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Stimulating children's engagement with an educational serious videogame using Lean UX co-design☆

Maria C. Ramos-Vega *, Victor M. Palma-Morales, Diana Pérez-Marín, Javier M. Moguerza

Department of Computer Science and Statistics, Rey Juan Carlos University, c/ Tulipán, s/n. 28933, Móstoles, Spain

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ABSTRACT

The *motivation* to stimulate children's learning engagement could be found in the fact that learning is not always motivational in itself. This is particularly true when learning is obligatory and based upon material that has not been chosen by the children themselves. A Lean UX *approach* to the co-design of an educational serious videogame (MOBI) is proposed in this paper. The core idea is that children's natural interest in playing can be stimulated by engendering the feeling that they are participating in the creation of something. The hypothesis is that this approach can increase the children's level of engagement and can facilitate their awareness of their learning perception. With the aim of testing this hypothesis, this paper describes an experience with 50 children with ages between 10 and 12 years old. The *results* indicate that the children's satisfaction grew significantly during the process, with an important reduction in the requests for changes and that 60% had the perception of having learned. It can be *concluded* that the co-design based upon a Lean UX methodology, of a children's educational serious videogame increases their level of product engagement and facilitates their awareness of their learning perception.

1. Introduction

Society has evolved in recent decades, incorporating technology in many ways to improve the lives of the majority and specifically to help people with special needs. In the particular case of education, technology has the ability to increase students' satisfaction with the learning process whilst stimulating their motivation and levels of engagement.

The past few years have seen growth in worldwide interest in the teaching of programming to children [1,2]. Multiple benefits have been studied in the development of not only computational abilities, but also more general abilities, applicable to any aspect of life [3]. Various authors have proposed alternatives to teach concepts, ability to program games and even "unplugged" experiences to develop logical thinking. However, at the time of writing it is not clear which is the best approach for teaching programming to children.

The novel alternative, that is proposed in this article, is the use of serious videogames in the classroom (gamified approach). Learning in gamified environments can increase students' engagement and hence their participation in class [4]. However, it is not yet clear that the mere use of a videogame will maximise student engagement when considering the learning of such abstract programming concepts as I/O, conditional statements or loops.

It is for this reason, that for the first documented time, a co-design has been undertaken with children between the ages of 10 and 12, to involve them in how a new kind of videogame could be created and how this would be educational, thence helping them learn programming, motivate them and increase their level of satisfaction. Multiple benefits derived from the participation of children in the design team for the creation of technology are described in the literature [5]. Specifically, from all the available participative techniques Lean-UX co-design was selected due to being a method applied to the design of the user experience, based on experimentation, with rapid iteration of ideas and the use of incremental processes. One of the advantages of using Lean-UX is that it enforces early and continuous user participation throughout the entire product design and development process, with the objective of obtaining continuous feedback to improve their experience [6].

The underlying idea is that through making the effort to perform the Lean-UX co-design with the children, taking into account their special

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* Corresponding author.
E-mail addresses: mariacristina.ramos@urjc.es (M.C. Ramos-Vega), vm.palma@alumnos.urjc.es (V.M. Palma-Morales), diana.perez@urjc.es (D. Pérez-Marín), javier.moguerza@urjc.es (J. M. Moguerza).

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characteristics such as lack of maturity, attention span and limited vocabulary, that both levels of engagement (taken in the context of the use of the videogame and participation in its design) and their learning perception (the awareness of the children to have learned something during the process and in playing with MOBI) would be maximised.

To validate this, a study with 50, 10 to 12 year-old children was undertaken. An initial prototype for an educational videogame for teaching programming was proposed (called MOBI) and feedback requested. From this initial baseline, its evolution was monitored with feedback gathered through open questionnaires, on 3 occasions over the course of a year. This led to a final evaluation that registered a significant increase in the children's satisfaction with the game (p value $<$ 0.01) and with 60% having the perception of having learned.

The remainder of this document is organized in the following sections: Section 2 reviews related works; Section 3 describes the MOBI videogame; Section 4 focuses on the research method employed; Section 5 provides the results obtained; Section 6 presents a discussion of the results; and finally section 7 ends the paper with the conclusions and identification of future areas for investigation.

2. Background

2.1. Teaching programming in Primary Education

In recent decades, there has been great interest in research regarding how to teach children how to program [1,2]. Worldwide interest in this is to be found in what some authors have called "computational thinking" ([3], i.e., use of resources from Computer Science to solve problems of any nature).

The goal is not that all children become Computer Engineers, instead it is to help children understand the world in which they live. Current society is used to devices and their applications/apps but without really understanding their potential and limitations. By teaching children how to program, it is expected that their understanding of their interactions with devices, applications and apps will improve. This belief is, however, still being researched.

Some lines of research are investigating the most effective methods and techniques for teaching programming to children. It is not clear that traditional methods for teaching programming in higher education can be replicated in Primary Education. This is because of some of the special needs of younger children, such as lower attention levels, limited vocabulary and possibly lower levels of motivation, due to the subjects in Primary Education not being chosen by them.

Four main approaches can be identified in the literature, regarding how to teach children how to program [7,8]: textual programming, visual programming, use of robots and unplugged activities. Textual programming dates to the sixties with the LOGO programming language [9,10]. Children gave instructions in LOGO to move a turtle. The idea of this approach is that the best learning comes from giving students resources to create and think [10].

A more recent approach consists on using visual block-based programming environments with multimedia languages such as Scratch [11]. Children all over the world are creating programs in Scratch. Fig. 1 shows sample of the environment with a sample program that moves a character 10 steps. As can be seen, on the left there are the instructions categorized in several types (motion, looks, sound, events, control, sensing and operators). In the centre of the screen children drag and drop the block of instructions to create a program as if it were a puzzle. Finally, on the right the result of the program can be seen (i.e. in this case how the cat moves 10 steps).

In countries without sufficient resources to allow children to program with devices, an unplugged approach has been tried, focused on using paper based exercises or mental games [12]. Finally, at the opposite end of the spectrum, in schools with ample budget to buy robots, another approach has been taken based on the use of robots such as Lego Mindstorms [8].

2.2. Gamification

The main motivation for employing gamification principles in children's education, as discussed in various studies in recent years [13], is derived from the necessity to create incentives that stimulate pupils' active participation and thereby accelerate their learning. These studies have demonstrated that pupils experience an increase in intrinsic motivation, as well as developing other abilities such as decision taking and competitiveness.

The trend in the latest studies [14] has been to define the principal gamification elements as orientation to specific objectives, the rewards corresponding to the achievement of said objectives and continuous reinforcement through feedback. Moreover, it is extremely important that a gamified game is satisfactory and fun for the children, such that periods of increased interest are sustained over time, helping to consolidate acquired knowledge [15]. When the game is not sufficiently attractive to children, gamification is rendered meaningless, as the user would not be willing to invest enough time to experience the benefits of the process.

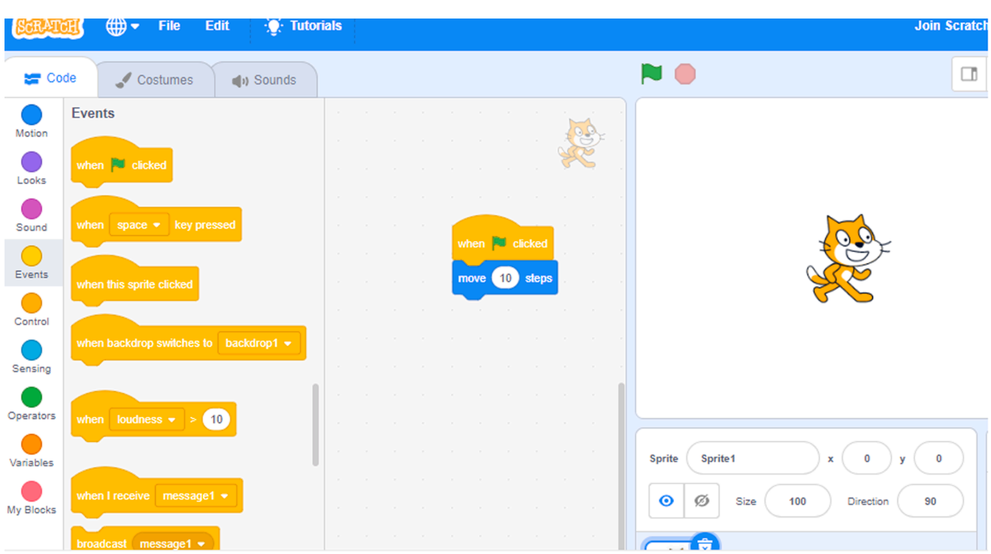

Fig. 1. Snapshot of Scratch.

Nevertheless, different investigations have highlighted that adding gamification to elements of traditional education does not imply a significant increase in the assimilation of these elements [16], despite showing that an increased level of pupil satisfaction is achieved. However, other studies have shown that in the context of a videogame there is a significant increase in the acquisition of knowledge [17] in which the concept of gamification forms an intrinsic part. Therefore, it is clear that there is a need to focus the videogame on attaining the highest possible level of satisfaction, not only to achieve the goal of the user taking advantage of the gamification and hence intrinsic motivation, but also, to acquire the knowledge being transmitted, in the most efficient way.

2.3. Lean UX

Lean UX [6] is an experimental method that strives for continuous improvement in the user experience whilst guaranteeing process efficiency by eliminating waste and squander. To this end, Lean UX is built upon 3 principal foundations: Design Thinking [18], Agile Software Development [19,20,21,22] and Lean Startup [23]. These foundations share a common element: they involve real users in an empirical interactive and iterative creation process with the goal of creating the best possible product user experience (which is the final goal of UX)

Design Thinking according to Tim Brown [18,24], is defined as the discipline that employs designers' sensitivity and methods to ensure alignment between peoples' needs and what is technologically feasible, and with a viable business strategy that will create value for the client and an important market opportunity.

Agile Software Development is a movement or trend with its beginnings around 2001 [19] based upon the experience of 17 software development professionals aimed at creating better ways to develop software, with "customer satisfaction" being the main driver; "to satisfy the customer through early and continuous delivery of valuable software", apart from, among other principles, to facilitate continuous adaptation to change and a high frequency delivery of functional software.

Lean Startup is a method focussed on making companies more efficient, understanding what consumers really want and reducing product development cycles [23]. Its origins can be traced to the client development methodology [25] and the Toyota production system [26] created by Taiichi Ohno y Shigeo Shingo, based upon Lean principles such as the elimination of waste, just-in-time production and the acceleration of cycle times, among others.

Among the experimental studies that currently exist related to the use of Lean UX [27,28,29,30], none have been identified as implementing a Lean UX co-design with children to create a serious videogame that facilitates the teaching of basic programming principles in primary education.

3. Mobi

MOBI[1] is a proposal to introduce programming to Primary School children worldwide employing the co-design of a serious videogame, in a fun way through achieving challenges (gamified approach). Although the videogame is in Spanish, all the text in the images has been translated to facilitate understanding by an international community.

The player accompanies the protagonist, MOBI (which is also the name of the videogame), to different places in the world, looking for his friend Tuitui's home. Tuitui is a bird that has lost his memory. In each place in the world visited, players must resolve problems related to diverse programming concepts.

To this end, a structure has been created based upon different levels set in different parts of the world. In each level, a grid of varying size and shape is presented within which the player must move MOBI in order to complete a series of challenges, whilst interacting with the environment. In the aforementioned grid, the player has the possibility of having MOBI execute the following instructions: bidirectional movement (forwards, backwards and turn), interact with a game element that is in front of MOBI and repeat a group of instructions in a loop.

The character MOBI, as shown in Fig. 2, was designed to offer a nexus between the player and the videogame that was as friendly and familiar as possible. Thus, the character's design is based upon a smartphone, a familiar element in the lives of children today. Additionally, MOBI is accompanied by Tuitui the bird. Tuitui's main function, apart from presenting the videogame's back-story, is to aid the player in their journey via tutorials and advice.

Starting from this conceptual idea, which was presented to the children at the beginning of the process, and following a Lean UX method for the co-design, the videogame was developed based upon the improvements requested by the children to maximise their own satisfaction. During the process, apart from the incorporation of the requested improvements, basic programming concepts were progressively implemented, exposing each in such a way that the child could attempt and assimilate it through trial and error. Moreover, metaphors are employed as an aid to simple assimilation, whilst facilitating future comprehension of more technical descriptions of related concepts. The concepts presented in MOBI, in order of their appearance to a player, are:

1. *Instruction*: each of MOBI's actions, such as for example "move MOBI one square down" with the orange down arrow as can be seen in Fig. 3.
2. *Program*: sequence of instructions, such as for example, the repeat, move up, turn right, move up sequence shown in Fig. 4.

3. *Output*: each time a program instruction is executed, the result is shown in the in the videogame. Thus, for example, the effect of the instruction "down arrow" would be that the MOBI's avatar moves one square down.

4. *Variable*: over the course of the game MOBI can collect objects (as shown in Fig. 5) in order to undertake tasks to resolve the assigned challenges. These objects are variables that may represent different types of values

5. *Memory*: MOBI's memory is a group of variables that are kept in his backpack (as shown in Fig. 6 on the left) which the user can visualise by clicking it.

6. *Conditional*: some actions can only be performed when certain pre-established conditions are met as shown in Fig. 7.

7. *Loop*: to execute the same action several times over, children must place it in a repetition box (as shown in Fig. 8, this mechanism is similar to robots such as Cubetto).

In the first MOBI prototipe evolution, the first playable videogame prototype was produced, according to the students' main request: to be colourful and animated. The result is shown in Fig. 9.

This first evolution included the concepts of *Instruction*, *Program* and *Output*, such that the student introduces instructions in a test box, using syntax similar to some common programming languages such as Java™ or C, these instructions specify a behaviour for the character to be executed once the "Run" button is pressed. The challenges to be completed for the level, as well as the available instructions were shown as notes below the text box into which the instructions were typed. For example, the first place in the world where MOBI was found, was the North Pole. MOBI wants to take Tuitui to the snowman, to ask him if he remembers him living there.

Based upon requests from the children, the second evolution of the concept arose from the necessity to, improve the graphics. This was

[1] The original, Spanish language, videogame is available on-line via the link (URL): vmpalmamorales.github.io/mobi

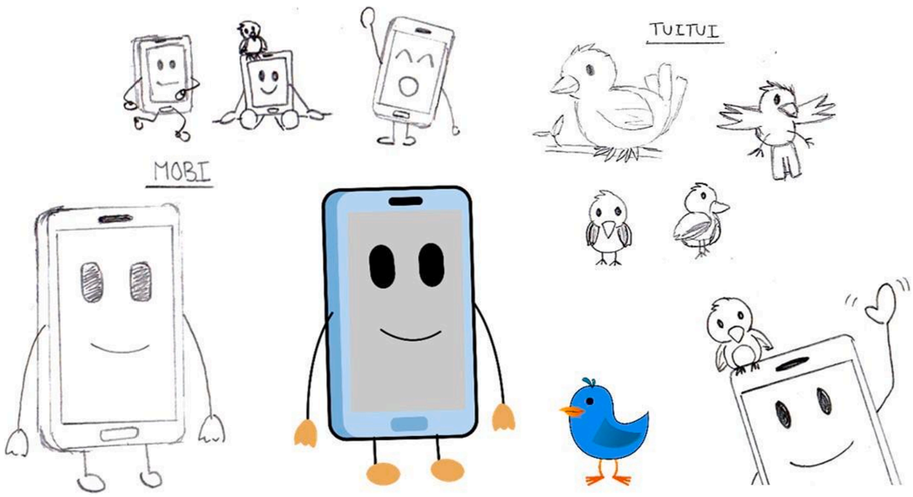

Fig. 2. MOBI storyboard.

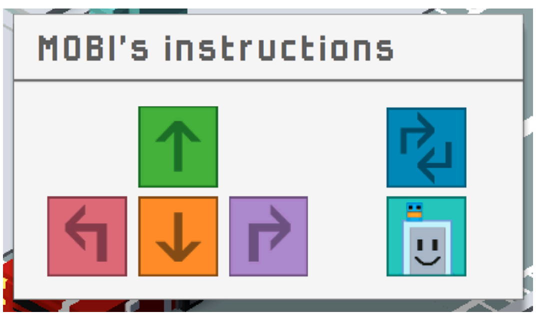

Fig. 3. Instruction concept.

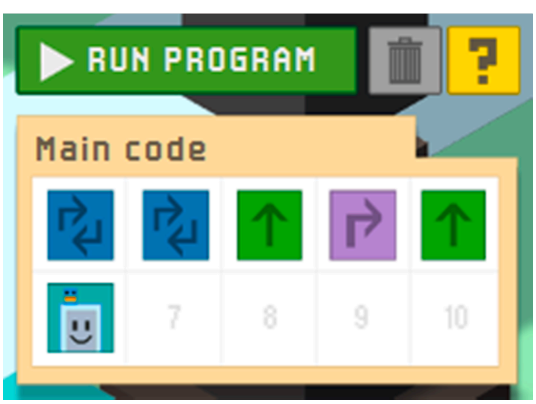

Fig. 4. Program concept.

reflected as the change from 2D graphics to 3D graphics, which can be seen in Fig. 10.

In this prototype the concepts of *Variable* and *Memory* were implemented. These ideas were introduced employing the metaphor of MOBI storing objects (Variables) he finds in the levels in his backpack (Memory). These variables can be used to interact with the environment to, for example, unlock doors. This is a simple metaphor for students to assimilate, being accustomed to mobile devices such as smartphones (MOBI) and hence the concept of *storage*. The available instructions and challenges, as before, are shown below the text box for introducing the instructions (programming).

Finally, a third evolution of the initial concept was undertaken in which improvements in the videogame's interaction and interface capabilities were included, due to children reporting dissatisfaction with having to introduce instructions manually. System interaction was changed to offer a *drag&drop* paradigm, that facilitated the completion of levels, and was a familiar approach to interaction due to the children's familiarity with smartphones. As can be seen in Fig. 11, instructions have been transformed into individual tiles that the child can drag into the yellow container for sequential execution, and into the blue one to create a loop. The remainder of the interface was also modified to give it the look&feel of a mobile device. In this third prototype, the challenges are clearly shown in a pop-up window at the beginning of the level, or can be viewed at any moment thereafter, selecting from the menu available to the left side of the interface, as shown in Fig. 6.

In this prototype, the concepts of *Conditional* and *Loop* were implemented. Conditionals were introduced with a combination of two boolean conditions. On one hand, MOBI displays the number of steps taken on the level above his head and can only interact if the number of steps is even. On the other hand, the interaction instruction could only be used if MOBI was positioned on a square with the interaction icon (a blue tile with MOBI's avatar). Finally, loops were introduced via a new action block, in which each time the *repeat* instruction (tile with arrows in a square loop) is used, the actions are executed. This action block can be executed as many times as desired, in a similar way to calling *methods* in programming. This final evolution can be seen in Fig. 11.

The third MOBI prototype is a functional prototype. Thus, it could be considered a minimum viable product (MVP) whose evolution (continue or pivot) will be based on the feedback of MOBI early adopters.

4. Method

Following an adaptation of the guidelines to report experiments in Software Engineering written by [31,32] this section is structured as follows: 1. Goal and hypothesis, 2. Participants and context, 3. Measurements, 4. Procedure.

4.1. Goal and hypothesis

The objective of this study is the validation of the following hypothesis:

The co-design based upon a Lean UX methodology, of a children's educational serious videogame can increase their level of product engagement and can facilitate their awareness of their learning perception.

To validate the hypothesis, the study will provide answers to the following Research Questions (RQ):

Fig. 5. Variable concept.

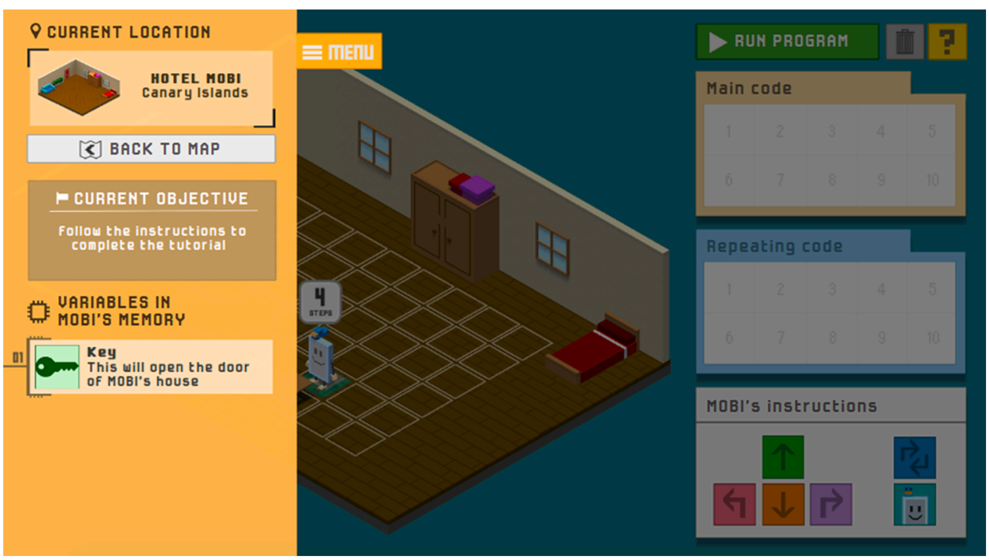

Fig. 6. Memory concept.

- RQ 1 - What degree of satisfaction do the children have with respect to the use of the videogame?
- RQ 2 - What perception do the children have with respect to their participation in the videogame co-design process?
- RQ 3 - What learning perception do the children have, six months after their last interaction with the videogame?

4.2. Participants and context

50 students from 10 to 12 years old, enrolled in the 5th and 6th years of a Madrid (Spain) Primary School, participated in the experience. Students were grouped in classes A and B, with 25 students per class. The distribution of children in both classes was 35% girls and 65% boys, as shown in Table 1.

The school was chosen because the Head Teacher was willing to teach programming as part of Primary Education. Teaching programming in Primary Education in Spain is not compulsory. Therefore, schools that are not private may not have the time or the resources to do so. In this case, an Art teacher was willing to dedicate part of their lessons to teach programming to students for six months. The teacher was also willing to let us deliver questionnaires to obtain responses from the students. However, neither the Head Teacher nor the teacher in question could give us more than the six months plus the final questionnaire six months later.

4.3. Measurements

The factors defined for the verification of the proposed hypothesis are product engagement and learning perception. For the purposes of this study, engagement is measured evaluating three factors: UX Satisfaction, Lean UX Co-design and Learning Perception.

The UX Satisfaction factor measures the degree of satisfaction for the child when using the videogame. In other words, what is the general opinion of the videogame combined with the quantity and quality of the changes they proposed. In practice, three dimensions have been measured for the factor, namely: general opinion of the user regarding the utility of the game for educational purposes, the need for changes to improve the game, and the overall level of satisfaction of the user. Using

Fig. 7. Conditional concept.

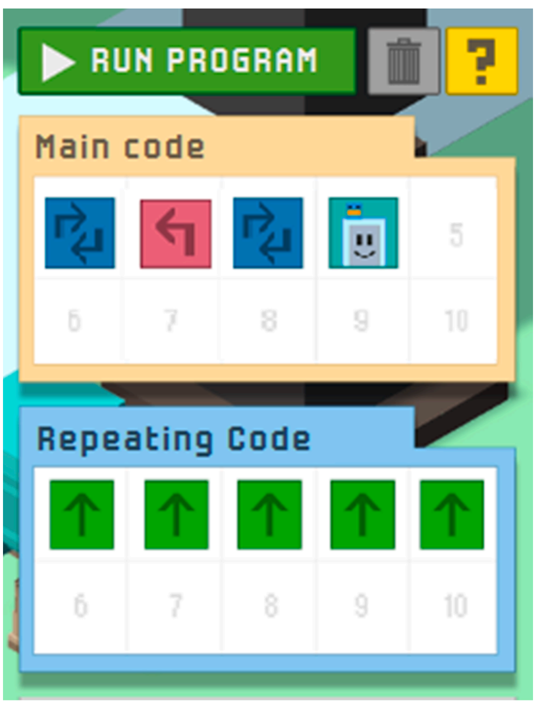

Fig. 8. Loop concept.

anonymous, open questionnaires, users were asked about their perception regarding the three dimensions. The age of the respondents (children between 10 and 12 years) made the use of open questionnaires advisable, as it would be easier for them to freely express their opinions, avoiding the interpretation of answer scales.

The Lean UX Co-design factor measures the level of participation that the child had in the videogame design process; that is to say, what quantity and quality of feedback was provided whilst they were involved. This factor is measured as a function of the child's responses to questionnaires: if they liked participating in the videogame design, if they detected that the videogame was changing as the process progressed and if they felt that their opinion had been taken into account with respect to the application of changes. This factor was represented as a percentage based upon answers provided by the children to questionnaires.

The Learning Perception factor reflects the child's awareness of having learned something through the videogame. This factor was measured as a function of the responses to a questionnaire provided at the end of the study. This factor was represented as a percentage based upon answers provided by the children to questionnaires.

4.4. Procedure

To date, there have been only a reduced number of studies that have employed Lean-UX for the co-design of IT applications [27,28,29,30], mainly due to how recent this approach is. Despite its newness, from the clearly demonstrated benefits that it provides [27,30], the proposal for this experience is to use Lean UX for the co-design of MOBI as a collaborative, iterative and incremental process with real users (the children), as shown in Fig. 12.

During the co-design part of the process in the first 6 months of the study, 4 co-design sessions were run with the children and three evolutions of the product (MOBI) were delivered (see Table 2). All sessions were held with the groups in their own classes, during school time. The first session (start of study, nov 18th) had the objective of getting to know the user, presenting the idea for the product and capturing their impressions. Paper based images of the prototype character and game storyboard were presented. Both the questions to ascertain the children's level of digital competence and their first impressions regarding MOBI were posed in an initial questionnaire[2].

Additionally, a field study was performed analysing the use that was being made of the Scratch platform to complete the profile of an archetypal user represented by the sample. To build the user archetype two techniques employed in client discovery were used: the empathy map (see Fig. 13) and the user profile (see Fig. 14).

The objectives for the following three sessions (first, second and the third a review of MOBI, feb, apr, may 19th) was to evaluate the evolution of the product done as a result of the feedback received during the co-design process. In the first and second reviews, information was gathered using direct observation and from a focus group (selecting 16 children from each group from amongst the most and least advanced

[2] Initial questionnaire is available at https://drive.google.com/open?id=13ivCLh50MfaIdtOFrfWfBw2drEjXoN80

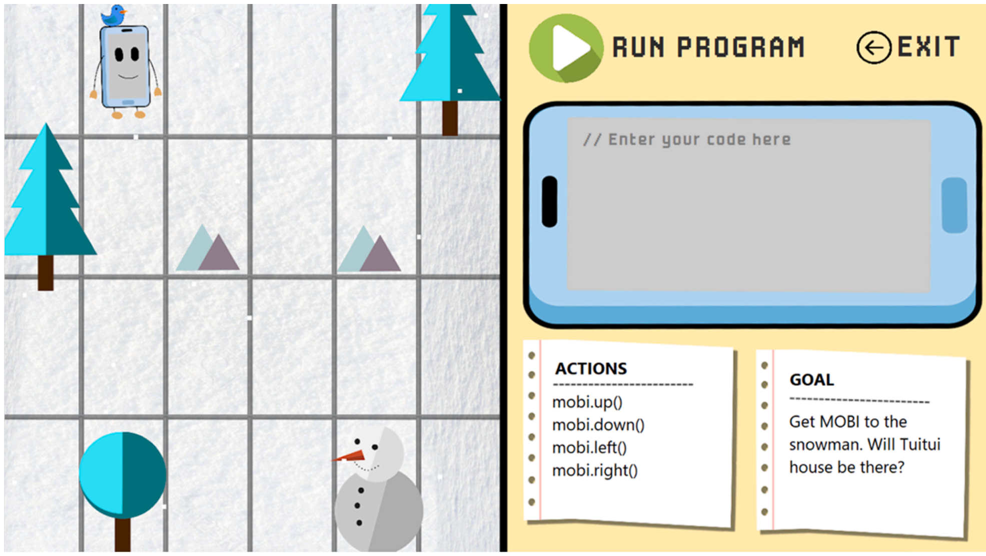

Fig. 9. First MOBI prototype.

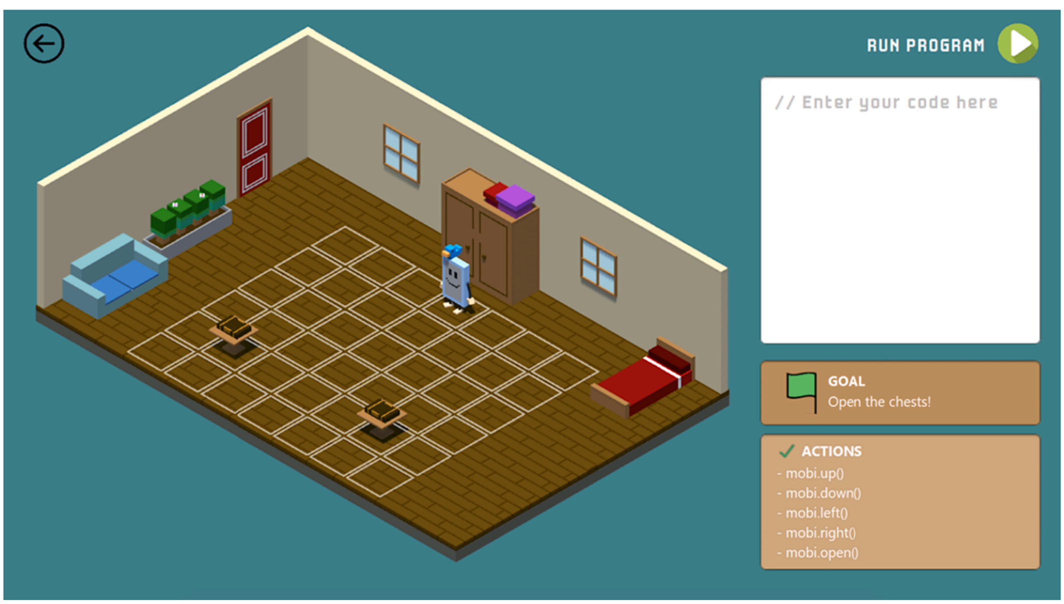

Fig. 10. Second MOBI prototype.

MOBI users). In the third and final review information was gathered using a review questionnaire[3].

Six months after the end of the co-design process and their last interaction with MOBI, a final session was held with the children, with the objective of evaluating their recollection of MOBI and their perception of the learning acquired through playing with it, bringing the study to closure. This final session was solely based on the recollection the children maintained regarding the product the last time they had interacted with it, six months earlier. The information corresponding to this session was gathered using the final questionnaire[4].

4.5. Expert background and contribution

Once the data had been collected, three independent experts (1, 2 and 3) evaluated the questionnaires gathered during the co-design procedure. The background of the experts is the following:

- Expert 1 – Expert in User Centered Design, Usability and Accessibility. She has worked in the creation of educational IT tools for children from infants to primary school ages. In recent years she has been, and is involved in a project to teach programming at early ages.
- Expert 2 –Expert in the creation of graphics, 2D/3D animation and videogame development. He has worked in the creation of various genres of videogame including: online, collaborative, platform, role and puzzles. Currently he is involved in the development and application of gamification in serious games.
- Expert 3 – Expert in Business Development, UX and Agile Frameworks. She has worked managing projects for clients in the Financial Sector and leading Business Units for companies in the IT sector.

[3] Review questionnaire is available at https://drive.google.com/open?id=1UEiWOjicnAwvxeGqKp9xrloy8d_S_78b

[4] Final questionnaire is available at https://drive.google.com/open?id=1yl4oOgj40PbnNUEws8Mo1lx9qC-4ql63

Fig. 11. Third MOBI prototype.

Table 1
Sample.

Study	5A & 5B Start	5A & 5B End	5A Start	5A End	5B Start	5B End
Boys	31	32	16	16	15	16
Girls	19	16	9	8	10	8
TOTAL	50	48	25	24	25	24

Additionally, she has participated in multiple Agile Transformation projects, utilising Scrum and Design Thinking. Currently she is collaborating in entrepreneurial projects with a focus on the creation of new business models employing Lean Startup and Business Model Canvas.

The Expert's evaluation of the questionnaires was necessary as the data gathered for the UX Satisfaction factor was free text written by the children. The idea was to let children freely express themselves without limiting their answers to multiple-choice options. The difficulty was that this prevented automatic processing of answers, and therefore made the reviewers essential for the effectiveness of the procedure.

Moreover, since the questionnaires were anonymous, samples were not correlated (see Table 2 for a detailed description of the sessions and participants). The different sample sizes were due to the fact that answering the questionnaires was not a mandatory task. Thus, each expert had to read all the children's questionnaire answers and evaluate the three dimensions of the UX Satisfaction factor at each of the three states of the co-design process: the start of the study and the co-design, 50 respondents (state i0), the review, 3 and end of the co-design, 32 respondents (state i1) and six months after the end of study, 48 respondents (state i2). To complete that task, they used Likert scales as shown in Table 3.

With respect to opinion, this was measured as a function of the responses to questionnaires in which they were asked what they thought about MOBI, if they liked it, if they would continue playing and if they would recommend it. Concerning the need for changes and user satisfaction, these were measured as a function of the responses to the aforementioned questionnaires in which they were asked what they would improve about MOBI.

Finally, the UX Satisfaction factor is represented with a Likert scale (1-not at all satisfied; 2-a little satisfied; 3-satisfied; 4-very satisfied; 5-extremely satisfied) as a combination of the value for the scale of opinion regarding the videogame, the value for the changes scale and the value corresponding to user satisfaction.

5. Results

5.1. Brief descriptive analysis

As already mentioned, three main factors were measured:

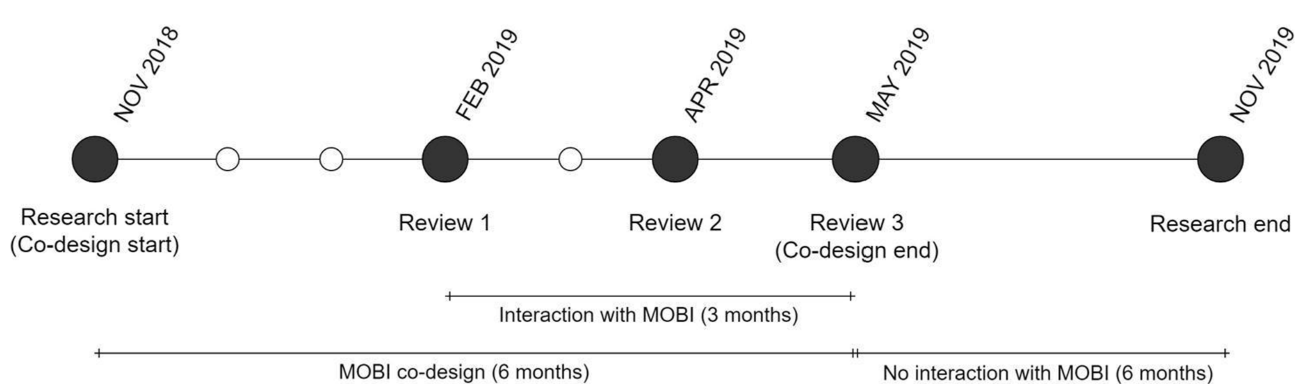

Fig. 12. Process timeline with children.

Table 2
Sessions with children.

Session	Objective	Users	Techniques and Tools	Date
Start of the study and the co-design process	Know the user and validate the MOBI concept	50	Field observation, paper prototype and initial questionnaire (state i0)	Nov 2018
Review 1	Feedback first evolution	32	Free observation and focus group	Feb 2019
Review 2	Feedback second evolution	32	Free observation and focus group	Apr 2019
Review 3. End of co-design	Feedback third (and last) evolution	32	Direct observation and review questionnaire (state i1)	May 2019
End of study	Understand the final user satisfaction	48	Final questionnaire (state i2)	Nov 2019

satisfaction with the game's user experience, participation in the game's design using Lean UX and the perception of learning with the game, these measurements being obtained using open questionnaires at the three states of the process described in section 4.3 (Measurements): state i0 (start of the study), state i1 (review 3 and end of co-design) and state

Table 3
Likert scales of three dimensions of the UX Satisfaction factor.

Scale	General Opinion	Need for Changes	User Satisfaction
1	Poor	No changes	Not at all satisfied
2	Could be improved	Low impact changes	A little satisfied
3	Good	Changes with impact	Satisfied
4	Very good	Changes with considerable impact	Very satisfied
5	Excellent	Changes with drastic impact	Extremely satisfied

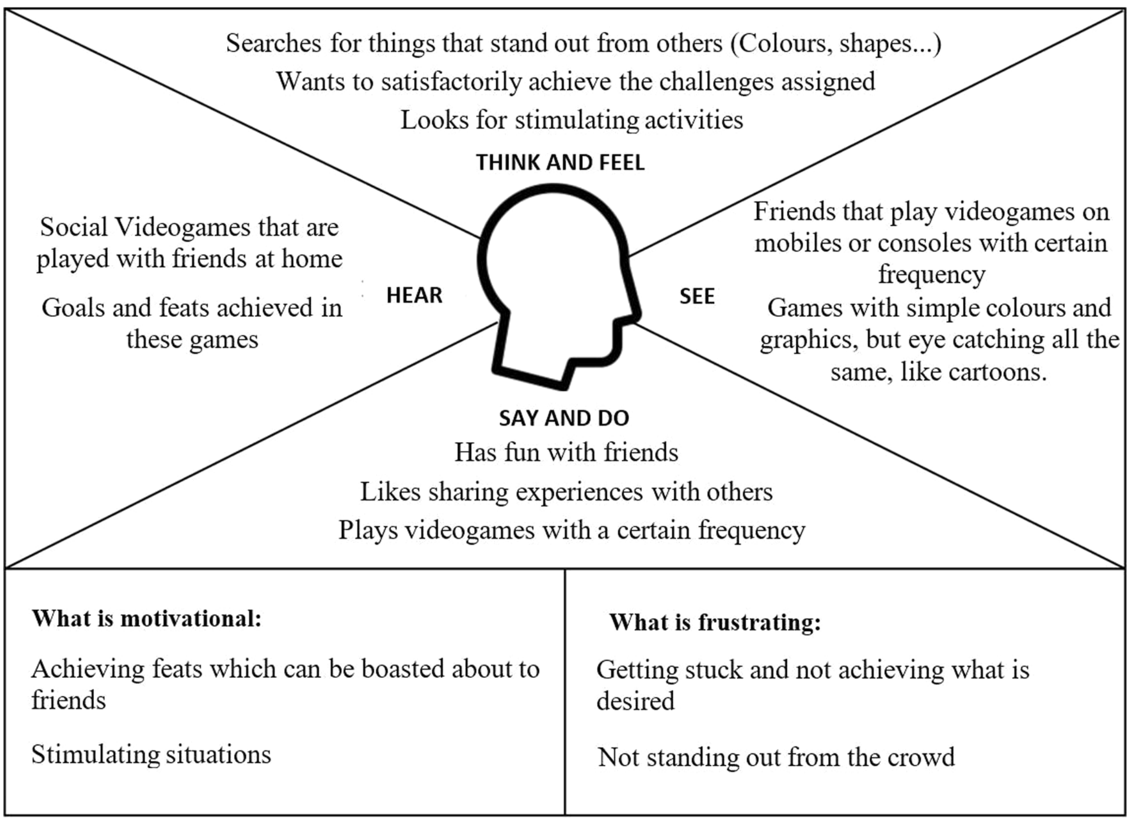

Fig. 13. Empathy map.

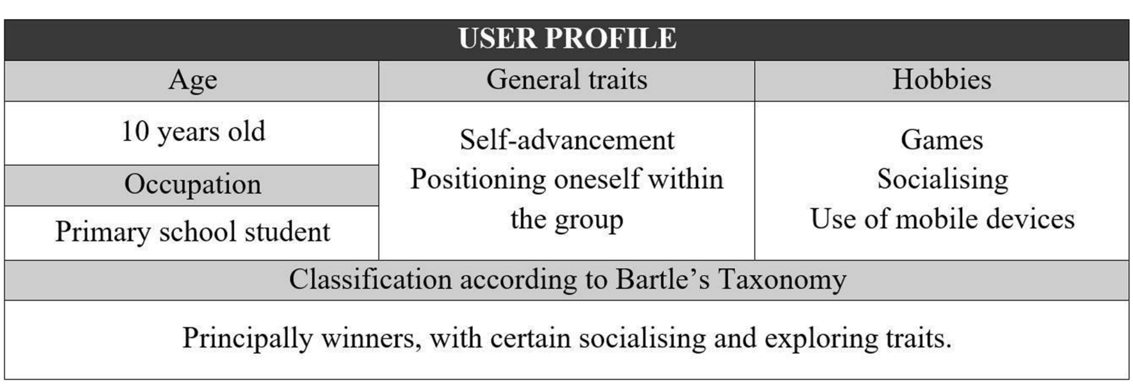

Fig. 14. User Profile.

i2 (end of study). The focus is on the descriptive results obtained at state i2. At this point, it is important to remark that this state takes place after the conclusion of the co-design with no interactions with the videogame during this period (six months). So, this state provides a record of the recollection that respondents have regarding their final perception of the game.

With respect to the participation in the design of the videogame, 94% of the children were satisfied with having participated, 85% noticed that the design of MOBI had been affected by their opinion and 63% would have liked have continued to contribute to the design.

With respect to satisfaction with the videogame's user experience, 92% of the children remembered MOBI, 85% were pleased with the finished game, 79% still liked playing with it and 85% would recommend it to their friends.

To better illustrate this data, the following are a selection of comments gathered from the children: "To begin with it was very basic but as I provided ideas to improve the game, it improved and finally was converted into a super-game, although it had very few levels", "I felt happy playing MOBI because I had programmed it.", "MOBI was changing according to what we were commenting", '' Initially, I didn't like it, but once it changed, I loved it", "I loved playing with MOBI and this year I would like to do so again.". Originally the comments were made in Spanish. They have been translated into English to facilitate clearer understanding in the international community.

With respect to their perception of what was learned, based upon the responses obtained from the final questionnaire, 60% of the children perceived that they had "learned to program". The following are a selection of the children's responses to the question: What have you learned from MOBI? - "That games do not have to be solely for play, you can also learn", "I learned to program better", "MOBI is a telephone that obeys your instructions and completes levels".

5.2. Inferential analysis

From the data described in Section 4.3 (Measurements), the results for each dimension of the UX Satisfaction factor are analyzed separately. The analyses were carried out using the statistical software "R" [33], and its packages "pspearman" [34] and "coin" [35].

5.2.1. General opinion of the user regarding the utility of the game

Firstly, the coherence between expert interpretations is validated; do the opinions of the experts correlate?

Spearman's rank correlation coefficient [36] was used for this purpose, delivering coefficients in the interval [–1,1]. The nearer the correlation value is to the limits of the interval, the more correlated the judgements are. Additionally, an hypothesis test was carried out to check the statistical significance of the correlation coefficients. As a result of the test, the probability value known as p is obtained. Intuitively, small p values (lower than 0.01, the usual significance level) indicate significant correlation values. Table 4 shows the matrix of Spearman's rank correlation coefficients with the corresponding p values in brackets.

The results confirm that the judgements of the independent experts are significantly correlated (all the p values having values close to zero). It is important to remark that the whole set of Spearman's rank correlation coefficients reach positive values which, for each pair of experts implies that large (small) Likert scale values provided by one expert are reciprocated by large (small) Likert scale values judged by the other expert. Therefore, from these results, it can be concluded that there is an overall coherency of the judgements of the three experts regarding the opinion of the users about the utility of the game.

Given that there is a positive correlation among the expert judgments, their judgments have been combined into a single assessment. For each questionnaire, the combined assessment has been built by averaging the judgements provided by each expert [37]. In this way, in the following sections, the results for 4 experts will be discussed, that is, the 3 previously identified independent ones and a fourth one that is referred to as "combined expert".

Table 5 shows the summary statistics (average and standard deviation) of the results obtained for each expert at the different states of the process. In general, there appears to be consensus between the experts regarding an improving trend as the process advanced.

Fig. 15 shows, for each expert, a box plot comparing the judgements regarding the opinion of the users at each state of the process.

The graph apparently identifies an increase in the positive opinion of the users as the process advanced. In fact, for experts 2 and 3, at the final state i2, most users have the highest possible opinion regarding the utility of the game for educational purposes.

To support this visual result, the Wilcoxon-Mann-Whitney test was carried out; a nonparametric statistical hypothesis test [38]. The test was used to compare groups of judgements at two different states of the process, that is, whether judgements at a given state were in general greater than judgements provided at a previous state. Within this test, small p values (lower than 0.01) imply that there is statistical evidence corroborating that the difference between both groups of judgements is large. Table 6 shows the results.

In the case at hand, the p values obtained for the comparisons of judgements at the final state (i2) and the initial state (i0) are all lower than 0.01 for all experts. Such small p values demonstrate that there is statistical evidence corroborating an increase in the positive opinions of the users as the process advanced, therefore supporting the visual results observed in Fig. 15. Regarding the remaining comparisons, only the judgements provided for states i1 and i2 by expert 2 lead to a p value larger than 0.01. This means that according to the judgements provided by this expert, there is not a significant increase in the positive opinion of the users from the intermediate state i1 to the final state i2. Nevertheless, the judgements provided by expert 2 still corroborate an overall increase in the positive opinion of the users, mainly due to the significant increase that takes place from the initial state i0 to the intermediate state i1.

5.2.2. Need for changes to improve the game

Following the approach of the previous analysis, a check was made as to whether or not the judgements that the experts made regarding the need for changes to improve the game are correlated. Table 7 shows the matrix of Spearman's rank correlation coefficients with the corresponding p values in brackets.

The results confirm that, concerning the need for changes to improve the game, the judgements of the independent experts are significantly correlated (all the p values are close to zero). Again, their judgments have been unified into a single average assessment referred as "combined expert".

Table 4
General opinion: Spearman's correlation between experts (p values in brackets).

Opinion correlations	Expert 1	Expert 2	Expert 3
Expert 1	1	0.78 (p value ≤ 0.0001)	0.68 (p value ≤ 0.0001)
Expert 2	0.78 (p value ≤ 0.0001)	1	0.67 (p value ≤ 0.0001)
Expert 3	0.68 (p value ≤ 0.0001)	0.67 (p value ≤ 0.0001)	1

Table 5
General opinion: Summary statistics.

Averages (standard deviation)	State i0	State i1	State i2
Expert 1	2.94 (0.91)	3.63 (0.55)	4.33 (0.78)
Expert 2	3.28 (0.90)	4.38 (0.79)	4.48 (0.87)
Expert 3	3.42 (0.97)	3.84 (0.77)	4.50 (1.29)
Combined expert	3.21 (0.86)	3.95 (0.65)	4.44 (0.80)

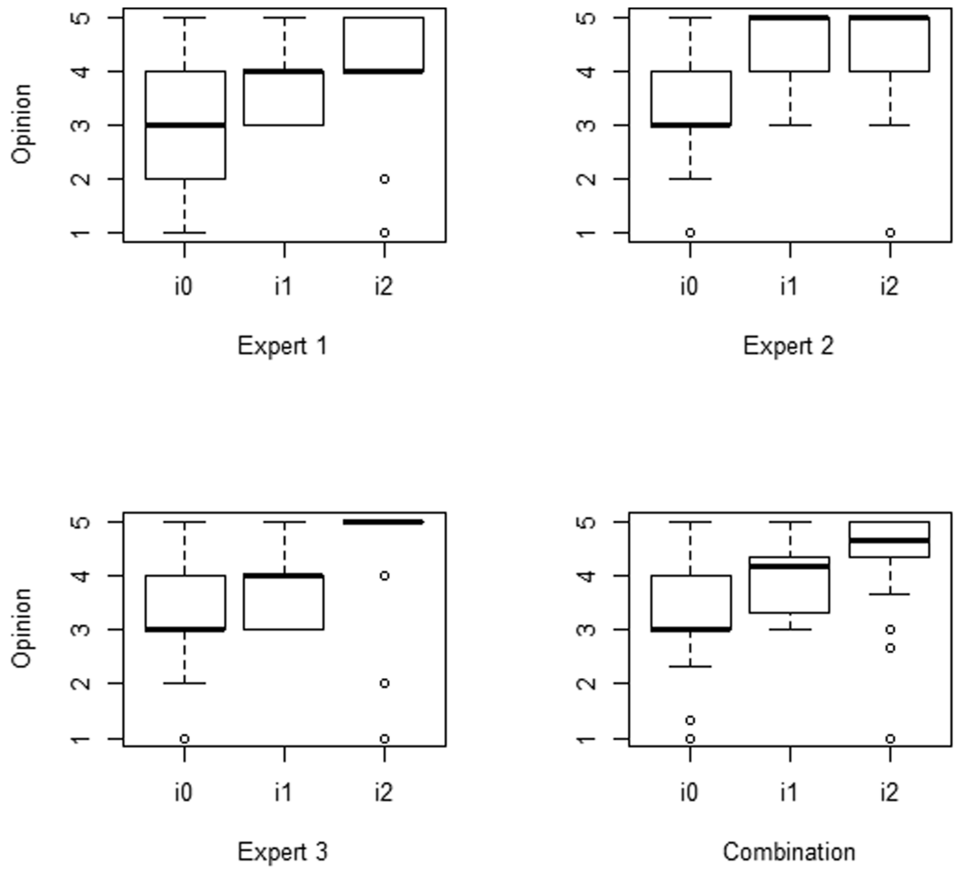

Fig. 15. General opinion: Box plots comparing the experts' judgements.

Table 6
General opinion: Wilcoxon-Mann-Whitney test results.

Opinion comparisons	State i0 vs state i1	State i1 vs state i2	State i0 vs state i2
Expert 1	p value $\leq$ 0.0001	p value $\leq$ 0.0001	p value $\leq$ 0.0001
Expert 2	p value $\leq$ 0.0001	p value = 0.4	p value $\leq$ 0.0001
Expert 3	p value $\leq$ 0.01	p value $\leq$ 0.0001	p value $\leq$ 0.0001
Combined expert	p value $\leq$ 0.0001	p value $\leq$ 0.0001	p value $\leq$ 0.0001

Table 7
Need of changes: Spearman's correlation between experts (p values in brackets).

Changes correlations	Expert 1	Expert 2	Expert 3
Expert 1	1	0.69 (p value $\leq$ 0.0001)	0.76 (p value $\leq$ 0.0001)
Expert 2	0.69 (p value $\leq$ 0.0001)	1	0.88 (p value $\leq$ 0.0001)
Expert 3	0.76 (p value $\leq$ 0.0001)	0.88 (p value $\leq$ 0.0001)	1

Table 8 shows the summary statistics of the results obtained for each expert at each state of the process. In general, there appears to be a consensus between the experts regarding the identification of a need for changes especially at the initial state i0.

Fig. 16 shows, for each expert, a box plot comparing the judgements at the three states of the process regarding the need for changes to improve the game.

The graph apparently shows a slight decrease in the perception of the users regarding the need for changes to improve the game as the process advanced. This is especially noticeable for experts 2, 3 and the combined expert.

Table 8
Need for changes: Summary statistics.

Average (standard deviation)	State i0	State i1	State i2
Expert 1	2.72 (1.31)	1.81 (0.90)	2.15 (1.07)
Expert 2	2.96 (1.41)	1.84 (0.88)	1.73 (1.25)
Expert 3	3.04 (1.43)	1.84 (0.88)	2.04 (1.40)
Combined expert	2.91 (1.32)	1.83 (0.86)	1.97 (1.06)

Again, to support this visual perception, the Wilcoxon-Mann-Whitney test was carried out, in this case, to check whether judgements at a given state were in general lower than judgements provided at a previous state. Now, small p values (lower than 0.01) imply that there is statistical evidence corroborating that there is a decrease in the values of the judgements. Table 9 shows the results.

The p values obtained for the comparisons of judgements at the final state (i2) and the initial state (i0) are all lower than 0.01 for all experts, that is, there is statistical evidence corroborating a decrease in the need for changes requested by the users as the process advanced. In this case, the results show that changes are mainly requested at the initial state of the process (i0), whereas such a request remains constant from state i1 to state i2. This is corroborated by the large p values systematically obtained for all experts when comparing the judgements at i1 and i2.

5.2.3. Users' satisfaction with the game

Once more, a check was made as to whether or not the interpretations that the experts made regarding users' satisfaction with the game are coherent. Table 10 shows the matrix of Spearman's rank correlation coefficients with the corresponding p values in brackets.

The results confirm that the judgements of the independent experts are significantly correlated (all the p values are close to zero). According

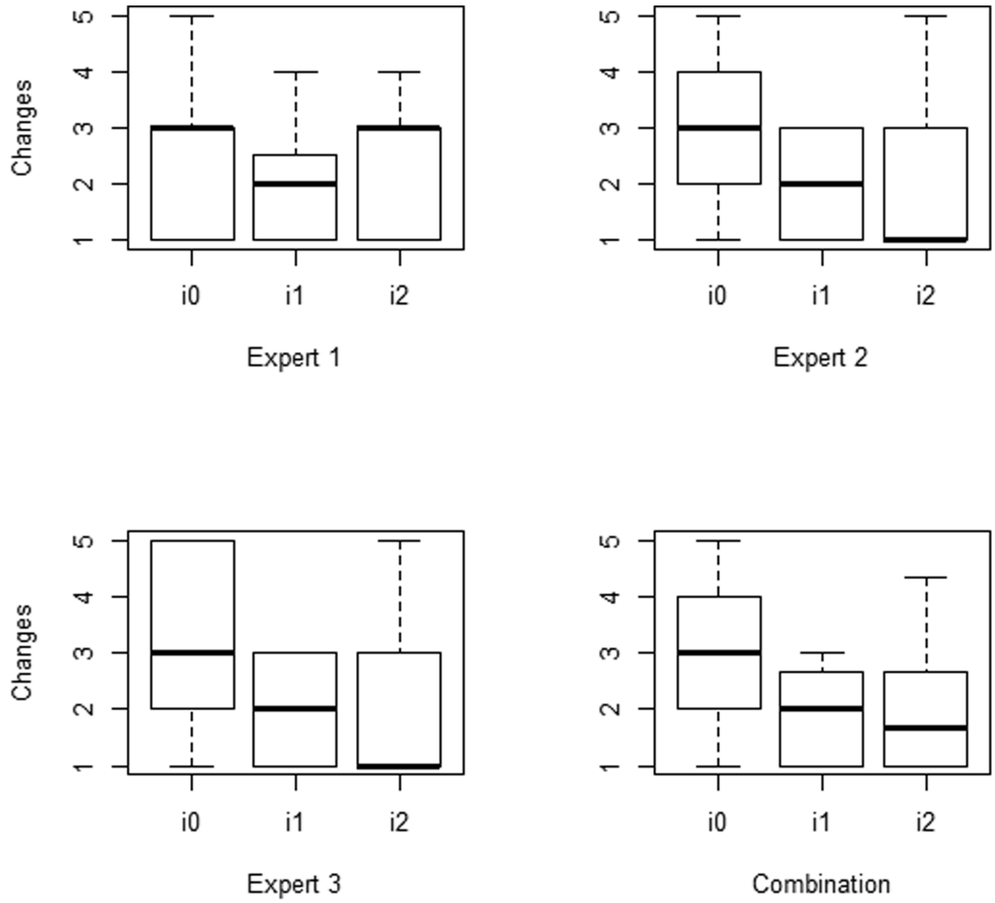

Fig. 16. Need for changes: Box plots comparing the experts' judgements.

Table 9
Need for changes: Wilcoxon-Mann-Whitney test results.

Changes comparisons	State i0 vs state i1	State i1 vs state i2	State i0 vs state i2
Expert 1	p value $\leq$ 0.0001	p value = 0.91	p value $\leq$ 0.01
Expert 2	p value $\leq$ 0.0001	p value = 0.10	p value $\leq$ 0.0001
Expert 3	p value $\leq$ 0.0001	p value = 0.51	p value $\leq$ 0.001
Combination	p value $\leq$ 0.0001	p value = 0.67	p value $\leq$ 0.0001

to these results, the conclusion is that there is an overall coherency of the judgements of the three experts regarding users' satisfaction with the game. Once more, their judgments have been merged into an average "combined expert".

Table 11 shows a summary (average and standard deviation) of the results obtained for the different experts at each state of the process. In general, there appears to be a consensus between the experts regarding increasing trend regarding users' satisfaction as the process advanced.

Fig. 17 shows, for each expert, a box plot comparing the judgements regarding users' satisfaction at the three states of the process.

Table 10
Users' satisfaction: Spearman's correlation between experts (p values in brackets).

Satisfaction correlations	Expert 1	Expert 2	Expert 3
Expert 1	1	0.52 (p value $\leq$ 0.0001)	0.43 (p value $\leq$ 0.0001)
Expert 2	0.52 (p value $\leq$ 0.0001)	1	0.62 (p value $\leq$ 0.0001)
Expert 3	0.43 (p value $\leq$ 0.0001)	0.62 (p value $\leq$ 0.0001)	1

The graph apparently identifies an increase in the positive opinion of the users as the process advanced, according to the judgements of the four experts.

Again, to support this visual result, the Wilcoxon-Mann-Whitney test was carried out. Table 12 shows the results.

The p values obtained for the comparisons of judgements at the final state (i2) and the initial state (i0) are all lower than 0.01 for all experts. Similarly, to the analyses performed for the two previous dimensions, such small p values demonstrate that there is statistical evidence corroborating an increase in the users' satisfaction with the game at the end of the process, therefore supporting the visual results observed in Fig. 17. Moreover, the table 12 shows that at the intermediate state (i1), a high level of satisfaction is achieved, not significantly different from the level achieved at the final state (i2). This is coherent with the fact that users keep requesting a similar level of changes to improve the game at states i1 and i2.

6. Discussion

The hypothesis that a co-design based upon a Lean UX methodology of a children's educational serious videogame can increase their level of

Table 11
Users' satisfaction: Summary statistics.

Average (standard deviation)	State i0	State i1	State i2
Expert 1	3.02 (0.89)	3.88 (1.04)	3.94 (0.99)
Expert 2	3.18 (0.94)	4.56 (0.67)	4.31 (0.83)
Expert 3	2.86 (0.93)	3.59 (0.84)	4.21 (1.15)
Combined expert	3.02 (0.79)	4.01 (0.63)	4.15 (0.77)

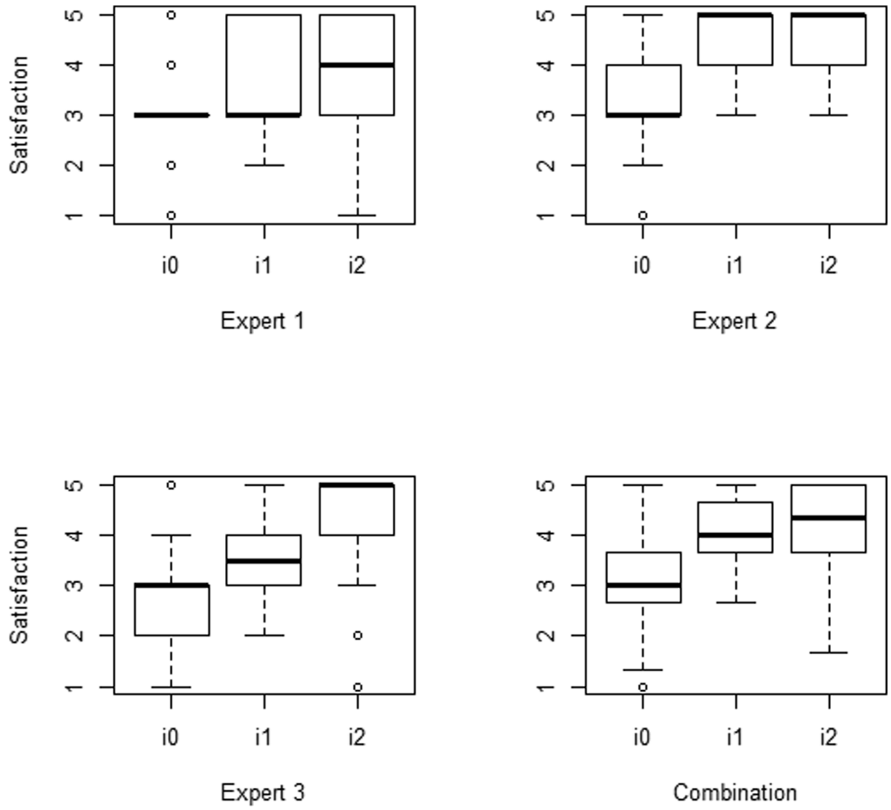

Fig. 17. Users' satisfaction: Box plots comparing the experts' judgements.

Table 12
Users' satisfaction: Wilcoxon-Mann-Whitney test results.

Satisfaction comparisons	State i0 vs state i1	State i1 vs state i2	State i0 vs state i2
Expert 1	p value ≤ 0.0001	p value $= 0.36$	p value ≤ 0.0001
Expert 2	p value ≤ 0.0001	p value $= 0.92$	p value ≤ 0.0001
Expert 3	p value ≤ 0.001	p value ≤ 0.001	p value ≤ 0.0001
Combination	p value ≤ 0.0001	p value $= 0.11$	p value ≤ 0.0001

product engagement and can facilitate their awareness of their learning perception has been validated by the experiment carried out. This study has provided answers to the research questions formulated as discussed below.

Regarding the first research question, *RQ 1 - What degree of satisfaction do the children have with respect to the use of the videogame?* 85% of the children were pleased with MOBI and would recommend it to their friends. They were even able to remember the videogame that they helped to create six months after their last interaction with MOBI which is something new and relevant to the literature.

Serious educational games have proliferated with many proven benefits in recent decades. Much has been written about their benefits, how children enjoyed them and in general, the benefits of gamification and co-design. However, there are few proposals for the design procedures for serious educational videogames [39] and their results, even less when they involved using Lean UX methods, which are quite recent to the videogame research literature.

Regarding the second research question, *RQ 2 - What perception the children have with respect to their participation in the videogame co-design process?*

Children perceived that they were involved in the process of creating the videogame. 94% of the children were satisfied with having participated, 85% noticed that the design of MOBI had been affected by their opinion and 63% would have liked to have continued to contribute to the design. Moreover, in their comments, children highlighted that they enjoyed MOBI more because they had helped to create it, and they asked for fewer changes as the iterative development process advanced and their changes were applied.

This result is similar to the one found by [40], in which following an approach based upon play improved the involvement of the users, specifically in this case adult users. Children are creative and they are always willing to share their thoughts and impressions. However, children can also be impulsive, their attention span and vocabulary could be more limited than in the case of adults and, it can be more difficult to make them focus on a task for a long period of time. This could prevent some designers from actively involving children in the co-design of learning environments.

Finally, regarding the third research question, *RQ 3 - What learning perception do the children have, six months after their last interaction with the videogame?*

60% of the children perceived that they had learned to program. Learning and engagement are both key goals in the design of serious educational videogames [41]. Gamification and co-design seem to help not only the creation of a more likable product for the users, but also to increase their learning perception as well.

As claimed by [42], it is essential to assess the actions and context of the users to improve the technology they are using. This remains valid in an educational context, in which children interact with technology to improve their learning of a certain domain. However, it is still a relatively new field with little research regarding approaches to user-centered or even, newer Lean UX design procedures with children, investigation of how actively and to what extent they can become aware of their learning needs [43], and the role and competencies required for the facilitators interacting with the children in the co-design [44]. Finally, as far as we know, and after a literature review, no published papers have been found regarding Lean UX experiences of children participating in the creation of a serious educational videogames to learn how to program in Primary Education. This can be highlighted as one of the main contributions of this paper to the state-of-the-art.

7. Conclusions and future work

A Lean UX Co-design of a serious videogame with children is possible and beneficial. The results of the Lean UX co-design of a videogame to teach programming to children enrolled in Primary Education supports the following conclusions in relation to the three factors under study (in bold):

1) *Satisfaction UX* (opinion and need for changes) can be improved if children are involved in the co-design of the serious videogame.
2) Children like to be involved in the iterative and incremental *Lean UX Co-Design* of the videogame. The number of changes requested for the videogame is significantly lower when children co-design the videogame.
3) Involving the children in the co-design of the videogame increases their engagement with the videogame and their *Learning Perception*.

However, some limitations have been found in this research because of having to adapt the students' needs to the actual software and hardware available in the classroom. Moreover, and although the validity of the values registered by the three experts and their inter-rater agreement has been tested, more experiences with more researchers and children should take place to support stronger claims.

As future work, it is intended, on the one hand, to repeat the experience with children with some kind of special educational need and on the other, to undertake an in depth study regarding the learning of each concept. In general, a request is made for more research involving young children (with or without special needs) in the design of gamified learning environments in which they are the users. From a business point of view, it could be interesting to commercialize MOBI as an MVP to make it available to students such that it could be bought and used at school and/or at home. Their feedback would guide the evolution of MOBI.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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