	History in game and narrative	Game Immersion		I felt the need for something more exciting at first, which lead me to want to build something	Problems: 13 ECU
		The role of narrative in game		you won the game but did not feel rewarded winning	Suggestions: 11 ECU
		Suggestions on the story		He (the farmer) has proposed a challenge for you (players)	Suggestions: 28 ECU
	Strategies	The designer's views about this prototype and game session dynamics		I do not know if you guys (players) realize your learning curve (during the game)	Problems: 3 ECU
		The participants' strategies during the game were described		The only thing that people thought was to open more land	Suggestions: 19 ECU
The Environment 43 ECU (15,6%)	Ecological Corridor	-	I saw that the issue of corridors was ignored	Problems: 7 ECU	
	Degraded areas	-	this would be a degraded area that has eroded	-	
	Farm's description		(the farm) would have been degraded by human activities	Problems: 2 ECU Suggestions: 3 ECU	

ness to play cooperatively, even though no advice or suggestion to encourage them to follow this path was made. It was possibly based on their expertise in other games, cooperative or competitive-driven ones. They frequently shown willingness to negotiate and all agreed to compete in a more constructive way. This cooperation resulted in close scores among players during the game. Despite the cooperation, all of them declared having played to win and the outcome was the highest score in all sessions. Consequently, competition and cooperation became a theme to further discussion, with 14.7% of all ECUs.

The first main category was the general discussion about game play and game characteristics such as balance, rules and strategy. This discussion involved 59,37% of the whole conversation and was composed by the following subcategories: a discussion about general features such as, how participants played and their feeling during the game (25.5%). As expected these participants have shown concern about game mechanics and its implications and offered insights about how they played. Like in other groups, event "fire" started a similar controversy to anterior meetings. Most suggestions approached the impact of changes in rules and how they would affect competition, randomness, strategy and learning. This group proposed an interesting solution to the issue of wildfires. They suggested a second collective score. The damage produced by wildfire, floods or degraded areas would score negative points and if a

specific point is reached the game ends and all players loose, the place would be simply unprofitable. This addition is interesting to make players experience a similar situation as observed in the tragedy of commons, proposed by Hardin [18]. This adds another social aspect in game, creating a new learning situation, a point of collaboration and an opportunity of reflection about individual and collective impact. This collective score was called "environmental thermometer" [3, p.82] and an informal test later was done to evaluate its feasibility. The second main category was related to developments of the game and the test session, involving their recommendations about how to apply the game, its balance and the post game discussions. From this point the researcher considered possible to develop a version stable enough to consider it an effective prototype; minor glitches were found and subjected for later correction and testing, but the game itself was considered functional, which does not deny the hypothesis of further evolution.

V. FINDINGS AND FURTHER RESEARCH

The experience of designing an educational game was important as it helped to observe features and limitations of educational games. As pointed by a participant at the second session: a greater number of rules describe the environment better and more accurately, but also add complexity to the game, making it more difficult to be played and less flexible to be employed in the classroom. This way, it is possible to consider a game a more

limited medium to ‘transfer’ content to students than a book or a lecture, for example. Game sessions suggested that the true learning potential of games relies on allowing learning through reflection rather than content transference. Following this path, participants also emphasized the importance of an educational context to frame the game. They recommended a reflexive session after the game to analyze the mosaics created during game, under an EE perspective. Their proposal was to analyze the terrain created during game under different “lenses”. It is possible to see the mosaics under different perspectives, such as vegetation, soil, human impact and others, forming different learning situations. Additionally, that reflexive session opened space to players discuss their decisions and acts during the game and evaluate consequences beyond the game goal. This idea was incorporated in further sessions, appreciated by newer participants and recommended for further application. This reinforces the idea of games as environment of learning rather than media

or tool to induce learning. It can be used to frame games together with other learning techniques. Further research is advised to analyse the best situations to employ games to support learning in and outside classroom.

The observation of game sessions suggested that learning happens at first to understand rules and, despite competition, players do it cooperatively, which supports Rapoport’s [19, p.9] idea of a hidden layer of cooperation even in a competitive game. The drive towards competition and cooperation varied according to game sessions, which suggests that competition does not exclude cooperation. Participants revealed willingness to help other players to understand rules and frequently suggested moves or corrected wrong manoeuvres. Some specific rules such as shared occupation and collective score acted as an opportunity to make players negotiate and cooperate without jeopardizing the competition. Thus, the experience suggests that competition and cooperation in game are not

TABLE 5: SUMMARIZED CONTENT ANALYSIS, ITEM E, EXPERIENCED PLAYERS [2].

Main Categories	Primary subcategories	Secondary subcategories	Example of ECU	Problems and Hints	
The Game 209 ECU (59,37%)	General features	-	conceptually you can identify various things (environmental elements in game)	-	
	Suggestions about game play	-	Maybe you could include a visual ad explaining how to create an ecological corridor	Suggestions: 23 ECU	
	Factors related to game duration	-	You can include a new rule: the first to reach 50 points wins	Problems: 2 ECU Suggestions: 16 ECU	
	Score	General features		The score has an interesting effect because a child will have to calculate the score	-
		Strategies employed to score points during the game		I was gambling a lot when this tile came	Problems: 5 ECU
	Rules, general features	-	Rules are better now	Suggestions: 2 ECU	
	Rules, specific features	Rain		That rule of rain scoring points to everyone is super cool	-
		Area recovery		We worked hard on recovery and the consequent damage was minimal	Suggestions: 2 ECU
		Fire		Fire was not a problem due to a circumstance of this match	Suggestions: 3 ECU
		Fitting Tiles		That way you can close a more compact terrain	Suggestions: 12 ECU
		Rivers		Frequently the rivers at Cerrado are more linear than this	Problems: 5 ECU Suggestions: 2 ECU
Game effects 143 ECU (%)	Competition x cooperation	-	This group had a collaborative spirit	Suggestions: 9 ECU	
	Strategy x randomness	-	The randomness in game is high	-	
	Learning	-	We are doing experiential learning here (in game)	Suggestions: 3 ECU	
	Content embedded in game	-	I would recommend this game for players older than eight years old due to the amount of data that must be managed	Suggestions: 2 ECU	
	Post-game discussion		Most learning will happen at this stage	-	

necessarily exclusive. Further research could analyse if this “constructive competition” really happens and measure its impact.

Game sessions also suggested that players learn dynamically from different sources, such as their own experiences, observation of other players, communication among players and questions to facilitator, which is convergent with Dyke’s [20, p.307] diagram of reflexive learning. The act of playing the game seemed motivating to participants. Despite having received instructions to just play and leave critics and discussion to the post game phase, some participants started to discuss about the experience of play during game as a consequence of excitement. That resulted in a slow game dynamics at some moments, but also in rich information to further discussion. Another point demanded by participants was the balance among rules, interface and story; there was controversy about unreal rules according to the proposed story or the ecosystem’s representation, which were considered problematic to enable players’ immersion and to offer a meaningful context to their learning. Game story is an element as important as the interface to contextualize the learning. According to them the effectiveness of an educational game is a balance of content, learning and game play.

Additionally, the game created at this work can be seen as a research instrument on game-based learning, offering options to a wide range of further research. It is necessary to: evaluate whether actual students learn or not based on the game; define what they learn; and measure it. A deeper study is needed to evaluate if there is a change in knowledge and attitude concerning the Cerrado as a consequence of play. The proposed game mechanics opens the possibility of a modular development, enabling the creation of new games with other themes. Participants pointed out this potential by suggesting themes such as sustainable development, hydrology or geology. The development of other games based on this work would be also important to define a framework to design educational games, which is applicable to the development of board games, so as videogames. As recommended by Duarte [21] boardgames can be employed in videogames development to improve prototyping.

REFERENCES:

- [1] T. Fullerton, *Game Design Workshop: a playcentric approach to creating innovative games*, Burlington: Morgan Kaufmann, 2008
- [2] R. B. Fonseca, *Developing an educational game applied to environmental education through action research: a game about cerrado*, Dissertation, United Kingdom: University of Southampton, 2011.
- [3] R. B. Fonseca, C.R.A. Delamare “Desenvolvimento de Ilustrações para um Jogo Educativo sobre o Cerrado Brasileiro através de Pesquisa-ação” Brasília: SBC - Proceedings of SBGames , Art and Design Full Papers, 2012, pp.77-86
- [4] K. Becker, “Classifying Learning Objectives in Commercial Games”. Proceedings of CGSA 2006 Symposium.[online] Available in <http://journals.sfu.ca/loading/index.php/loading/article/download/2/14>, June 2010
- [5] J. McNiff, P. Lomax, J. Whitehead, *You and your action research project*, 2nd ed., London: Routledge, 2003
- [6] D. Buckingham, *Beyond Technology: Children’s Learning in the Age of Digital Culture*, Cambridge: Polity, 2007
- [7] J. Mattar, *Games em Educação: Como os nativos digitais aprendem*. São Paulo: Pearson, 2010
- [8] L. Cohen, L. Manion, K. Morisson, *Research Methods in Education*, 6th ed., Oxford: Routledge Falmer, 2007
- [9] R. Harris, *Action Research’. Institutionally-Based Research and Enquiry-10890* [Online] Available at: http://blackboard.soton.ac.uk/@/A4EEEE9224291613B5440672CEF5674D/courses/1/EPI/content/_1213996_1/T%AR%talk09.ppt, February 2010
- [10] P. Jarvis, J. Holford, C. Griffin, *The Theory & Practice of Learning*, 2nd. ed., London: Koogan Page, 2003
- [11] M. Hale, *Ecology in Education.*, Cambridge: Cambridge Press, 1995
- [12] G. Dias, *Fundamentos da Educação Ambiental*, Brasília: Universa, 1992
- [13] L. Bardin, *Análise de Conteúdo*. Lisbon: Edições 70, 1977
- [14] J. Borges-Andrade, G. Abbad, L. Mourão, *Treinamento, Desenvolvimento e Educação em Organizações e Trabalho*, Porto Alegre: Artmed. 2006
- [15] J. A. Ratter, J. F. Ribeiro, S. Bridgewater, “The Brazilian Cerrado Vegetation and Threats to its Biodiversity”. *Annals of Botany* 80 : 223-230 [online] Available at: <http://ecologia.ib.usp.br/ecovegetal/leituras/Cerrado%20charac%20and%20threats%20Ratter%20et%20al%201987.pdf>, May 2010
- [16] A. Fraser, D. Argles, G. Wills, Gary, “The Same, But Different: The Educational Affordances of Different Gaming Genres.” Proceedings of the Eighth IEEE International Conference on Advanced Learning Technologies. 891-893.
- [17] BoardGameGeek German – style game. [online] Available in: <http://www.boardgamegeek.com/wiki/page/glossary#toc82>, July 2010
- [18] G. R. Hardin, *The Tragedy of Commons* [online] Available in <http://dieoff.org/page95.htm>, february 2011
- [19] A. Rapoport, *Fights, Games and Debates*. Ann Arbor: University of Michigan Press . 1960
- [20] M. Dyke, “An enabling framework for reflexive learning: Experiential learning and reflexivity in contemporary modernity”, *International Journal of Lifelong Education*, 28: 3, 289 — 310. 2009
- [21] L. C. Duarte, “Jogos de Tabuleiro no Design de jogos Digitais” Brasília: SBC - Proceedings of SBGames , Art and Design Full Papers, 2012, pp. 132-137