Festarola: a Game for Improving Problem Solving Strategies

Ricardo Rodrigues
INESC-ID and Instituto Superior Técnico
University of Lisbon, Portugal
ricardo.rodrigues@gaips.inesc-id.pt

Paula Ferreira
CICPSI, Faculdade de Psicologia, University of Lisbon, Lisbon, Portugal
INESC-ID of Instituto Superior Técnico
University of Lisbon, Portugal
paula.ferreira@campus.ul.pt

Rui Prada
INESC-ID and Instituto Superior Técnico
University of Lisbon, Portugal
rui.prada@tecnico.ulisboa.pt

Paula Paulino
CICPSI, Faculdade de Psicologia
University of Lisbon, Portugal
a.paula.paulino@gmail.com

Ana Margarida Veiga Simão
CICPSI, Faculdade de Psicologia
University of Lisbon, Portugal
amsimao@psicologia.ulisboa.pt

***Abstract*—When performing problem solving tasks, teachers need to guide students' activities through the regulation of learning with meaningful resources that exemplify students' daily life. As a contribution to the learning and teaching processes in problem solving in math, we created *Festarola*, a digital game designed for young children, ages eight to ten, where a team of players is tasked with organizing a birthday party for a group of children. The game fosters both self and shared regulation of learning in problem solving by guiding students through a forethought phase, an execution and monitoring phase, and lastly, a self-reflection phase. A user study was conducted with children from the Portuguese primary education to measure the impact of the game. Children interacted with the game individually and in groups throughout several sessions. Positive results indicate that the game successfully *stimulated and developed problem solving strategies in students*.**

***Index Terms*—Digital Game, Problem Solving, Collaborative Learning**

I. Introduction

Students are often cognitively, emotionally and motivationally reliant on their teachers when performing tasks in the classroom [1]. Teachers tend to use formulas and model procedures to demonstrate how to solve Mathematical problems, presenting students with tasks that are completed within a small amount of time. Therefore, teachers serve as models who guide students in executing their tasks, often leaving little room for the latter to self-regulate their learning autonomously. Within this framework, students tend to formulate beliefs that Mathematics are bound by a set of fixed skills and that correctly completing an exercise implies following a series of rules offered by the teacher [2]. At the same time, when uses of mathematics are not related with everyday activities, students tend to assume that mathematics are not part of the real world, which leads to a lack of understanding regarding its utility [3].

II. Problem Solving in Math

In problem solving, one of the most important steps is understanding the problem itself and what students are being asked to do [4]. To solve a problem, students should *read the problem*, *identify the context* and what is asked of them, *paraphrase the problem* in their own words, *take notes* of necessary data, *draw diagrams* and/or schema that better organize the data, allowing for better understanding of their connections. Additionally, *articulating thoughts* promotes reflection on the problem and strategies used to solve it, which in turn, leads to a greater understanding of the problem [4], [5].

A study with Mathematics' teachers found that most teachers (85.5%) asked their pupils to read the text of the problem carefully, while 77.5% of them guided their pupils to write down the data of the problem and the relations between these data. However, only 61.3% asked the pupils to reword the problem [4].

One of the main goals of school education is developing problem solving skills [6]. Students who tend to be more self-regulated usually have more success in problem solving, mainly because the development of problem solving skills is related with acquiring self-regulation strategies that allow the learner to understand *what to do*, *how to do it* and *why do it* [7].

III. The Regulation of Learning in Problem Solving

Self-regulated learning refers to the degree with which students motivationally, meta-cognitively and behaviorally manage their own learning [8]. If *self-regulation* is tied to the way students regulate their own learning, sharing this regulation refers to the way students, together, regulate the processes of learning to reach a common objective [9].

In sharing the regulation of learning, students may develop self-regulation strategies, pro-social skills (e.g., conflict resolution strategies) and an assertive communication style by having opportunities to verbalize their thoughts and strategies to solve problems [10]. Nonetheless, the coordination of a collaborative learning task is a demanding process due to the fact that each element of a group is an agent with varying levels of self-regulation, individual objectives, cognitions and emotions, which in turn, creates challenges to the maintenance of motivation in contexts of social interaction [11].

During the executing of tasks, such as, a problem to solve, the elements of a group must be responsible and capable of regulating their own learning (i.e., self-regulation learning); support colleagues in the regulation of learning to reach their objectives (i.e., co-regulation of learning); and, together regulate the learning processes of the group to reach a common objective (i.e., shared regulation of learning) (e.g., [12]). Additionally, the success of a student during this process seems to depend on the success of the whole group, making it essential for different elements to trust the team and recognize a common direction [13].

Independently of whether a problem-solving task is performed individually or in group, the regulation of learning implies various cyclical phases, such as forethought, performance and self-reflection [8]. These phases are in line with the problem solving phases proposed by Polya [14]. Specifically, these phases include *understanding* the problem, *planning* how to solve it, *carrying out a plan* and *reviewing* the process [14], a self-regulated process which may lead to better problem-solving accuracy in math.

IV. Games for the Regulation of Learning in Problem solving

In parallel with the self, co and shared regulation of learning, the literature has highlighted the role of games in developing learning skills. Games, problem solving, and learning are part of everyday life [15]. Games in particular, are seen as a tool to think [16], to learn [17], and to learn to think [18]. Digital games require diverse skills considered essential to learning [19], such as: attention, research, planning, communication, creativity, and self confidence (e.g., [20]–[23]). Additionally, games promote problem-solving skills, as they are challenging, accessible and cognitively demanding [15].

Digital game-based learning has been a focus of education professionals in various fields, such as mathematics [24], [25], to improve learning effectiveness and efficiency in motivating and ludic learning environments. The literature has highlighted that games can make specific subjects, which are often perceived as difficult, more accessible [26]. Digital games have also been specifically used to support children's learning [27].

In terms of problem-solving specifically, some of the literature has indicated that digital games are user-centered in developing problem-solving strategies while promoting challenges, cooperation and engagement [28]. Shih et al. [29] demonstrated how a game designed to help elementary school students solve problems, fostered collaboration during problem-solving, and thus, better learning effectiveness. Yang [30] investigated the effectiveness of Digital Game-Based Learning (DGBL) on 9th-grade students' problem solving, learning motivation, and academic achievement. Results revealed that DGBL was effective in promoting students' problem-solving skills and motivation. Additionally a recent study [31] with 6th and 8th grade students using a programming game found that problem solving behaviors were significantly associated with students' self-explanation ability.

DGBL also has the potential to develop and assess children's self-regulatory capabilities [32]. A recent study [32] provided evidence that a digital assessment tool integrated in daily classroom activities has the potential to promote self-regulation in children.

V. Objective

Considering the previously discussed impact of self, co and shared regulation, as well as games for learning to solve problems, we developed a digital game named *Festarola* designed for young children, ages 8 to 10. With this game we aimed to fulfill the following objectives:

1) Develop problem solving strategies in students. These strategies are based on processes of self-regulation of learning, applied in several phases, namely: (a) understanding the problem; (b) elaborating a plan to solve it; (c) executing the plan; and (d) reflecting on the obtained results – these phases were based on the global heuristics of Polya [14] that presented 4 phases to guide problem solving. Moreover, these phases were in accordance with the processes for the self-regulation of learning [33].
2) Provide students with diverse ludic and appealing learning scenarios to foster motivation and knowledge in problem solving, bridging Mathematics and a real world scenario.
3) Improve students' autonomy in regulating their learning individually and collaboratively during problem solving by providing options for solving the problem through interactive scenarios.

VI. Festarola, the game

Fig. 1. Festarola cardboard mockup.

The game evolves around the activity of organizing a party for a group of children. The player is part of the organizing team, which, is constituted by two to four players (it is also possible to have a single player experience). The team needs to perform some tasks in a sequence that highlights different processes of problem solving, as described previously in the objectives (see section V).

The overall goal is to please the guests of the party. To organize the party, the team needs to decide on a proper theme for the party, buy food and drinks, props and hire entertainers, while dealing with budget and time restrictions.

The activity is divided in three main phases. The first phase is performed in group and includes choosing the theme for the party and defining a plan for the team, which consists of a list of things to buy, rent or hire. Defining the plan includes assigning individual responsibilities to players. Different shopping lists are defined (one per team member) and part of the overall budget is assigned to each player. In the end, players need to agree on which list each one is responsible for.

The second phase is performed individually. Each player performs the concrete shopping actions in the town shops according to the items on their shopping list and the assigned budget. However, this activity does not impose strong restrictions, as players can buy different things and go over budget. Actions in town take time, hence, there is a limited number of actions that players can perform in this phase.

The third phase is played in group again. The team meets to share the items they bought. This provides them with have opportunity to check the initial plan and revise their shopping options by returning some items if they choose to. These decisions are made together and once agreement is reached, the game advances to the set-up of the party. In this activity, the players distribute the items in the room where the party will take place. Once they finish, the party starts and the final score is presented.

The game is designed to promote the regulation of learning in problem solving in math through face to face discussions and to be used in classes at school. The first and third phases are played at the same computer. Players gather around the computer during the activities and are invited to move to a different computer once the second phase starts. That is, one player stays at the initial computer and the others go to a different one. When the second phase ends, players go to the first computer again.

A. Detailed gameplay

1) Game start: In the beginning, players are asked to choose a character and give it a name. This character serves as the player's avatar during the game. Once all players are happy with their avatars, they must choose a name for their team. The main idea of this action is to reinforce the establishment of the team, but the team name is used to support the save and resume mechanism as well. After initialising the game, which starts after the definition of the team name, players have the option to resume a previously saved game. Saving is automatically performed after each activity.

2) Gameplay activities: The game unfolds in a sequence of five activities:

1 – Choosing the party theme (in group). In this activity, the players take time to explore the interests of the party's guests and choose a theme for the party. The party has a total of eight guests. Each has up to four likes and dislikes from a set of four different themes: medieval, space, farm and sea. For example,

Fig. 2. Festarola screenshots. The top images refer to the first phase. On the left is the theme selection, while on the right is the definition of the team plan. The bottom left depicts a shop (phase two) and the figure on the bottom right shows an example of the revision of the execution (phase three).

a character may like the medieval theme and dislike space and sea. The challenge of the team, in this activity, is to select the theme that will please most guests. Players have to count the number of guests who like/dislike each theme and pick the theme that maximizes the like/dislike ratio. This activity presents a numerical challenge and enables perspective taking, as players should consider others' preferences. This choice is presented in the remaining activities to support the team's future decisions, however, it does not enforce any decision. For example, if medieval is the theme selected, players can still buy a pirate cake (from the sea theme) if they choose to. The choice of the theme will change the main decoration of the party room shown in activity 5. It is in this first phase also that students are asked to interpret the information that is being given to them and what is being asked of them (What information do you have and what do you have to do?). Students may write a response on the computer.

2 – Defining the team plan (in group). In this activity, the players create several shopping lists and assign each one to a different player. The shopping list contains a set of items and is built around 10 different categories (e.g. drinks, cakes, entertainers, activity items, cup-cakes). The challenge in this activity is to define a set of lists with a good distribution of items. A good distribution assigns a similar number of categories to each list and places items of similar categories in the same list. Additionally, it should include enough items for the eight guests. The main idea is to distribute the items in a way that all members use a similar amount of time to perform the shopping task while avoiding that they travel to the same shops, hence, minimizing the total travel time of the team members. An additional concern in this task is the distribution of the budget. The team receives a limit to the amount of money they can spend (e.g. 100€). That amount needs to be distributed by the lists. This brings an additional challenge to the players to foresee which list contains the most expensive items. There is no direct scoring in this activity, but the planning will influence the performance of the players in activity 3. A good balance in the plan leads, for example, to players spending less time travelling and shopping and hence getting higher score in the end. At the end of this phase, students are asked why they chose to proceed the way they did. Students may write a response on the computer.

3 – Performance - Executing the plan (individual). In this activity, players navigate in the town and enter shops to buy the items needed, according to the plan. Players can consult their assigned shopping list anytime during the activity. Movement actions (i.e. entering a shop) and buying actions take time. Players receive a time budget (equal to all) and need to buy everything before the time runs out. Players may return items if they wish to with no money penalty, but this action takes time. The challenge in this activity is to buy all the items in the list taking into account the party theme and the budget restriction. Note that the list specifies generic items, such as cakes. However, the stores sell items of the different themes as well, such as, a farm cake or a pirate cake. Players need to make the buying decisions carefully to match the party theme and the interests of the guests. However, themed items are more expensive than generic ones and players should meet the budget. The actions that players may take in this activity are not limited by any means. Players can buy items that are not on the list and are not forced to buy items of the chosen theme. Additionally, they may spend any amount of money over the budget. This freedom is included in the gameplay to allow players to perform mistakes and to make them actively responsible for following the plan. Players may leave the town as soon as they feel that their part of the plan is concluded. However, they are forced to leave if the time runs out. At the end of this phase, students are asked why they bought what they did.

4 – Revising performance (in group). In this activity, players see the items that all members of the team bought and decide if they keep them all or if they return some items. They can check the initial plan to support the decision. The team may only finish this activity if the total cost of the items kept is equal to or lower than the limit of the budget. The team incurs in no monetary costs for returning the items, but will be penalized for the number of items they return (check the budget scoring bellow). The challenge in this activity is to reach an agreement on the items to keep and to ensure that the cost is lower than the budget. A good decision keeps the items that will please the guests more without overspending. Note that, if the team defined a good plan and its members performed it well, this activity will not present any challenge as there is no need to return any item. Then, students are asked to reflect on their score and explain why they received that score individually and in group.

5 – Setting up the party (in group). In this activity, players may distribute the items they bought throughout the room where the party takes place. The room starts empty with base decorations according to the chosen theme. The players may select items and place them in the room. There is no restriction on the placement and there is no need to place any items at all. This activity is not a challenge per se, as it functions more like a gratification and cool-down activity. It presents a playful and fun experience where players express themselves and imagine the party setting. The team may discuss the options to take, nevertheless. Once they feel that the set-up is ready, the party starts and they receive the feedback from the guests and the final scoring.

Fig. 3. On the left is an example of the party set-up activity. On the right is a sample of a party scoring.

3) Scoring: The score in the game has three different components: the success of the party, the budget spent and the time taken while shopping for items.

The success of the party depends on the number of pleased guests. Guests are pleased if there are more items in the party that they like than items that they do not like. Big items count more than small items (e.g., an inflatable castle counts more than a princess cupcake for the Medieval theme). Also, there is a demand on themed items according to the number of guests that like a theme. This means that if most guests like a theme like space, for example, the party needs several space items as one is not enough to please them all. Despite the choice of the party theme, the computation of the amount of guests that are happy takes into account all likes and dislikes. The decision is made for each guest, according to the following:

$ItemsLike - ItemsDislike >= K$, then the guest is pleased with the party

$ItemsLike - ItemsDislike <= -K$, then the guest is not pleased with the party

Otherwise, the guest is neutral towards the party.

The $ItemsLike$ represents the weighted amount of items of the themes that the guest likes, while the $ItemsDislike$ represents the same for the themes that the guest dislikes. The constant K is introduced to control the challenge. The higher the value of K the more difficult it is to move the guests from the neutral state. For example, imagine a scenario with 2 guests. One likes the space theme and dislikes the farm theme, the other likes the space theme and dislikes the medieval theme. If the party includes 2 items of the space theme and 1 item of the medieval theme, for K=1, the first guest if pleased (as he gets one item he likes and no dislikes, hence $1 - 0 = 1 >= K$) and the second one is neutral (as he get one item he likes and one item he dislikes, hence $1 - 1 = 0 < K$). In the case of K=2 both guests will be neutral. More items of the space theme would be needed to please the first guest.

Each pleased guest accounts for 1 point in the score and each guest who is not pleased accounts for -1 point.

The budget score is computed based on the number of items returned in the revision of the teams' performance (activity 4). There is a base number of points (e.g. 10) that is decremented by one for each item returned. The rationale behind this scoring mechanism is the fact that the main reason for returning items is overspending beyond the limits of the budget.

The time score has a similar mechanism. There is a base score (e.g., 10) that is decremented for each player that runs out of time.

There is an additional score feedback in the form of stars attributed to the performance. The party can get zero to three stars. It gets one star for each condition: the team had no time penalties, the team returned no items, and there are more than five participants pleased.

Fig. 4. On the left is a character presenting the overall goal of the game. On the right is a character asking for the reason for cancelling the changes performed in the revision activity.

4) Guiding and Reflection: The game includes two additional characters to guide players in the activities and to prompt them to reflect on their decisions. At the beginning of each activity, one character presents a description of the activity. During the activity or at the end, another character asks players to justify their actions and decisions. For example, players should justify the choice of theme, the way they divided the tasks in the plan, the reasons for their shopping actions in town, and why they returned items (or not) during the revision activity. These justifications are written in a text box and are in most cases a team responsibility. Therefore, a discussion among the group of children is expected.

5) Defining new scenarios: The game was developed to be a tool used by teachers and researchers. For this reason, it records all actions performed in the activities and all texts written by the students to allow future analyses to be performed.

Additionally, different scenarios may be presented in the game by configuring a set of features. It is possible to change the set of interests of the party's guests, thus, changing the difficulty of the overall challenge. For example, if most guests share common interests, it will be easier to reach a good solution regarding the theme of the party. However, in case of conflicting interests, it will be harder. It is also possible to define the budget limit and time limit for actions in town. By doing this, teachers can define different levels of pressure and flexibility in the task. For example, allowing more exploration and correction actions if the time limit is higher. Finally, the prices of the items in the shops can be changed as well. This may change the nature and difficulty of the math calculations needed in the game. For example, if the prices are all in round small (e.g., one figure) numbers, it will be easier for the players to estimate the overall costs of buying actions rather than if the numbers in the prices are higher (e.g., two figures) or include decimals.

VII. User Study

To understand the impact of the *Festarola* in young students, two user studies were conducted in which participants were tasked with completing the phases of the game in different sessions.

A. Samples

This user study involved 269 primary school students, spanning over 17 classes, from the 3rd and 4th grades, in Lisbon's public schools, with ages ranging between 8 and 11 years old.

B. Resources

To allow us to better measure the impact of the game in students, we used the following resources listed below. We used a mediated assessment approach to dynamic assessment, which has been found to be appropriate to use with children [34].

1) *The four phases of the regulation of learning in the game.* During gameplay, after some phases, the students were asked to justify their actions through written text. The replies were coded by phase as follows:
   - *Choosing the party theme:* 1 = no response; 2 = irrelevant information for the resolution of the problem; 3 = information provided of what students were asked to do; 4 = information provided, and students mention what they were supposed to do.
   - *Defining the team plan:* – 1 = no response; 2 = irrelevant information for the resolution of the problem; 3 = explanation as to why students planned the way they did (e.g. "we divided the budget evenly so we could all have time to go shopping").
   - *Performance:* – 1 = no response; 2 = irrelevant information; 3 = information provided is according to the game's overall objective of organizing a party (e.g. "we bought things for the party"); 4 = information provided is according to the team's specific plan to organize the party (i.e. "I respected the budget I planned with my colleagues.").
   - *Revising performance:* – 1 = no response; 2 = irrelevant information; 3 = general self-evaluation with no criteria (e.g. "we did well"); 4 = specific self-evaluation with criteria (e.g. we did well because we bought only what we had planned to.").

The users' in-game responses revealed a reasonable reliability of $\alpha = .71$. These phases were used as the independent latent variable of the regulation of learning in problem solving in a structural equation modeling analysis.

2) *Performance in the game.* Game performance was an objective measure of performance and evaluated the number of items students returned (in the gameplay activity 4), as this indicated students were either not able to execute the task according to their plan , and overspent money, thus, not respecting their budget or did not define a good plan. This served as one of the dependent variables and was recoded from 1 (returned more items) to 5 (returned less items).
3) *Mathematical Problem on paper.* With the aim of better understanding students' performance with regards to problem solving, they solved a mathematical problem on paper, which was created by a team of primary education teachers. The math problem served as an objective measure of performance and revealed a reasonable reliability of $\alpha = .71$, and was used as another dependent variable reflecting students' performance. Since this mathematical problem evaluates the same construct as the performance in the game, it serves as a concurrent validity.
4) *Questionnaire for the evaluation of the game by the students* A questionnaire with open-answer questions was created to gather the students' self-reported perceptions of the game (i.e., "What I learned form the game was..."; "What I most liked about the game was..."; "What I least liked about the game was..."). Thematic analysis was performed with the data [35].
5) *Questionnaire for the evaluation of the game by the teachers* A questionnaire was created to gather the teachers' perceptions of the game, namely its impact and potential as a pedagogical tool. Thematic analysis was performed with the data [35].

C. Procedure

This study included 2 workshops with teachers (one at the beginning and one at the end of the study) and 8 sessions with each class of students (128 sessions total). Each session lasted around 60 minutes. An extra 4 sessions were performed for the pilot test. The workshops occurred as follows:

Session 1: First workshop with teachers. This workshop was performed with the objective of presenting the theoretical context of the project and create awareness of the themes and contents of the game. Furthermore, a pilot test was performed to test the game and evaluation procedures (e.g., detect bugs and errors in the game).

Sessions 2 and 3: Introduction to the intervention in problem solving. Presenting the game to students. Students could view and play around with the game to learn how to use it.

Sessions 4 and 5: Understanding the Problem and Planning. In this session students played the first and second stage of *Festarola*, *Understanding the problem* and *Defining the team plan*, respectively. The students also needed to reflect on how they thought and what strategies they used.

Session 6: Executing and monitoring the plan. In this session students played the third stage of *Festarola*, *Executing the plan by shopping in the stores in town*.

Session 7: Revision of the performance. In this session students played the fourth and fifth stage of *Festarola*, *Revising their performance* and *Setting up the party*, respectively. The students discussed their results and reflected on the successes and/or failures of their tasks, self-evaluating their performance.

Session 8: Improving self-regulation strategies and problem solving. In this session students were tasked with playing the full game individually with a higher difficulty - party guests would have conflicting tastes in themes.

Session 9: Problem solving (class). In this session students solved a mathematical problem on paper and discussed how they solved it. The students also evaluated the game.

Session 10: Second workshop with teachers. In this session the teachers were asked to evaluate the game and its impact.

VIII. Results and Discussion

In this section we will present our objectives (see section V) and the results from our user study.

A. Developing problem solving strategies in students

This objective focused on the development of problem solving strategies through processes of self-regulation of learning. Results seem to suggest the achievement of this objective, not only by the teachers' input after filling the questionnaires regarding the questions on problem solving, but also through the in-game explanations given by the students regarding stages 1 and 2 of the game (session 3) and the performance in the game and in the math problem on paper.

1) Teachers' input on problem solving strategies: Teachers pointed to positive changes in the students, mainly regarding mathematical reasoning, in particular the "explanation of results, data sorting, strategy planning, the steps to follow in problem solving and development of mental calculation". The majority of teachers also reported an increase in the awareness of the students regarding the problem solving phases, shown in the verbalization of the different tasks regarding *understanding*, *planning*, *executing* and *revising*. Furthermore, teachers also reported an improvement in students' calculations (in particular mental calculus), memorization capabilities, and the ability to follow and apply clues throughout problem solving tasks, which were presented during classroom activities.

2) The impact of the regulation of learning in problem solving in math: The phases of the regulation of learning in problem solving in the game were used to measure their impact on students' performance. Structural equation modeling (SEM) was computed with AMOS 24.0 software package (IBM, SPSS, Amos 24). The chosen causal model presented a good fit [36] to the data with the independent variable of the regulation of learning in problem solving (i.e., the phases presented in the game) and the dependent variable of performance in problem-solving in math (problem on paper and game performance) [$\chi^2(10) = 1.36$, $CFI = .98$, $TLI = .97$, $IFI = .98$, $RMSEA = .03$, $LO = .00$, $HI = .08$, $p > .05$].

Bootstrapping confidence intervals were used, and the p-values were calculated. The model proposes that students' performance accuracy in problem-solving in math is predicted by their self-regulated learning phases presented in the game (problem to solve on paper, $\beta = 0.28$; performance in the game, $\beta = 0.41$). All trajectories were positive and statistically significant. Students who were more self-regulated in solving problems in math, attained better problem-solving accuracy.

B. Providing diverse learning scenarios to foster knowledge on problem solving strategies

Our objective was not only to foster knowledge on problem solving strategies, but also to *present students with a ludic way to solve problems* by using the game to present different scenarios for training strategies in an appealing manner.

The teachers' opinion of the game was quite positive, stating that the game offers a learning dynamic that favors the development of mathematical reasoning. The use of this type of technology is perceived by teachers to be advantageous, since it makes the tasks more appealing and motivating. The value of the game was particularly highlighted for money management, conflict resolution and decision making. The ability to play games and perform teamwork in a collaborative learning context was considered beneficial for the students' growth on a personal and social level. In the teachers opinions, the game "educates through respect and mutual aid", since students "need to learn to give in, hear others' opinions, respect ideas, and listen to others' strategies", which fosters positive "relationships, help and sharing among colleagues". The game is overall described as "very stimulating", "fun, important", "a motif for learning", "positive", "motivational", "beneficial".

Students mentioned that *Festarola* showed them the different phases of problem solving, enabled them to practice throughout the sessions, and transfer this knowledge to different problems ("I learned that when I am going to solve a problem it is necessary to understand, plan, solve and review it"; "I learned to review the problems"; "I learned to plan before doing"). This was visible in the traditional math problem, as the regulation of learning in the game predicted students' performance. Students also mentioned that tasks performed in-game allowed them to reflect on the importance of some topics lectured in class, such as the mathematical operations and the explanation of the solution ("I learned to divide the money"; "I learned how to write a complete answer"). Moreover, other learning topics were also mentioned, such as money management and teamwork ("I learned to work in a group"; "I learned to manage my money"). The game also provided the students with awareness to important factors to achieve a good performance, such as effort, responsibility, and organization ("I learned to use the time set and to do everything correctly").

C. Improving the students' autonomy in regulating their learning in problem solving

An objective of this project was to improve students' autonomy in regulating their learning individually and collaboratively during problem solving by providing options for solving the problem through interactive scenarios. To measure the success of this objective students answered a questionnaire to provide feedback on the game and describe their experience of solving problems with it.

The majority of the students mentioned feeling involved in the execution task (i.e. shopping in town, setting up the party) and appreciated the look of the game. Students stated that they felt capable of solving the tasks presented by the game autonomously, and that they gave more importance to numeric calculus and its written explanation in order to better verbalize their mental processes throughout the stages of the game. The opportunity to play the game in a team, and to manage money were points equally considered positive and motivational to the students.

In a previous user study, Marques et al. [37] used *Festarola* to study the relation between students' perceived support (by their team members) and shared regulation of learning in problem solving (among their team members). Perceived Support referred to the way students perceived the support given by their team members in order to adapt to challenges imposed by different contexts [38]. Their work aimed to better comprehend how perceived support in a group affected the shared regulation of the task, and how students understood the task's potential to foster self and shared regulation. They evaluated groups of children by using *Festarola* as a way to present tasks which may be solvable in a group. Results from this work revealed that when students felt support from their group, they tended to better regulate their tasks within their group. These results suggest that *Festarola* has the potential to foster not only self-regulation, but also shared regulation of learning in problem solving in math.

IX. Conclusion

Festarola was designed to promote the regulation of learning in problem solving and to foster both self and shared regulation of learning. The regulation of learning was used as basis for the four stages in the game: (1) understanding the problem – learning each party participants' likings and selecting a theme for the party; (2) elaborating a plan to solve it – deciding what each player will purchase or rent for the party; (3) executing the plan – visiting the town and obtaining the previously planned items; and (4) reflecting on the obtained results – revising the items brought by each player, having the option to return items if the total cost is higher than the budget. A final stage, *Setting up the party*, was added for enjoyment of the players, where they could arrange the items bought in a room where the party would be held.

A user study was performed with 269 primary school children from ages 8 to 11. In this user study, children interacted with the game throughout several sessions, allowing for the evaluation of each stage separately. Positive results indicated that the game successfully stimulates and develops problem solving strategies in students and provides diverse learning scenarios to foster knowledge on problem solving strategies. These results, as well as the findings reported by Marques et al., (2019), suggested that *Festarola* has the potential to improve students' autonomy in regulating their learning individually and collaboratively during problem solving by providing options for solving the problem through interactive scenarios.

In conclusion, *Festarola* was shown to be an appealing game that allows children to develop skills not regularly developed in schools and improve their competences not only in problem solving, but also collaborative work and other skills needed later in life. This study served as an example and to test possible trends of performance with the game, so that future research with different study designs (e.g., with a control group) may find our results useful to confirm the findings presented.

X. Acknowledgement

This work was financed under the participative budget of the Lisbon City Council. It was partially supported by national funds through Fundação para a Ciência e a Tecnologia (FCT) with ref. UID/CEC/50021/2019; SFRH/BPD/110695/2015.

References

[1] M. Boekaerts, "Bringing about change in the classroom: Strengths and weaknesses of the self-regulated learning approach - EARLI Presidential address, 2001," *Learning and Instruction*, 2002.

[2] L. Bendixen and F. Feucht, *Personal epistemology in the classroom: Theory, research, and implications for practice*. Cambridge University Press, 2010.

[3] L. Verschaffel, B. Greer, and E. De Corte, *Making sense of word problems*. Taylor & Francis, 2000.

[4] I. Marchis, "How Mathematics Teachers Develop Their Pupils' Self-Regulated Learning Skills," *Acta Didactica Napocensia*, 2011.

[5] E. Fenneman, J. Sowder, and T. Carpenter, "Creating Classrooms that Promote Understanding," in *Mathematics classroom that promote understanding*, 1999.

[6] I. Zsoldos-Marchis, "Influence of cooperative problem solving on students' control and help-seeking strategies during mathematical problem solving," *Acta Didactica Napocensia*, 2014.

[7] B. Kramarski, I. Weisse, and I. Kololshi-Minsker, "How can self-regulated learning support the problem solving of third-grade students with mathematics anxiety?" *ZDM - International Journal on Mathematics Education*, 2010.

[8] B. J. Zimmerman, "Chapter 2 - Attaining Self-Regulation: A Social Cognitive Perspective," in *Handbook of Self-Regulation*, M. Boekaerts, P. R. Pintrich, and M. Zeidner, Eds. San Diego: Academic Press, 2000, pp. 13–39. [Online]. Available: http://www.sciencedirect.com/science/article/pii/B9780121098902500317

[9] S. Järvelä and A. F. Hadwin, "New Frontiers: Regulating Learning in CSCL," *Educational Psychologist*, 2013.

[10] C. Kyriacou, Å. Hultgren, P. Stephens, M. M. Brown, D. H. Schunk, P. R. Pintrich, J. L. Meece, L.-E. Malmberg, J. S. Eccles, A. Wigfield, S. A. O'Neill, E. L. Low, S. K. Lim, A. Ch'ng, K. C. Goh, and M. A. Gaeke, "Motivation in Education: Theory, Research and Applications," *Teacher Development*, 2008.

[11] S. Järvelä, S. Volet, and H. Järvenoja, "Research on motivation in collaborative learning: Moving beyond the cognitive-situative divide and combining individual and social processes," *Educational Psychologist*, 2010.

[12] H. Jeong and C. E. Hmelo-Silver, "Seven Affordances of Computer-Supported Collaborative Learning: How to Support Collaborative Learning? How Can Technologies Help?" *Educational Psychologist*, 2016.

[13] M. Laal, "Positive Interdependence in Collaborative Learning," *Procedia - Social and Behavioral Sciences*, 2013.

[14] G. Polya, *How to solve it: A new aspect of methematical method*. Princeton University Press, 1957.

[15] A. Monteiro, J. A. Moreira, A. C. Almeida, and J. A. Lencastre, *Blended learning em contexto educativo: perspetivas teóricas e práticas de investigação*. DeFacto Editores, 2012.

[16] R. P. Brenelli, *O jogo como espaço para pensar: a construção de noções lógicas e aritméticas*. Papirus, 2008.

[17] R. M. Golinkoff, K. Hirsh-Pasek, and D. G. Singer, *Play = Learning: How Play Motivates and Enhances Children's Cognitive and Social-Emotional Growth*. Oxford University Press, 2006.

[18] K. J. Holyoak, R. G. Morrison, L. A. Holyoak, Keith J. (University of California, and L. A. Morrison, Robert G. (University of California, *The Cambridge Handbook of Thinking and Reasoning*. Cambridge University Press, 2005.

[19] W. R. Boot, A. F. Kramer, D. J. Simons, M. Fabiani, and G. Gratton, "The effects of video game playing on attention, memory, and executive control," *Acta Psychologica*, 2008.

[20] F. Frossard, M. Barajas, S. Alcaraz-Domìnguez, A. Trifonova, and J. Quintana, "GBL Design for Enhancing Creativity in the Classroom," *Games and Creativityin eduCation and traininG*, 2011.

[21] J. P. Gee, "Learning and games," in *The Ecology of Games: Connecting Youth, Games, and Learning*, 2008.

[22] ——, "Bons videogames e boa aprendizagem," *Perspectiva*, 2009.

[23] J. McGonigal, *Reality is broken: Why games make us better and how they can change the world*. Penguin Books, 2011.

[24] N. Bos and N. S. Shami, "Adapting a face-to-face role-playing simulation for online play," *Educational Technology Research and Development*, vol. 54, no. 5, pp. 493–521, 2006.

[25] R. Van Eck and J. Dempsey, "The effect of competition and contextualized advisement on the transfer of mathematics skills a computer-based instructional simulation game," *Educational Technology Research and Development*, vol. 50, no. 3, pp. 23–41, 2002.

[26] S.-W. Chen, C.-H. Yang, K.-S. Huang, and S.-L. Fu, "Digital games for learning energy conservation: A study of impacts on motivation, attention, and learning outcomes," *Innovations in Education and Teaching International*, vol. 56, no. 1, pp. 66–76, 2019.

[27] N. Che Pee, "Computer games use in an educational system," Ph.D. dissertation, University of Nottingham, 2011.

[28] B. Gros, "Digital games in education: The design of games-based learning environments," *Journal of research on technology in education*, vol. 40, no. 1, pp. 23–38, 2007.

[29] J.-L. Shih, B.-J. Shih, C.-C. Shih, H.-Y. Su, and C.-W. Chuang, "The influence of collaboration styles to children's cognitive performance in digital problem-solving game "William Adventure": A comparative case study," *Computers & Education*, vol. 55, no. 3, pp. 982–993, 2010.

[30] Y.-T. C. Yang, "Building virtual cities, inspiring intelligent citizens: Digital games for developing students' problem solving and learning motivation," *Computers & Education*, vol. 59, no. 2, pp. 365–377, 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0360131512000139

[31] Z. Liu, R. Zhi, A. Hicks, and T. Barnes, "Understanding problem solving behavior of 6–8 graders in a debugging game," *Computer Science Education*, vol. 27, no. 1, pp. 1–29, 2017.

[32] J. Day, K. Freiberg, A. Hayes, and R. Homel, "Towards Scalable, Integrative Assessment of Children's Self-Regulatory Capabilities: New Applications of Digital Technology," *Clinical Child and Family Psychology Review*, vol. 22, no. 1, pp. 90–103, mar 2019.

[33] A. L. da Silva, A. M. V. Simão, and I. Sá, "A Auto-regulação da Aprendizagem : Estudos Teóricos e Empíricos," *Intermeio: revista do Mestrado em Educaçao*, 2004.

[34] Z. Lin, "Interactive dynamic assessment with children learning EFL in kindergarten," *Early Childhood Education Journal*, vol. 37, no. 4, p. 279, 2010.

[35] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, 2006.

[36] B. M. Byrne, *Structural equation modeling with AMOS: Basic concepts, applications, and programming, second edition*. Routledge, 2013.

[37] J. Marques, S. Oliveira, P. C. Ferreira, and A. M. Veiga Simão, "Trabalho Colaborativo no 1º Ciclo: Suporte Percebido e Regulação Partilhada," *Cadernos de Pesquisa*, 2016.

[38] J. Song, M. Bong, K. Lee, and S. I. Kim, "Longitudinal investigation into the role of perceived social support in adolescents' academic motivation and achievement," *Journal of Educational Psychology*, 2015.