An Analysis for the Identification of Use and Development of Game Design Strategies as Problem Posing Activities for Early Childhood Learners

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Abstract. Examining and identifying the way that designers approach game design could support the improvement of game design curricula. This paper explores how kids in the early childhood approach develop and apply game design strategies during participatory game design sessions. During a period of three months, eighteen kindergarten learners participated in game design sessions, creating their own games. The data analysis suggests that those learners applied different game design strategies than the ones they initially started using. The frequency and intensity of the use of those strategies also changed, showing patterns that indicate learners' development in their use of game design strategies and add empirical evidence to the field of game design education. Additionally, the Game Design Strategies Analysis (GDSA) is presented, which elaborates on the different types of strategies encountered when designing games.

Keywords: Game design · Game based learning · Participatory design

1 Introduction and Theoretical Background

Rapid and continuous technologic advances have strongly impacted modern education. An educational aspect with a continuously increasing research interest is that of game design, both as a tool for the support of curricular activities but also for their potential to create meaning making of children's developing capacities in diverse contexts and practices [1]. Additionally, research interest on the development of game design skills has been developed in the last years [2].

Learning about game design is related to the general notion of learning by design, which requires the combination of problem-solving, critical thinking and creative thinking skills [3]. This process has been addressed through different approaches and

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practices in order to establish and facilitate students' involvement in the game design process [4]. According to Schell [5], games could also be viewed as problem situations, engaging the participant in a playful attitude. Hence, game design could be considered similar to problem posing [6]. The development of strategies to solve and design mathematical problems has been identified as a key aspect of students' mathematical thinking [7]. So, the development of game design strategies by students could potentially help them better understand the process of game design.

Game design education has also been addressed through the prism of participatory design. Designing games with the participation of students has been a topic of increasing interest in the field of human computer interaction. Previous studies have focused on students' engagement in the design process [8], in the evaluation and communication of the process [9] and in organizing the design process through the creation of design tools [10].

The current paper aims at examining which types of game design strategies are developed and used by students in the early childhood while designing games during organized participatory game design interventions. The paper also presents the Game Design Strategies Analysis, a framework that stemmed from the qualitative analysis of this study, taking into account previous work in this field.

1.1 Game Design with Students

Engaging learners in the role of game designers is not a new concept. Previous research has focused on the impact of students' involvement in game design on their narrative, cognitive, creative and design skills [11]. Design sessions with young partners have been studied through the prism of cooperative inquiry [12]. Those studies showed a positive impact on students' interest in the field and the understanding of the concept of game design [13], the construction of knowledge and raised the question of the transfer of acquired knowledge and skills in other contexts [14].

Several frameworks have been proposed for the analysis and design of games in learning contexts [15]. Each of those frameworks approach game design through different perspectives, including game and learning mechanics, flow, interaction, decision making and problem solving and posing. Research has also focused on the identification of common patterns in order to address problems and issues that frequently appear in game design processes [16], while others have focused on the use of design strategies for greater player engagement [17]. Games have been examined as problem-solving environments. One approach considers problems presented in games and classifies them as either ill-structured or well-structured [18]. Contrary to well-structured problems, which have fixed answers, ill-structured problems are more open and urge players to come up with diverse problem solving strategies [19].

1.2 Problem Posing Strategies in Mathematics and Game Design Education

Problem posing has been the subject of research interest mainly for its connection to problem solving [20]. Problem posing education has proved to be a challenging endeavor, because of the subject's difficulty [21]. Games, creating intrinsically

motivating learning experiences, are proposed as a tool for the facilitation of problem posing education [22]. In order to structure better learning environments, different approaches on identifying and analyzing problem posing strategies have been proposed [23]. Those approaches include the use of relevant questions, generating problem posing strategies and modifying existing problems in order to create new ones. To facilitate problem posing instruction, Stoyanova [24] classified problem posing situations as: Structured, Semi-Structured and Free of structure. Similar approaches have been proposed for the design of game spaces.

2 Methodology

2.1 Participants

The study involved a group of eighteen children in the kindergarten, eight girls and ten boys. The participants were 5–6 years old and were all children of the same kindergarten classroom, located at a suburb of Thessaloniki, Greece.

2.2 Setting

Game Design Situations
For a period of three months, the study's participants were introduced to two hourly game design sessions per week. The sessions would not occur during the same day. The structure of game design sessions was also based on participatory design techniques and the problem posing analysis by Stoyanova [24], as well as the Kalmpourtzis' [25] structured, semi-structured and free situations of creating games.

- **Structured game design situations** included already designed games that learners needed to reformulate or redesign at will, starting from a concrete and defined basis.
- **Semi-structured game design situations** provided learners with half-finished games, requiring from learners to come up with their own fully working games. In semi-structured game design situations, players were asked to design their own games, taking into consideration those elements as a scaffolding mechanism.
- **Free game design situations** did not offer external support to players, obliging them to design their own games in any way they deemed preferable.

These different types of design situations were proposed to create a scaffolding mechanism where learners would be accustomed to the proposed game design process and familiarize themselves with the process of creating games.

Game Design Sessions
For the context of game design, an iterative process consisting of four steps was proposed. Those steps included:

- **Understanding the game**: learners identify their resources and define their objectives, understand their technical restrictions and decide the direction they will take towards the design of their games.

- **Designing the game**: learners brainstorm, exchange ideas, analyze the proposed game components, leading to their games.
- **Implementing the game**: players construct their game prototypes.
- **Presenting and looking back**: players present their games, observe their peers play them and receive their feedback.

Game design sessions focused on the creation of low-tech prototypes for both physical and digital games. For this purpose, different kinds of materials were supplied to learners. Low-tech prototypes included wireframes, content representations and they were accompanied with instructions learners needed to present at the end of each design phase. During each session, learners worked in small groups [26]. Each group consisted of three to five participants and an adult observer. The role of the observer was to attend and take notes, as well as facilitate the team's design process but only in cases where the team members were stuck [27]. The selection of the team's members aimed to maintain the balance between the age of the children (teams are composed by 5 and 6 years) and the mix between boys and girls.

During the period of the study, learners were also presented with a variety of different games (board games, outdoor games, card games, treasure-hunt games) and technologies in order to be aware of their various options and creative possibilities [12]. These activities included both physical and digital games.

2.3 The Game Design Strategies Analysis

The Game Design Strategies Analysis (GDSA) was proposed based on the work of Stoyanova and Ellerton [28]. The GDSA was proposed before the design sessions as a starting, considering that it will be modified, based on the findings of the current study. The initial GDSA consists of five main categories:

1. **Reformulation game design strategies**: describing cases where game elements are only rearranged or differently presented, with no apparent changes on gameplay.
2. **Reconstruction game design strategies**: describing cases where the content or materials of game components change with no other apparent change on game components and their interaction.
3. **Imitation game design strategies**: describing the modification of existing components, based on previously encountered experiences.
4. **Expansion game design strategies**: describing the expansion of existing games and components, based on previously encountered experiences and components.
5. **Invention game design strategies**: describing the proposal of novel, not previously encountered game components.

3 Design of the Research and Data Analysis

For the present study, a qualitative research methodology was used. The selection of a qualitative methodology was also supported from the understanding that in order to better examine the process of designing games, several other factors needed to be taken

into account, such as practices, common patterns, interaction among peers, thought processes and emotions, which are difficult to extract through conventional research methodologies [29]. Our study focuses on the collection of data from the conversations among peers during design teams, their actions and decisions and their final creations.

The collection of data was carried out in two ways. From one side, semi-structured interviews [30] with each participant were conducted at the beginning and the end of the interventions period. These interviews focused on the application, suggestion and incorporation of strategies and common practices of learners while they were designing their games. The interviews presented learners with three game design situations, one structured, one semi-structured and one free, during which leaners needed to create their own games, digital or physical, according to their preference. From the other side, learners' work in design teams was audio recorded with the intention of later analysis. Additionally, the works of the design teams were collected and stored to provide additional information for the analysis of data.

The findings deriving both from personal interviews and design teamwork were all transcribed. A line-by-line coding was used to identify emergent themes. The GDSA acted as a first point of reference. Initially codes would be based on the five strategy categories proposed by the initial GDSA. Through these codes and the analysis of teams' deliverables and observers' notes, categories were identified through a flexible category standard and an iterative process, where categories would emerge, change or be refined based on the constant examination of incoming information. A "thorough and interrogative" approach to data [31], where information would be cross-checked between cases, interviews, audio recordings and produced work did take place.

This iterative process led to the refinement and re-structuring of a final GDSA because of the qualitative analysis that was conducted.

4 Results

4.1 Game Design Strategies

The final and revised GDSA (Fig. 3) describes the strategies incorporated in game designers' decisions while preparing, implementing and presenting their games. Those game strategies are also related to learners' perception of the structure and consistency of games, their structural elements, materials, representation and interaction with players. The analysis of data finally showed four principal game strategy categories: Reformulation, Reconstruction, Expansion and Invention, each of which consists of different subcategories. After the analysis of data, the initially proposed strategy category of Imitation was eventually merged with the category of Expansion. A detailed analysis is presented below.

Reformulation Game Design Strategies

Reformulation strategies describe a set of game design strategies during which designers' resort to changing the presentation of a given game by altering its initial presentation description, and without impacting the initial game in any way. Learners used reformulation strategies in several occasions. Those cases were grouped in three subcategories.

The first one is related to learners' reformulation and different presentation of an existing game. When applying strategies of this category, learners were deliberately changing words related to the description of given games or were just repeating the initial game instructions with another word sequence. For instance, during a session where the base game was *Hide and Seek*, a team presented the same game by just rephrasing the initial instructions.

The second subcategory describes players' involuntary response to shifting away from an existing game implementation. When this strategy was encountered, learners wanted to recreate an exact replica of a previously encountered game. This is seen in the following discussion between learners, who were designing a matching game. One learner, proposed the use of color matching between cards, which was an addition to the game's existing presentation where there were some animal images:

> *Learner 1: This is not a butterfly that goes with a butterfly. The teacher said we should create the same combination: butterfly with butterfly.*
> *Learner 2: Yes, but this is red. They both have a red color.*
> *Learner 1: Yes, but it's not a butterfly with a butterfly, a crown with a crown, and a princess with a princess.*

The third reformulation subcategory is related to providing playable examples of how a whole game or some parts of it, are being played. In such strategies, players do not change the game and do not repeat its instructions but provide a playable example of how the game could be played to present it to other learners who are potential co-designers or players. For example, when playing Snakes and Ladders, a team, instead of presenting the game's instructions, gave an example of how it is played. The team had not changed the game at all during their design session and only focused on how to present it to their peers, which eventually ended up being in the form of an example.

Reconstruction Game Design Strategies

Reconstruction game design strategies describe the use of the same game mechanics of an existing game while changing the content, material and sizes of game components, but without affecting the nature of the game. In reconstruction game design strategies, learners addressed games as a defined system whose attributes are prone to change. Four subcategories for this category group were identified during this study.

The first subcategory is related to the modification of symbolic content of game elements. When this type of strategy was applied, learners would change the content of cards, videos or board games. However, in this type of strategy, the final game would not change in nature. As presented in Fig. 1, changing the symbolic content led learners to redesign the video game *Forest Maths*, while they did not perform any other type of change on its game play.

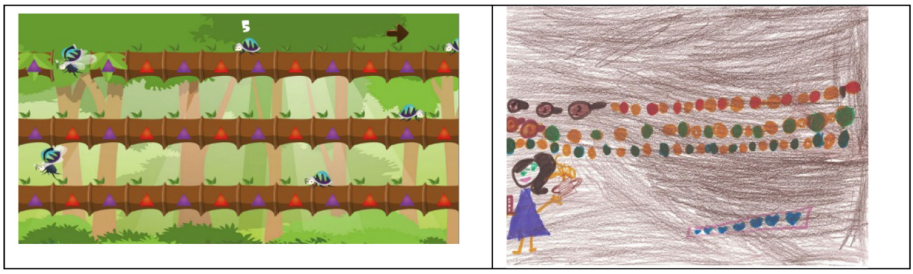

Fig. 1. Forest Maths and learner prototype

The second subcategory is connected to the modification of game component sizes. This subcategory could be potentially merged with the first one, but its high frequency during the analysis led to the proposal of a separate subcategory. Strategies of this subcategory describe learners' decision to change the size of the game objects, the repeatability of events, like the number of rounds required to complete a level, the number of game elements required for the completion of a game, the number of players, team sizes, point number or time duration. Figure 2 represents a prototype for a puzzle game, initially based on the concept of *Forest Maths*, where the number of holes and their position has been increased.

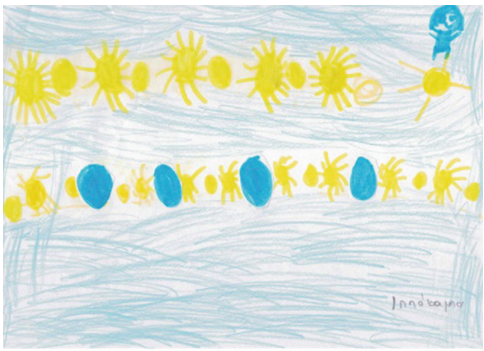

Fig. 2. The result of intentional modification reconstructive game design strategies

The third and fourth subcategories describe the rearrangement and modification of spatial elements and time sequences of events during the game. The third subcategory describes the repositioning of game components in different spatial arrangements. For example, for the game *Snakes and Ladders*, learners decided to arrange the tiles differently than the original square arrangement. The fourth subcategory describes the repositioning of game events in different chronological order. For example, for the game *Forest Maths*, a platform game where players need to complete patterns on a line to allow bugs to pass to the other side, learners decided to modify the intervals of bugs' appearance so that they change the difficulty of the game.

Expansion Game Design Strategies

Expansion game design strategies describe a set of strategies used to expand the structure of a familiar game or game element with the incorporation and refinement of other known elements or whole games. Even if expansion strategies result to possible new game experiences, they describe cases where proposed game structures were based on previously known games or game components. Expansion strategies also include the total or partial omission or removal of game elements from a game. Expansion strategies consist of two subcategories.

The first one describes the set of strategies that apply the use of familiar games or game structures to expand an existing game concept or base or the use of such structures in order to start a game from scratch. In one of the game sessions, learners that were influenced by the video game *PiBot: Math & Action*, decided to incorporate different familiar elements to expand the game. Consequently, they added new rules that corresponded to other games that were familiar to learners, such as collecting artefacts, defeating enemies by bumping on their heads and using super-powers. During a session the following discussion among learners took place:

Observer: What type of game would you like to create?
Learner 1: I propose French hide and seek!
Observer: What is French hide and seek?
Learner 1: One kid will hide and all the others are chasing.
Observer: And why did you decide to name it like this?
Learner 1: This is how I call it. It's played outside in the school yard and this is how it's played in France.

This discussion shows that the learner modified the rules of the familiar game hide and seek, by changing its gameplay.

The second subcategory describes strategies of generalizing or transferring a game structure and incorporating it as a component of another game or using the mechanics of existing game elements to their own. During one session, learners decided to create a game, based on their own narrative, inspired by the *Turtle Mutant Ninja* franchise. Wanting to keep the narrative element, they decided to create a game based on the mechanics of Snakes and Ladders. The designers generalized the use of one game to incorporate their narrative elements.

Invention Game Design Strategies

Invention game design strategies describe the use of strategies that led to the creation of new information or structures related to the produced games. Learners that use those strategies come up with new structures that are not relevant to previously familiar games or game elements. Invention strategies are related to whole games or game concepts. This study identified the use of invention strategies to expand familiar game structures with new and unique elements. Not one single complete game came up as the result of using this strategy.

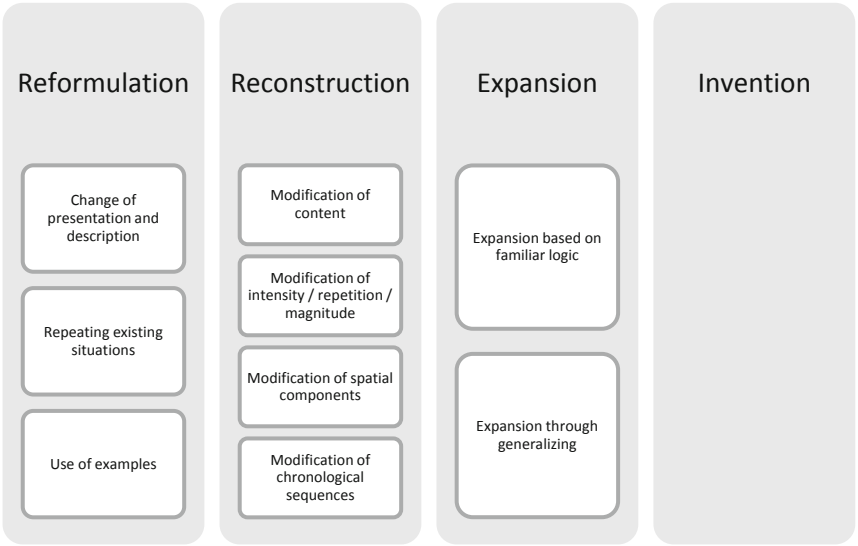

Fig. 3. The revised GDSA after the qualitative analysis

5 Discussion and Conclusions

This study, which examines the use of strategies by learners during participatory game design sessions, offers a perspective on the nature and way of utilization of different types of game creation strategies. The use and development of the strategies presented by the GDSA was examined during the three months of interventions. The use and development of all encountered strategies was examined during three different phases, each of which corresponded to the three game design situations: structured, semi-structured and free ones (Table 1). Each period corresponds to approximately a period of 4–5 weeks. The analysis shows three patterns that evolve during time. The first one is related to the decrease in the use of reformulation and reconstruction strategies. The use of those two strategy categories are very frequent during the first game design sessions and fall rapidly in the two last phases. The first one is the reversely proportional utilization of reformulation and reconstruction strategies during the duration of the sessions. Learners were observed to use such strategies at the early sessions and can be linked to the fact that learners were new to the design process, and were not accustomed to their functions as designers. To this direction points also the increased number of random uses of strategies with a trial and error approach on behalf of them, that tends to decrease later in the duration of the study. The great number of usages of different strategies during the first period, in comparison to the others, also points the experimental approach of learners, during which they resorted to a continuous and not always intentional or purposeful, proposition of strategies to create their games.

Table 1. Frequency of game design strategies in the course of the study

	Situation type		
	Structured – phase 1	Semi-structured – phase 2	Free structured - phase 3
Reformulation strategies	51	32	35
Reconstruction strategies	71	38	33
Expansion strategies	5	17	33
Invention strategies	0	2	5

The second one is connected to the increase of use of expansion and invention strategies during time, in the context of this study this period was three months. The second tendency is described by the proportional increase of use of expansion and invention strategies over time. This increase is also followed with a more cautious, intentional and targeted use of strategies during game design sessions. The increase of use of those types of strategies is also related to the nature of the tasks that design teams were asked to design. As part of the scaffolding mechanism that the study examined, the cases that learners would face would be structured, semi-structured or free-structured. As a result, initially learners would be asked to change existing games, then start designing games from half-made games and eventually come up with their ones. As presented in Table 1, the frequency of using different types of strategies is different in those phases. From one side, time and familiarity may play a role in this phenomenon. Additionally, the nature and different demands in terms the nature and structure of the activity in each of the three design situations may also play a role in the use of learners' strategies.

The third one is connected to the decrease in the overall use of strategies throughout the course of time. During phase one, the number of strategies used is almost twice as big as the number of strategies encountered during the next two phases. The strategies used during phase one are mainly reformulation and reconstruction and they consist of several trial and error efforts from learners' side. This aspect is related both to the decrease in trial and error strategies, familiarity with the design process and resultant observation of the previous two observations.

Consequently, this difference in the use of different strategies both as design situations change from structured to semi-structured and free-structured in the course of time indicating that experience and familiarity with game design processes impact the way that learners use different game design strategies that involve the recollection, identification and combination of other game elements or invent totally new game concepts. The shifting from reformulation and reconstruction strategies towards ones that fall into the categories of expansion and invention also seems to be followed by a decrease in the use of trial and error or arbitrary use of strategies without a purpose.

Further studies around the topic, where the GDSA will be used and reflected upon will shed more light in the framework's capacity to describe game design strategies during the process of game design.

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