

# Game-based Co-design of Games for Learning with Children and Teachers: Research Goals and a Study

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**Abstract.** This paper reports on the research topics and goals for my Ph.D. In the opening, game-based learning and co-design are overviewed. Issues emerging from the surveyed literature are used to frame the research goals of my Ph.D., broken down into propaedeutic objectives. The paper continues presenting the co-design studies for tackling the stated objectives, and focuses on the study conducted with tablets. The design of this study is discussed rather in details so as to foster the discussion and gather expert feedback from CHIItaly community. The paper ends recapping the main lessons learnt across the co-design studies.

## 1 Introduction

This paper is part of my Ph.D. work at the Free University of Bozen-Bolzano, within the Ph.D. program in Computer Science, under the supervision of Prof. Gabriella Doderio and Prof. Rosella Gennari. Part of the work is done in collaboration with the University of L'Aquila. My research investigations lay at the intersection of *co-design* [1, 2] and gamification of learning or *game-based learning* (GBL) [3, 4]. Both are analysed in the background section of this paper. My Ph.D. deals with the co-design of games with and for children, more specifically, educational games for analysing and interpreting stories. After analysing the *human computer interaction* (HCI) literature concerning design methods for children [5], co-design was chosen for working in the traditional school setting, like in [6, 7], so as to get children's and teachers' ideas, and foster the inclusion of marginalised children in the classroom. Following current trends, co-design studies were designed as game-based activities, that is, gamified, so as to foster the engagement of learners in the activities.

At present, we have already designed and performed 5 co-design studies with 85 children and 7 teachers from primary and secondary schools in the Province of Bozen-Bolzano. Table 1 summarises involved schools and children, specifying their age and number per school. Since we had primary and secondary schools, we did 2 different types of co-design studies according to the age of children: the first study was done in a Merano secondary school with tablet devices; the second study was done in primary schools in Brunico and Bolzano with paper-based material. The paper focuses on the Merano study with 18 learners, aged 11–14 year old, and 3 school teachers being most innovative one with tablets.

Firstly, the paper overviews background information concerning GBL and co-design. It moves on explaining the research topics under consideration, outlining the rationale and motivations of the reported work. Then the paper explains the goal of the study,

who the participants were and the main results. Finally, the paper sums up the lessons learnt from the study, and the refined objectives of my Ph.D. work.

## 2 Background

This section briefly presents what GBL is in the context of this paper, and then the used co-design methodology.

### 2.1 GBL overview

From both theoretical and empirical points of view, learners are expected to be more motivated to participate in educational activities if these are shaped like games, e.g., [8]. GBL requires several elements [3]. From a purely game-theoretic view point, the game concept requires specifying the actions or moves of the players, with their outcomes, so that an action of the players makes the game progress from state to state. From the player view point, from a motivation theory perspective, this is not sufficient for explaining why a game is engaging. The authors of [9] propose a motivational model for game engagement. They overview research findings investigating correlations between the appeal of games and the satisfaction of psychological need that play can provide. Surveyed results demonstrate that at least three elements make, in the short term, independent contributions to game engagement: (1) autonomy, which can be realised by allowing the learner to take decisions; (2) competence, which can be realised by carefully balancing challenges and providing motivating rewards and feedback; (3) relatedness needs, which may be realised by the presence of a personal guide in the form of an avatar, or by playing with or against other peers.

Starting from that, [8], discusses the elements of nowadays' games for learning that support learners' engagement, like feedback. Such elements, necessary in designing a game, can be specified by means of a game framework, like in the [10] or [11] projects. However, according to Morris et al. [8], whereas there are already several good examples of GBL via games, educational or purely entertainment ones, the involvement of teachers in GBL activities has still received very little attention.

### 2.2 Co-design overview

Co-design is an approach to design attempting to actively involve all stakeholders in the design process in order to help ensure the designed product meets their needs and it is usable.

**Table 1.** Recap of participating schools.

School	Type	Town	Age of learners	Number of learners
Negrelli	Secondary school	Merano	11–14	18
King	Primary school	Bolzano	08–09	19
King	Primary school	Bolzano	09–10	15
Galilei	Primary school	Brunico	08–09	15
Galilei	Primary school	Brunico	09–10	17

In [12], Sanders defines co-design as “collective creativity as it is applied across the whole span of a design process” [12]. Involvement of users early in the research and ideation phases of the design of a new product, is often equated to asking users what they want. However, therein, the key and the main goal of a co-design session is the collaboration between users for supporting anybody to imagine, express and access their experience and expectations so that they can actively and effectively participate in shaping a proof-of-concept prototype of a common idea [13]. Co-design sessions allow to create a shared understanding and shared language between participants and designers, so as to understand the new product from the point of view of participants [14]. Outputs are sources of both inspiration and information for designers and participants. Specifically, in the area of co-designing with children, the work of Alison Druin [15, 1] has provided many frameworks and methods that allow to work with children as partners during product design. Several co-design methods can be used with children at different stages of product design, and the appropriate methods may vary depending on the purpose of the research [16, 17, 2]. In particular, co-designing with children at school is not new. For instance, in [18], the authors explore the applications of co-design methods with 7–9 children. In [19] the authors describe the embodied-narrative method, and the empirical studies conducted with 36 children at home and at school environment.

Co-design has been also widely adopted for creating products for disabled children, also for enhancing their inclusion in class. Noticeable examples are [20], with children having motor or cognitive disabilities, and the COSPATIAL European project [21], with autistic children. Garzotto et al. [20], discuss how to achieve a wider form of inclusive education by involving non-disabled children as co-designers of technology for their disabled schoolmates. The COSPATIAL project [21] explores how develop effective and useful educational technologies in the form of shared active surfaces and collaborative virtual environments with autistic children.

Co-design with teachers as members of the co-design team is receiving increasing attention in the HCI community, for instance, see [6].

### **3 Rationale and motivations**

#### **3.1 Research setting and topics**

According to the above review of the literature, structuring co-design activities as games for learning, which we briefly refer to as *GBL co-design*, can foster the engagement of the learners, specifically, for the competences, relatedness and autonomy needs [3, 5].

GBL co-design within school setting is the focus of my Ph.D. work and this paper alike. The co-designed products are so-called *smart games* for analysing a story [11]. GBL co-designing smart games at school has potentially several benefits, from the class’ viewpoint and the designers’ view point.

From class’ viewpoint, GBL co-design can promote at least two main benefits: (1) fostering learning, which, in our case, is concerned with analysing a story and interpreting it [22]; (2) the inclusion of marginalised children, by structuring activities so as to employ diverse skills, also those that are not always promoted in traditional school settings.

From designers' view point, co-designing in school allows designers to grab learners' and teachers' ideas, in our case, for the design of novel smart games for a story. In particular, from the game design perspective, such activities allow us to trace (1) what the most popular game genres are that the learners would think of for analysing a story, and (2) what the most frequent elements for the game design are. Finally, structuring co-design activities as games even further promotes the engagement of the class.

### **3.2 Research Goals, Objectives and Questions**

The main research goals of our work are to contextualise, analyse and refine GBL co-design with learners and teachers alike, so as to foster the collaboration within groups of learners and the inclusion of marginalised learner in class, like, for instance, deaf children. Another research goal is understanding what games learner would design for analysing a story. In order to achieve such goals, I broke them down into the following four research objectives, and related questions, one propaedeutic to the other.

*O1: analysing the context of use.* Our first research objective is to explore if and how learners, teachers and designers, collaboratively, can work together in GBL co-design activities within a traditional school environment. A learning environment, like a classroom of a school, is a structured ambient with precise spaces and a series of rules that affect learner interactions. Can GBL co-design be imported in such a setting? What are the constraints that such a setting imposes on the GBL co-design activities?

*O2: promoting and designing GBL co-design at school.* By answering the above questions, I can craft the GBL co-design activities according to the needs of the class and tackle the following related questions. How shall I organise a co-design session? What are the roles of participants, that is, teachers, learners and designers? What are the specific objectives of a co-design activity and how to measure their achievement? What are the GBL activities that mostly engage the learners?

*O3: analysing the games emerged via GBL co-design.* By analysing results of co-design sessions across schools, I aim at understanding if there is a common pattern in co-designing games for analysing stories. What game genres emerge most frequently? What common elements of a game emerge? Co-designed games are then evaluated by a composite jury so as to select the best according to specific evaluation criteria, e.g., the best cooperation; that works as reward for groups of learners. Then, which are the most effective evaluation criteria? Which co-designed games are most successful according to specific evaluation criteria? Which according to adults? Which according to learner?

*O4: refining the co-design method for GBL.* Abstracting from lessons learnt by tackling the above objectives, finally, I aim at refining the co-design methodology for GBL at school, in order to foster learning, collaboration and inclusion. Specifically, how can GBL co-design promote learning in class—in particular, the analysis and interpretation of a text by building games for it at school? How can GBL co-design promote learning across classes? How can GBL co-design favour the inclusion of marginalised learner?

## 4 GBL co-design with a secondary-school

A GBL co-design study was planned and conducted in spring 2013 in the Luigi Negrelli secondary school in Merano, in a class of 11–14 year old children, with 5 children that are non native Italian speakers. The class was asked to co-design games for analysing a story. The objectives tackled within the study were O1 and, partly, O2 and O3.

In this paper, we report the co-design study following the structure in [23], and hence describing (1) the study design, (2) the user teaching, that is, the training for teachers about the *modus operandi* in the study, (3) the main characteristics of the users participating in the study, (4) the study execution.

### 4.1 Study design

During the GBL co-design study there are activities to be done by groups and activities to be done by the entire class. Since group activities require a facilitator per group, the co-design study gets divided into sessions. Each session is itself divided into 3 main phases. In the first phase, teacher and students read and comment on the story in class; then learner reads it silently at home. The second and the third phases see the interventions of the facilitators. The second phase requires the class to be divided in groups, each coached by a facilitator. The third phase sees the class reunited under the moderation of the teacher. The design of the game mainly takes place during the second phase, which is structured into tasks, created following a game framework. The tasks and framework are outlined in the remainder of this subsection. In the end, we also specify the roles that the teachers, learners and facilitators have in the three phases.

**Tasks of the second phase.** In the second phase of the study, the design of a group's game is divided into 3 sequential tasks. The first two are carried on verbally, with the help of paper material. The remaining task is done with a tablet per group. Each task is preparatory for the subsequent one. The tasks are designed as follows:

- T1. verbally establishing the objective of the game, e.g., who the main characters of the story are;
- T2. in verbal and written form establishing the main game idea in relation to the objective, that is, the actions of the players, their outcomes and termination conditions;
- T3. implementing the game idea on the tablet by using a specific program.

Each task comes with predefined timings. If children do not progress through the task within a certain time, then the facilitator will intervene and help them in expressing their ideas. If even with the help of the facilitator the group does not succeed within a certain time, then the facilitator will resolve the task on behalf of the group. That is necessary because the second and third tasks depend on the achievement of the previous task.

**Game framework for the first and second tasks.** The first two tasks aim at realising specific elements of a game framework, resulting from the *TERENCE* framework [11], and adapted for the GBL co-design in Merano. The framework used in Merano has several items and is structured as follows (see Table 2):

- the *red items* are the main elements that should be in every engaging game according to the literature, e.g., the actions of the player and the feedback for them; each facilitator has to explicitly ask his or her group to define such elements;
- the *yellow items* are not explicitly asked but are always deducible from red items;
- the *white items* are not explicitly asked and the facilitator has to trace whenever they spontaneously emerge.

ELEMENTS	QUESTIONS FOR EACH GROUP OF CHILDREN	TASKS FOR EACH FACILITATOR	S (0-1)	C (1-2-3)
<b>Title</b>	What title would you choose for your game?	Track the children's answers. Observe them.		
<b>Objective of the game</b>	What does this story tell you about your game?	Track the children's answers. Observe them.		
<b>Player interaction model</b>		Track and observe the interaction model		
<b>Genre</b>		Track and observe if the game falls into an existing genre.		
<b>Levels</b>		Track and observe if there are levels, how many and the passage conditions.		
<b>End of game</b>		Track and observe when the game ends.		
<b>Instructions</b>		Track the instructions for the player, and where they are placed.		
<b>Storyline</b>		Track of the narrative, if any.		
<b>Initial condition</b>	What is the game's setting? Where does it take place?	Track the children's answers. Observe them.		
<b>Actions and challenges of the player</b>	What kinds of challenges will the player face? What kinds of actions will the player take to overcome them?	Track the children's answers. Observe them.		
<b>Termination condition of the level</b>	<b>Victory Condition</b> How does the player win?	Track the children's answers. Observe them.		
	<b>Loss Condition</b> How does the player lose?	Track the children's answers. Observe them.		
<b>Feedback</b>	<b>Victory</b> What happens if the player wins?	Track the children's answers. Observe them.		
	<b>Loss</b> What happens if the player loses?	Track the children's answers. Observe them.		
	<b>Interaction or others</b> What happens if the player touches here ? (e.g., sound effects)	Track the children's answers. Observe them.		

**Table 2.** Game framework

The framework guides the facilitators both in collecting the data during the second phase and in analysing them in a structured uniform manner.

**Roles of participants.** During the first and third phases, one of the teachers conducts the activities as tutor. In particular, in the first phase teacher conducts the reading of the story in class. In the third phase, teacher moderates the discussion and promotes the sharing and improvements of ideas in the class. During the second phase, children are divided into pairs, previously created by the teacher, and are coached by one facilitator. Teacher is still present and supervises the class. The facilitator is a HCI expert with the key role of scaffolding [24] the GBL co-design activities: facilitator explains and guides his or her group through the tasks, avoiding that the group does not succeed in completing them, e.g., diverges from them. Facilitator stimulates each child to share their ideas and interacts as an “equal” member of the group, and intervenes to complete a task only if group children cannot conclude it otherwise.

## 4.2 User teaching

Firstly, we had a meeting at school involved with the school dean and interested teachers. In this meeting, we exposed our project and outlined the study. Afterwards, we fixed dates for the co-design study and we gave consent forms for the families of participating children. A week before the study, we carried out a training session for teachers during which we explained, in details, the study and clarified the roles of teachers and facilitators. Then we also provided teachers with a form to fill in in order to create balanced groups of learners for the second phase. In the form, teachers had to annotate, for each child, personal and interpersonal characteristics and their school performances: (1) gender; (2) age; (3) social skills, to be measured with a 3-level scale; (4) work attitude, whether the learner is able to work alone, or in group or something else; (5) learning style, whether the learner is global-creative, or deductive-analytic, or something else; (6) school skills, whether the learner is highly proficient, proficient or lowly proficient, or otherwise at school; (7) friendship, whether the members of the group are friends or not; (8) hierarchy, whether there is a dominant group member or not. Teachers then created groups for co-design study so as to balance social skills and school skills.

## 4.3 User description

We had 18 children, 11–14 year old and 3 teachers participating in the study. The characteristics of the learners, specified by teachers via the form, are recapped in Table 3.

## 4.4 Study execution

We conducted the study on March 18th with one class of 11–14 year old learners. The material used for the study was: one tablet device for each group, with a total of 8

Group	Gender	Age	Social skill	Work attitude	Learning style	School skills	Friendship	Hierarchy
1	M	13	2	other	other	lowly proficient	No	No
1	F	12	2	in group	deductive-analytic	proficient		
3	M	12	3	something else	deductive-analytic	highly proficient	Yes	Yes
3	F	12	3	something else	deductive-analytic	proficient		
4	F	12	2	something else	global-creative	proficient	No	No
4	M	12	3	in group	global-creative	proficient		
5	M	12	1	other	other	other	No	Yes
5	F	12	2	something else	deductive-analytic	highly proficient		
6	F	11	2	in group	other	lowly proficient	No	No
6	M	12	2	something else	something else	proficient		
7	M	12	3	something else	deductive-analytic	highly proficient	Yes	Yes
7	M	13	3	in group	global-creative	lowly proficient		
8	M	11	3	something else	global-creative	highly proficient	No	No
8	F	14	2	other	other	proficient		
9	M	14	2	alone	deductive-analytic	lowly proficient	No	Yes
9	F	12	3	something else	something else	highly proficient		
10	F	12	2	alone	global-creative	proficient	No	Yes
10	F	12	1	alone	other	lowly proficient		

**Table 3.** Personal and interpersonal characteristics of learners according to their teachers

tablets; paper and pencil to take notes both for children and for facilitators. Each facilitator had a paper sheet with the tasks and timings, as well as the game framework. The study got recorded via 4 cameras, used during the second and third phases. We executed 3 sessions of about 1 hour each, with 4 groups per session. Each group, composed by 2 children, was coached by a facilitator. In the remainder, we report the second and third phases mainly.

In the opening of the second phase, teacher, with possibly the assistance of the facilitators, gave a small introduction about the study and the collaborative conduct to be maintained intra groups. Teacher made clear that the group would be competing against each other: the group best collaborating according to the facilitators and teachers, and realising the best game according to other learners would see their prototype implemented as a game for tablets, to play with. However, said the teacher, the work of each group would be rewarded: “all game prototypes will be recorded and displayed in a web page of the University of Bolzano”. During the second phase, for each task, the facilitator presented progressive challenges with timings. He or she reminded his or her group the importance of sharing ideas for completing the challenge so as to move to the next one, and win the competition with the class. The facilitator stressed the importance of all team members understanding what was being created because, in the end, the group, together, would be presenting their prototype to the class and get feedback.

In the third phase, the videos of the games were presented by the children of the group under the guidance of their facilitator so as to make clear to all what the objective, actions and feedback of the game are. Teacher assisted and partially moderated the presentation that, for time limits, became rather short to the point that the sharing of ideas was minimal.

The day after the co-design study, the teachers distributed to the class a questionnaire for getting feedback from the learners. In particular, questionnaire asks what problems learners encountered in the various tasks, whether timing was appropriate, and whether they would prefer doing something different in future sessions.

## **5 Preliminary results and considerations**

All data were stored in an open source DBMS and attributes of the DBMS were derived from the collected data. We run statistical analyses on the quantitative data and descriptive analyses on the qualitative data. The analyses are still on-going and, in the remainder, we can only report the preliminary results. In particular, for the second phase, we measured success and collaboration intra-groups as follows.

### **5.1 Success**

For the second phase, we measured success in establishing an element of the game framework as follows: success=1, if the group does not establish the element, and the facilitator has to complete it on behalf of the group in case the element is explicitly required as part of a task; success=0, otherwise.

In the remainder, we report success firstly for the red and yellow elements of the framework, that is, those explicitly required or derived from explicitly required ele-

ments, and then success for the white elements of the framework, that is, those spontaneously emerged.

**Red and yellow elements.** Success results for the red and yellow elements of the framework are as follows.

- *Title.* All players chose at least one title for their game.
- *Objective of the game.* All players succeeded in setting at least an objective for their game. 60% of the groups chose to represent the morale of the story. More in general, all groups considered one the main events that happen in the story, in the climax, for realising their objective.
- *Player interaction model.* In all games, groups chose one or more characters of the story as their avatar, actively involved in the game play and personifying the player.
- *Genre.* 40% of groups chose a simulation game, 30% of them created an action game, 20% realised adventure or simulation games with puzzle elements, and 10% realised purely casual games.
- *Actions and challenges for player.* All groups developed an idea of the game, illustrating the actions and challenges of the player.
- *Termination conditions of the level.* All groups made explicit the victory and loss conditions for the game, in case it has only one level, or of at least one levels, in case the game is divided into levels.
- *Feedback.* 80% of groups defined a type of feedback.

In brief, all tasks were successful except the feedback that, however, was not established by only 20% of groups.

**White elements.** Success values for the white elements are as follows:

- *levels:* 60% of groups layered the game into levels;
- *end of game:* 50% of groups made it clear when the game is over;
- *storyline:* 60% of groups created a storyline;

The main observations concerning the success in relation to the characteristics of the group are as follows:

- presence or not of a dominant member does not affect success in white elements of the framework;
- success in white elements is not affected by presence in the group of a learner that is highly proficient in routine school activities;
- success in white elements increases when there is at least a global-creative group member;
- similarly, it increases if there are friends or socially skilled members.

## 5.2 Collaboration

In a debriefing phase, with videos of the recorded sessions, facilitators also assessed collaboration intra-groups in the second phase. In the remainder, separately, we report collaboration assessed in creating elements of the framework and in usage of tablets in the third task.

**Elements of the game framework.** For the second phase, we assessed collaboration within the group with a 3-valued scale. To each task, we assigned one out of the following 3 values:

- 1 if the task is carried on by only one of members groups, or by all but the results are different per member;
- 2 if the task is carried on by all members but there is one dominant member;
- 3 if there is a collaboration intra-group without dominant members.

The main preliminary observations concerning collaboration intra groups are as follows. They are measured for the required elements of the game framework, that is, the red ones, and the spontaneously emerging elements of the framework, that is, the white ones.

- Children who are friends show a slightly higher average score of collaboration for both the red (8.5 vs 7) and the white elements (11 vs 8).
- Presence of a dominance child has no impact on collaboration for the red elements (without/with a dominant child: 7,4 vs 7). Collaboration for white elements slightly increases with dominant children (9,22 vs 7,5).
- School skills seem to affect less collaboration for the red elements. The lowly proficient children seem to increase collaboration for the white elements (4 vs 7 vs 10,5 vs 8,8).
- The higher the sociability of the group members, the greater is the degree of collaboration.
- Children that prefer to work individually show a lower average degree of collaboration than the others (8.75 vs 30.95).
- Children with a learning style that is globally-creative have the highest average score of collaboration.

**Usage of tablets.** The third task required each group to work with a shared tablet. For that, we also tried to estimate the collaboration within the group in two manners.

- 1 if there is collaboration intra-group in neither choosing nor animating;
- 2 if there is a collaboration intra-group in either choosing or animating;
- 3 if there is a collaboration intra-group in both choosing and animating.

Secondly, we observe two things: if the group maintains the hierarchy provided by the teachers in the form; if the group maintains the same hierarchy that is established until the third task, as observed by the facilitator.

Collaboration results for the third task are as follows:

- 30% of groups collaborated equally and there were no dominant members;
- 90% of groups maintained the same hierarchy as that provided by the teachers;
- 40% of groups subverted the hierarchical relation maintained until using the tablet.

Thus working with tablets promotes an equal sense of participation, which may facilitate the collaboration—group members that, in the verbal and paper based tasks show low collaboration, participate more and make collaboration increase within the group when using tablets.

## 6 Conclusions

This paper deals with the GBL co-design of smart games for stories with children and teachers in schools. The first part outlines key issues, emerging from the literature of GBL and co-design for schools, that lead to the formulation of my Ph.D. research goals. These are detailed in the third section, and broken down into 4 measurable propaedeutic objectives, with related questions. The remaining part of the paper presents a co-design study, done in a secondary school in the Bolzano area.

The results of this studies allow us to tackle the first objective and, partly, the second and third objectives of my Ph.D. work. The GBL co-design activities, structured and timed as explained in the fourth section, were suitable (all tasks were performed within the time limit without the facilitator or teacher completing them on behalf of children) and engaging for children and teachers. The presence of facilitators and teachers was necessary for guiding the learners with the game framework so as to produce a game (and, not, say, simply a drawing) and for avoiding that the younger learners diverge from the objective of their game prototype. The engagement in the activities, the collaboration intra-groups, the creativity of children were fostered by structuring the co-design activities like games: (1) there were tasks with predefined challenges to achieve, and only by achieving one challenge the group can progress to the next challenge; (2) there were motivating rewards, frequently reminded by the facilitator, and related to the (3) collaboration intra-groups and (4) competition inter-groups (e.g., “the more we cooperate, the more we are likely to have our game implemented for tablets”); (5) the material to be used in each task was made available to children and discovered by them only when needed. Albeit the co-design tasks for groups were highly structured like in cooperative learning, there were no predefined roles for the members of the groups. However, the tasks were designed so that each member could contribute according to their skills, in line with [24]. During the third phase, each child had to represent a part of the group’s game, according to his or her skills and preferences.

Finally, our studies showed that, albeit use of tablets for co-design is limitative for the size of the groups, still tablets coupled with cartoon animation programs can foster the engagement of children in the activities and also increase intra-group collaboration: members that, in the verbal and written tasks show low collaboration, participate more and make collaboration increase when using tablets and animating their games.

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