Designing a Math Game for Children Using a Participatory Design Experience

I. Rodriguez, A. Puig
Applied Mathematics and Analysis
University of Barcelona
Catalonia, Spain
inmarodriguez,annapuig@ub.edu

S. Grau
UScience Tech
University of Vic
Central University of Catalonia
sergi.grau@uvic.cat

M. Escayola
Escola del Mar
Barcelona
Catalonia, Spain
montserrat.escayola@gmail.com

***Abstract*—Today teachers have in their hands learning resources, such as games, to engage primary school students in dry subjects. Nevertheless, many of these games have a mechanic very similar to in-class exercises, e.g., question -answer and match up images. Then, children end up boring. In this research, we aim to design a game for and by children. We present results of two Participatory Design (PD) sessions performed with children of 6th grade of Primary School to jointly design a game about fractions. The experience has been very fruitful both for us and for children. On one hand, they had an exciting experience as game designers, enforced their learning about fractions, and contributed with numerous and diverse ideas. On the other hand, we have co-created a game with enthusiastic stakeholders. Additionally, this research constitutes a further step in the study of methodologies and techniques of participatory game design with children. As a result of our experience we can say that participatory sessions with children should be very dynamic, with well-differentiated parts and using very different activities. We have used individual brainstorming using post-its, brainstorming and discussion in groups. We have also organised written activities, which seem to be adequate, provided that children have templates to be filled with ideas related to elements and mechanics of the game. We observed they showed really concentrated in these writing activities. Those parts of the participatory design that required the use of computers were the most appealing for them. Moreover, teachers and designers should pay attention and give children positive reinforcement regularly in order to avoid distraction during the PD sessions.**

Keywords–Serious Games;Participatory Design;child-computer Interaction.

I. INTRODUCTION

Learn by doing is already here, we can find a myriad of learning resources, which aim to provide the learner with more engaging and fruitful experiences, i.e., simulations and games [1]. Nevertheless, if we ask students to play games, they sometimes get bored and frustrated after some poor gameplay, mainly because is difficult to qualify them as ”real games” but as mere interactive quizzes.

What if we allow students to actively participate in the creation of these gaming experiences? [2][3] [4] After all, children are ideal partners for co-design mainly because they have grown with the technology and their game literacy can undoubtedly trigger the generation of creative ideas during the design process. Moreover, a psychologic study states that children today are more imaginative than those decades before [5].

Through participatory design, this research aims to bring together the worlds of designers and children in an effort to design more engaging and satisfactory games for learning. In particular, we focus on a dry math subject, fractions, which is difficult to grasp by children, as stated after some discussions with teachers of primary school of Escola del Mar in Barcelona. We thanks them for their participation.

Participatory design approaches may follow either a germinal method, where participants start the design from scratch, or a transformational one, where the design team creates an initial proposal to present to the users. In this research, we have followed the transformational method, initially presenting a basic rationale of the game concept to children and incrementally introducing them four game design tasks: characters and game settings, activities these characters may perform in the game, metres influencing both characters and environment state, and then translate learning goals into game mechanics (i.e., challenges creation).

These design tasks have been scheduled in two participatory sessions which have taken place in students' classroom. Participants of the study had already worked with fractions a few months before. Therefore, some of them could be considered ”experts” in the concept of fractions, favouring the generation of well founded and quality ideas. The results of the participatory design experience are fruitful both for us and for children. From our point of view, we have a game designed by and for children and have defined a methodology to be applied and refined in future experiences. From the perspective of children, they had a new experience as ”game designers”, and they went again over fraction concept, achieving a better grasp of their learning.

This paper is structured as follows. Section II presents the state of the art. Section III describes the steps in the participatory design. The discussion in Section IV provides a high level analysis, which results from the participatory experience. Finally, Section V concludes and gives some hints about future work.

II. RELATED WORK

Since its early introduction in the HCI field, Participatory Design (PD) has been a topic of study in the research of software and hardware design [6] [7]. Concretely, child-computer interaction has raised the attention to PD in the design of serious games for children.

In the serious game literature, several works present methods, experiences and results when involving children in all the stages of design process, with a variety of interesting results [3] [4]. Games range from those focused on emotional intelligence [8], collaborative storytelling [9], social skills [10], and social inclusion of children with disabilities [11].

A common concern raised in these research studies is the lack of children's domain content familiarity and game design literacy. Domain content familiarity depends on students back-

 ISBN: 978-1-61208-440-4

ground, and, if missing, it can be afforded either by previous basic training or by selecting user groups who adapt well to demands of PD sessions. Another key issue that is considered of great importance is to tightly couple domain content to game mechanics. In this research, we have focused on the intrinsic metaphor as introduced by Fabricatore, where player's cognitive tasks are related to the learning objectives and are relevant to achieve the goal of the game, thus being part of the activities of the game [12]. Moreover, nowadays we find a lot of children with a high degree of "game literacy", which although not being "game design literacy", can be enough valuable if participatory sessions are adequately focused and conducted.

Additionally, many of these works see the significance of the results centred in two aspects: the actual contribution of participants to the design of the game, and a very valuable domain experience gained by participants.

Related to PD methodologies, a recent research describes two case studies of a game intended to teach primary school students conflict resolution skills [2], each of them using a different PD method. In the first case study, they apply well-known germinal (i.e., generating ideas from scratch) PD methods, such as brainstorming and storyboarding, to support the generation of children' ideas in the early steps of game design. In the second one, they follow a transformational method (idea generation by modifying existing solutions) for involving children in middle steps of serious game design. Results on the former case study were not as positive as expected, mainly because of the limited domain knowledge of children. Nevertheless, children in the second case study proposed manifold and useful ideas on game mechanics and its relationships with the conflict resolution issue (learning objective). As stated before, our research follows the transformational method.

III. Stages on the design experience

We have followed the three basic stages of participatory design [13]: the initial exploration, the discovery process and the prototyping. The first stage, to know and learn from stakeholders (teachers and children), and second and third stages to elicit narratives and mechanics for the game from students, and create a lo-fi prototype of the game, respectively. Nevertheless, as will be introduced in the description of PD session 2, we did not arrive to define the prototype of the entire game, but fractions challenges which will form part of a gymkhana in the first game level.

A. Initial Exploration

We started this research work with some meetings with teachers in the school Escola del Mar in the city of Barcelona (Spain). They expressed us their concern about the difficulty on engaging students in specific math concepts. Particularly, they currently struggle on teaching the basic concept of fractions using physical objects like cords and wooden sticks, [14] and they would like to use other technical media, such as computer games. Nevertheless, available games do not fulfil teachers' expectations, mainly because they usually are really similar to those exercises performed in the blackboard, not favouring students' engagement.

We used existing fraction games to gather data (opinions, desires and feelings) from children. We met children in school labs and applied conventional contextual inquiry methods for user and task analysis, i.e., questionnaire, observation and interview.

The participants were 6 children of primary school, with ages between 10 and 12 years. Some of them had studied fractions in the previous academic year, and others had just learned the concept and basic operations with fractions.

The design team consisted of one moderator and one note taker. The study was performed individually for each student. The moderator welcomed and thanked each child for participating in the study, explained the goal of the session and what we wanted him/her to do. He also explained that the study was not an exam, but a way of getting his/her opinions and feeling about the games.

The protocol of the session consisted in three main steps: pre-gaming questionnaire, playing games, post-gaming questionnaire and short interview. In the playing game step, meanwhile the child was interacting with the game, the observer took notes. We encouraged them to think aloud. Although not all of them were able to do it, those who expressed their feelings while playing, did it pretty well.

In the pre-gaming questionnaire, we asked children general questions about their habits and likes about games: how frequently they play computer games, how many hours per week, what kind of games they like more (RPG, adventure, sport, others), how they get more fun in games (overcoming either their record or friends' scoring, living adventures, achieving levels), their preferences on play mode, either individually or multi-user. The post-gaming questionnaire included questions directly related to just played games. We asked which game they preferred and why, which one they did not like and if they thought that playing these games they would learn more about fractions. We also asked them to score the played games.

We selected four fractions games, which are representative of those we can find in the market. They differ in the metaphor, setting, story, graphics and sounds. Nevertheless, all of them share a common mechanics consisting of either questions or fractions matching.

We gave the children the following games (see Figure 1) about fractions: pipo club [15], fraction booster [16], Melvin's make a match [17] and Problem solving [18]. All these games work around fractions' basic concept and equivalent fractions.

The first game, pipo club, shows an image of the sky with three airplane parkings. The child is the pilot of the plane which must answer a question about fractions, if done correctly, he/she parks the plane in the parking, if not, the plane crashes. The second game displays a pizza and the player has to answer questions related to pizza portions. It has 5 different levels, and each level has several sublevels. The theme of the third game is witches and magic potions. There is an image of a shelf with bottles displaying fractions or figures with shaded parts. The player selects pairs of bottles/figures that represent the same fraction (equivalent fractions). In the scale displayed below, he/she can see if they match correctly. Finally, the fourth game displays a platform with a walking lizard, it stops when there is a gap. The gap is a measure (1m , 1/2 meter, etc.) and the lizard can pass through the gap only if the player correctly placed boards. These boards have different sizes and colors, depending on the fraction that they mark.

Later, we analysed the data collected during the contextual inquiry. Pre-gaming questionnaire showed that all participants play games between 2 and 5 hours per week, and they prefer adventure and role play games. When the question was related

 ISBN: 978-1-61208-440-4

to single-user versus multiuser, the majority of them prefer multi-user games, due to the competitive aspect of existing games.

After analysing the post-game questionnaire and observer notes, taken meanwhile children played the 4 fraction games, we draw on the following conclusions. Children like games with sounds or messages that encourage them to make further progress in the game, a fact corroborated by Reeves and Naas who found that computers that flatter and praise users in education software programs produce positive impact on them [19]. Children also like to have a guide or a clear indication of the target, if not they feel lost and lack interest in the game. Additionally, they do not want to answer all the time similar questions with similar format. At the time of playing they wanted to go changing between different screens, having new characters and new challenges about fractions. Some players, those who had just learned about fractions, wanted puzzles enough simple to be able to solve, but not extremely easy, some of them said "that's so easy...". When children were asked about if they got fun with the game, most of them answered "well .. not much".

The games better scored were Problem Solving (lizard) y Make-a-Match (magic portions) because students got more fun with them and seem to be less repetitive and less boring than others. Anyway, none of the games completely fulfilled children' expectative as they wanted to be immersed in a really fun experience and not in a serie of questions-answers similar to the exercices performed in the blackboard.

B. The Discovery process

In this stage, we worked with children to jointly design the fractions serious game. As game target audience is 9 to 12 years old kids, we selected a focus group of students with an intermediate level of fractions (sixth grade, with ages 10-11), rather than students of a higher grade that could add difficulty to game activities designed along PD sessions.

This stage was organised in two participatory sessions, which consisted of 25 children, the class teacher, three designers and an assistant. One of the designers actuated as moderator, introducing and explaining sessions' objectives and activities to be performed along the sessions. Session 1 was 2.5 hours long and session 2 lasted for 3.5 hours.

1) Participatory session 1: game conception: As previously mentioned, we have followed the transformational approach of participatory design. First, we introduced children the initial game concept - genre, goal, main characters, and scenario. Then, we elicited children ideas to incrementally add new elements to the game.

The group of 25 children was divided in 5 teams of 5 students, mixed in genre. The composition of each team was facilitated by the class teacher. Each team had a leader who had the role of team' spokesperson.

We presented children the initial game concept with slides (see Figure 2). 'The game scenario is a remote island in the middle of nowhere. Two shipwrecked players have to survive by eating, drinking, fighting and discovering stuffs in the island. Some of these actions have to be based on mathematical challenges related to fractions. For instance, players have to cut a part of wooden boards to build a bridge over a river that blocks the road. Game goal is to get away from the desert island.

We divided the session in three main parts. First, we asked

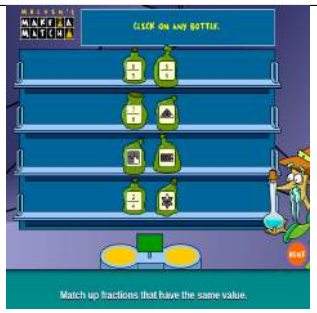
Fractions Game	Snapshot	Scoring (0-10)
PipoClub		7
Fraction Booster		7
Melvin		9
Problem Solving		9

Figure 1. Games used in contextual inquiry

them to propose objects and NPCs which may live in the island. In the second part, we asked children to think about how to escape from the island and to propose fraction-solving activities in the game. In the final part, we discussed and reviewed together emerged ideas, and we tried to obtain an initial consensus about game dynamics.

In the first part, we asked children three open questions:

1) "What kind of things do you want to find in the island?". In this case, we encouraged kids to propose stuffs that are normally in an island, but also contribute with fun and original objects of other contexts.
2) "Which characters do you want to meet in the island?". We also encourage them to be originals.

 ISBN: 978-1-61208-440-4

Figure 2. The proposed scenario: An island in the middle of nowhere and the two shipwrecked players.

Figure 3. The set of the stickers obtained from the questions about the game configuration.

3) ”If you were not a shipwrecked kid, who would you like to be?”. With this question, we wanted to know the character that children would like to be.

To gather children' answers to these questions we used the Nominal Group Technique (NGT) which is a group brainstorming technique to gather ideas but want everyone's opinions taken into account [20]. In this context, 'Nominal Group' means that people are nominally in a group but mostly work on their own. To do so, we distributed sticky notes and pens to each member of the teams [21]. Each team member wrote down the response individually on the sticky notes, promoting the participation of all team members, even shy kids. We fixed that it should be one idea per sticky note. Nevertheless, we did not fixed the ideas on a set of predefined categories, encouraging kids to be free to express their ideas. At this point, the class teacher, the three co-design experts and the design assistant acted as facilitators to help children to express their ideas.

The leader of each team collected sticky notes and filtered repeated answers. Then, he/she arranged them in a vertical cork surface (see Figure 3). A co-design expert grouped notes with similar categories and explained aloud generated ideas. We used the color-code sticky notes as team group identifier to easily visualize groups' preferences.

As a result of this first part of the session, we obtained a huge shower of ideas for the game concept. Surprisingly, some groupings of categories naturally emerged, such as vehicles, electronic devices, magical objects, sportsmen, famous people etc. Different scenarios were proposed as answers to the first question (ice-playground, soccer stadium, etc.), and a huge amount of characters were suggested in the second question (music players, sportsmen, fairies, animals, etc.). This large amount of ideas suggests us to integrate them in different levels of the game and therefore allow a variety of game scenarios. Again, in the third question about the player appeareance, kids' imagination was really far from our expectations. They proposed characters such as sailors, dancers, multimillionaires, pirates, actress, roller-bladder, fairies, survival experts, etc. As conclusion, our game design should include multiple configurations and mods to expand the game with new levels and characters.

In the second part of the session, we used brainstorming in teams of 2 students to gather design ideas about player's interactions in the game, such as how to get away from the island, how to survive, how to obtain things or how to solve a puzzle. As co-design experts, we gave to kids special scaffolds and resources to answer these questions. We gave children “templates for a design task” (i.e., a fill in the gap sentences) that allowed them to express their ideas while writting in “gaps”. This material was used in another context, to facilitate teachers the design of reading tasks [22]. For instance, we encouraged them to fill the gaps in sentences such as ”If you are a ..... and you want to get away from the island doing ....., you have to ..... in order to get .....”. Moreover, the proposed challenges had to be related to the fraction concept. The class teacher was especially important at that point to help children validate their ideas related to the fraction concept. Initially, we planned to use digital tablets to help kids to propose their ideas. However, in the live session we used paper-drawings and written activities to enhance and facilitate informal and quick interactions.

Finally, in the last part of the session the entire group shared the proposals elaborated during the brainstorming and pushed the most popular ideas under vote.

From the second and the third parts we obtained some consensus about the main game dynamics. The most preferred idea to escape the island was that both players had to construct together an engine or a ship to get away from the island. In order to obtain the pieces of the engine, players had to follow a Gymkhana through some middle challenges related to fractions (e.g., a fraction of gas is needed to get out the island, use a fraction of a rope to avoid to be killed by a carnivorous plant). Additionally, students suggested that good results could be awarded by obtaining short-cuts in the roads. Children also proposed to play some challenges competitively and some challenges in collaborative mode with the second player.

2) Participatory session 2: challenges design and lo-fi prototype: The main goal of this second session was to work with children to define the fractions' challenges that the players have to complete to achieve the goal of escaping the island.

At the beginning of the session, the moderator recapped last session. Then, she presented a video of the intro to the game. The video showed the two players, and two mysterious boxes, arriving to the island after a sinking. Each box contained some tools and appareils that could be useful for the players to survive and leave the island. These tools were some of those proposed by children in the first participatory design session, i.e., knife, iPad, pieces of wood, and rope. As seen in Figure 4 boxes' content formed part of game HUD, which is player's inventory. Note that in addition to tools, the HUD includes fractions (1/2, 3/4, 4/5) which are used to cut some proportion of rope, wood, or any other resource encountered or collected along the game.

After the video, the moderator explained the rules and dynamics of the game. The goal of the game is to escape

Figure 4. The proposed game HUD and the six proposed challenges.

the island. Then, when players pass each level of the game, they achieve a piece of the boat needed to go back home. During their initial stay in the island (first game level) they will participate in a gymkhana. Therefore, they have to overcome several challenges in order to arrive to a 'magic' cave. Once in the cave, they have to solve a final enigma (big boss) that conducts them to the next level of the game. To complete the challenges the player has to use resources in her inventory. Initially, each player has 5 lives which loses when she fails fraction challenges.

The participatory design session continued with a proposal of six challenges (see Figure 4) children had to select to work on:

1) The bridge challenge.
2) The oasis challenge.
3) The carnivorous plant challenge.
4) The trap challenge.
5) The treasure challenge.
6) The cave challenge.

At this point, the class was divided in 12 teams of 2 children. Each team selected one of the six challenges. Nevertheless, nobody selected the bridge challenge. Instead, they proposed a new one related to a wall.

Afterwards, and to define a challenge, they should fill an empty template with questions that should be answered by the children. In the following, we show in caps, questions children should answer. In other words, this template should capture the design of the challenge.

- SCENARIO DESCRIPTION: PART OF THE SCENARIO WHERE PLAYERS ARE SITUATED, OBJECTS IN THE SCENARIO, TOOLS IN THE INVENTORY, AND OTHERS TOOLS THEY COULD NEED TO PERFORM THE CHALLENGE.
- WHAT'S THE CHALLENGE?
- HOW CAN THE PLAYER COMPLETE THE CHALLENGE USING FRACTIONS?
  - WHICH ACTIONS SHOULD PERFORM THE PLAYERS?
  - WHICH OBJECTS DO THE PLAYER NEED? EITHER FROM THE INVENTORY OR THE SCENARIO.
  - HOW PLAYERS COULD COLLABORATE IN THIS CHALLENGE?
- WHAT HAPPENS WHETHER:
  - THE PLAYERS COMPLETE THE CHALLENGE. THAT MEANS, WHAT HAPPENS IN THE SCENARIO AND HOW IT MODIFIES PLAYERS' STATE AND INVENTORY.
  - THE PLAYERS DO NOT COMPLETE THE CHALLENGE BECAUSE:
    - THEY EITHER FAILED COMPLETELY.
    - THEY FAIL PARTIALLY AND HAS NO TOOL TO CUTS FRACTIONS OF HERBS PROPERLY.

In the following we show the example (filled) template which we gave to them, 'The roads challenge'. Again, in caps, the questions children should answer and, in italic, examples responses.

- SCENARIO DESCRIPTION: PART OF THE SCENARIO WHERE PLAYERS ARE SITUATED, OBJECTS IN THE SCENARIO, TOOLS IN THE INVENTORY, AND OTHERS TOOLS THEY COULD NEED TO PERFORM THE CHALLENGE.
  The players are in front of several roads. Some roads are closed for herbs/flowers. There is an open path that leads to the river, the player can not cross the river because there is no bridge. On the other side of closed roads, there are dangerous animals (bears and monkeys), rope and wood. The player has knives in her inventory of different sizes (fractions) that can be used for cutting vegetation.
- WHAT IS THE CHALLENGE?
  Open the roads
- HOW CAN THE PLAYER COMPLETE THE CHALLENGE USING FRACTIONS?
  - WHICH ACTIONS SHOULD PERFORM THE PLAYERS?
    Cutting the fraction of herbs that close the roads that leads to some ropes and woods.
  - WHICH OBJECTS DO THE PLAYER NEED? EITHER FROM THE INVENTORY OR THE SCENARIO.
    Knife, with the adequate size, e.g., 2/3
  - How players could collaborate in this challenge?
    The player, who has the knife with the adequate measure, cuts the herbs.
- WHAT HAPPENS WHETHER:
  - THE PLAYERS COMPLETE THE CHALLENGE. THAT MEANS, WHAT HAPPENS IN THE SCENARIO AND HOW IT MODIFIES PLAYERS' STATE AND INVENTORY.
    Both roads open and players can arrive to the roads and woods, which are added to their inventories. These materials may be useful in the next challenge, to build the bridge.
  - The players do not complete the challenge because:
    - THEY EITHER FAILED COMPLETELY.
      The bear, situated behind the herbs, eats both players.
    - THEY FAIL PARTIALLY AND HAS NO TOOL TO CUTS FRACTIONS OF HERBS PROPERLY. *Players fail consciously to die, lose one live and start again.*

 ISBN: 978-1-61208-440-4

Figure 5. The basic material delivered to kids in a power point presentation.

Figure 6. Children working in couples to create the challenges' comicboards.

Children had 30 minutes to discuss in group the definition of the challenge they had selected. Once they filled the challenge description, they had to visually describe their proposal and so produce a lo-fi prototype of the design. They used a powerpoint document to compose the scenario using different images. We provided children with a set of images that could use (See Figure 5), but they were also free to search for other images in the Internet.

This strategy is based on the Comicboarding technique, that is a variation of storyboarding intended for children that has been used to brainstorm with children aged 6 to 13. Comicboarding can be used early in the design process to depict user interactions and to capture user scenarios, cases, and tasks [23]. Figure 6 shows teams of children working in a Comicboard. The three co-design experts, the design assistant and the teacher helped the students in the process of finding the needed images that better expressed their ideas.

Figure 7 shows one of the challenges designed by a team of two children. The top-left of the figure shows the start of the challenge, the top-right the proposed fraction's challenge to be solved, the bottom-left what happens when the player hits the fence, and the bottom-right what happens when the player fails the challenge. Specifically, the description of one of the challenges designed by children was: 'Our challenge is to obtain the 8 keys to open the treasure's chest and overcome the enigma. There is a treasure's chest in front of you, but you can not open it. There are 8 keys to open the chest. The players need to find the 8 keys inside the forest to be able to open the treasure. Each key is located in a tree. When the chest is opened by the 8 keys, a fairy will appear from the chest and it will ask the next enigma to the players: Which fraction of the trees in the forest have you visited to obtain the keys? The players have to answer correctly to open the door of the cave (the next challenge).'

Figure 7. Children design.

In the template card, the children had to explain also what happens when the players perform different actions. In the same example, the children explained the following cases: 'In the case the players do not answer correctly the fairy's enigma, the fence will be opened, then the bear will attack them, and they will lose 1 life each of them', 'In order to obtain the 8 keys, the players need to collaborate using their different inventory, the players can not obtain the 8 keys alone', 'In the case they can not obtain the 8 keys, they are able to skip the current challenge to return to the island, but losing the keys they have collected'. Figure 7 shows an example result of the visual description of this challenge proposed by children.

This session was initially designed to be done in 1.5 hours, but the children were so motivated, and they wanted to work one more hour on their designs. Finally, the entire session was 3.5 hours long. The results of this session were two different descriptions for each of the six challenges. Each team explained their proposal to the rest of the class, and the best two challenges were awarded. The selection of the bests ones were made by a voting of the children. Some of the ideas obtained after this session were used to define the game design document.

Although children were rather motivated during all the session, but they were even more engaged during the creation of comicboards using the computer and searching for images in the web. Undoubtedly, computers are a tool they love to use, either for playing games or for helping in design of the game. Furthermore, they improved transversal competences such as their powerpoint skills, e.g insert images, cut & paste, etc.

IV. Results Analysis

This section provides a high level analysis of relevant issues raised during our Participatory Design (PD) experience. This analysis aims to provide foundations and useful knowledge for other researchers who will engage with children in future PD experiences.

An important factor related to PD planning is the proper scheduling of sessions. From our experience we have learned that sessions should be scheduled within close time periods. Otherwise, it is needed a considerable part of the session time

 ISBN: 978-1-61208-440-4

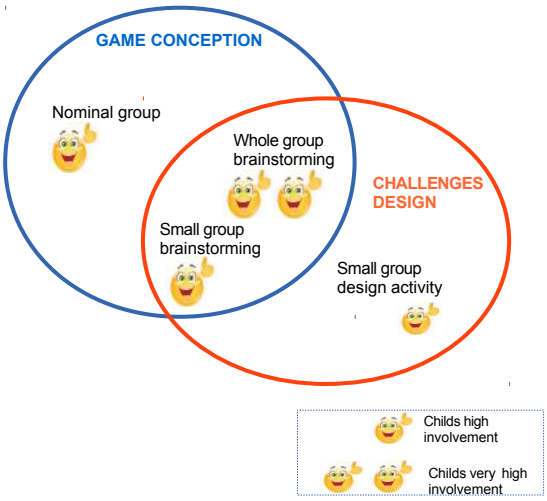


Figure 8. Childs' involvement in different phases of PD

to refresh childs' memory, and they have a harder time to put their minds in the game design endeavour.

Regarding kids' involvement, they pay more attention and are more committed and motivated in whole group brainstorming activities. However, we think that it is important to define individual activities such as nominal groups. These activities place them in context and foster an initial involvement in the design activity. Figure 8 shows kids' engagement in different activities performed during game conception and challenges design.

When it comes to facilitate children participation, both co-designers and teachers can help them to express their ideas, and material and examples are also essential to guide them in the design task. Therefore, the group of co-designers and teachers should be capable to assist all the children. We recommend at least 4 co-designers and 1 teacher for a class of 25 pupils. Additionally, when designing a participatory session with a classroom of primary school children, it should be taken into account that they need breaks and their level of attention is short. If the activity is not well defined and constrained, they may become bored, upset and a large variety of ideas may overcome the design. Designers should pay attention to give positive reinforcement at regular intervals to encourage children to continue in their work. However, once they are engaged in the problem, they may be rather creative and flexible about others' ideas.

V. Conclusions

In this paper, we have presented a participatory design experience to create a game by and for children. Particularly, this game focuses on the math concept of fractions.

We, designers, have attempted to empower children decisions about the fractions game they would like to play. Children role can be as a design-partner (early steps of the design's conception), as evaluator (with early prototypes), and as user (with the final game). We have focused in the first role, and aimed to exploit the collective creativity of students during the steps of game conception and challenges creation.

The outcomes of this research are twofold. First, the design experience constitutes a further step in the understanding and study of methodologies of participatory game design. Second, design ideas and challenges resulting from the PD sessions have been used to develop a first prototype (link to video in youtube).

As future work, we will consider a full conceptual map of fractions that children have to learn in primary school in order to consider a complete set of fractions' challenges in the game. We are also interested in providing teachers and parents with real-time monitoring of students' interactions and learning progress within the game.

Acknowledgments

Research work funded by SGR-623-2014 and TIN2012-38876-C02-02.

References

[1] C. Aldrich, The complete guide to Simulations & Serious Games, Pleiffer, Ed., 2009.

[2] R. Khaled and A. Vasalou, "Bridging serious games and participatory design," International Journal of Child-Computer Interaction, vol. 2, no. 2, 2014, pp. 93 – 100, special Issue: Learning from Failures in Game Design for Children. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S2212868914000063

[3] M. Horton, J. C. Read, E. Mazzone, G. Sim, and D. Fitton, "School friendly participatory research activities with children." in CHI Extended Abstracts, J. A. Konstan, E. H. Chi, and K. Hook, Eds. ACM, 2012, pp. 2099–2104. [Online]. Available: http://dblp.uni-trier.de/db/conf/chi/chi2012a.html#HortonRMSF12

[4] A. Druin, "The role of children in the design of new technology," Behaviour and Information Technology, vol. 21, 2002, pp. 1–25.

[5] S. W. Russ and J. A. Dillon, "Changes in children's pretend play over two decades," Creativity Research Journal, vol. 23, no. 4, 2011, pp. 330 – 338.

[6] D. Schuler and A. Namioka, Eds., Participatory Design: Principles and Practices. Hillsdale, NJ, USA: L. Erlbaum Associates Inc., 1993.

[7] M. J. Muller, The Human-computer Interaction Handbook. Hillsdale, NJ, USA: L. Erlbaum Associates Inc., 2003. [Online]. Available: http://dl.acm.org/citation.cfm?id=772072.772138

[8] E. Mazzone, J. C. Read, and R. Beale, "Design with and for disaffected teenagers," in Proceedings of the 5th Nordic Conference on Human-computer Interaction: Building Bridges, ser. NordiCHI '08. New York, NY, USA: ACM, 2008, pp. 290–297. [Online]. Available: http://doi.acm.org/10.1145/1463160.1463192

[9] G. Taxen, A. Druin, C. Fast, and M. Kjellin, "Kidstory: a technology design partnership with children." Behaviour & IT, vol. 20, no. 2, 2001, pp. 119–125. [Online]. Available: http://dblp.uni-trier.de/db/journals/behaviourIT/behaviourIT20.html#TaxenDFK01

[10] J. L. Tan, D. H. Goh, R. P. Ang, and V. S. Huan, "Child-centered interaction in the design of a game for social skills intervention," Computers in Entertainment, vol. 9, 2011.

[11] B. Brederode, P. Markopoulos, M. Gielen, A. Vermeeren, and H. de Ridder, "powerball: The design of a novel mixed-reality game for children with mixed abilities," in Proceedings of the 2005 Conference on Interaction Design and Children, ser. IDC '05. New York, NY, USA: ACM, 2005, pp. 32–39. [Online]. Available: http://doi.acm.org/10.1145/1109540.1109545

[12] "Learning and videogames: an unexploited synergy," 2000, URL: http://www.learndev.org/dl/FabricatoreAECT2000.pdf [retrieved: September, 2015].

[13] E. B.-N. Sanders, E. Brandt, and T. Binder, "A framework for organizing the tools and techniques of participatory design," in Proceedings of the 11th Biennial Participatory Design Conference, ser. PDC '10. New York, NY, USA: ACM, 2010, pp. 195–198. [Online]. Available: http://doi.acm.org/10.1145/1900441.1900476

[14] M. Canals, Fracciones. Los dossiers de Maria Antonia Canals. Ed. Octaedro, ISBN: 978-8492748068, 2009.

[15] "PipoClub game," 2015, URL: http:/www.pipoclub.comjuegos-para-ninos-gratisjuego-fracciones.html [retrieved: September, 2015].

 ISBN: 978-1-61208-440-4

[16] “FractionBooster game,” 2015, URL: http:/www.maths-games.orgfraction-games.html [retrieved: September, 2015].

[17] “Melvins game,” 2015, URL: http:/pbskids.org/cyberchase/math-games/melvins-make-match/ [retrieved: September, 2015].

[18] “ProblemSolving,” 2015, URL: http:/www.mathplayground.com [retrieved: September, 2015].

[19] B. Reeves and C. Nass, The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places. New York, NY, USA: Cambridge University Press, 1996.

[20] D. Marvin, J. Campbell, and K. Jaastad, “The effect of group participation on brainstorming effectiveness for two industrial samples,” Journal of Applied Psychology, vol. 47, no. 2, 2001, pp. 30–37.

[21] J. A. Fails, M. L. Guha, and A. Druin, Methods and Techniques for Involving Children in the Design of New Technology for Children. Hanover, MA, USA: Now Publishers Inc., 2013.

[22] V. Phillips and C. Wong, “Teaching to the common core by design, not accident,” Kappan. Education week, vol. 93, no. 2, 2012, pp. 31–37.

[23] S. Wahid, D. S. McCrickard, J. DeGol, N. Elias, and S. Harrison, “Don’t drop it!: Pick it up and storyboard,” in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ser. CHI ’11. New York, NY, USA: ACM, 2011, pp. 1571–1580.

 ISBN: 978-1-61208-440-4