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Puzzle-based Games as a Metaphor for Designing *In Situ* Learning Activities

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Abstract: *In situ* learning activities are recently becoming of higher interest in education because they facilitate contextualized learning experiences. A particular case is the creation of learning routes containing geo-located questions. In this line, teachers are increasingly more interested in getting involved in the design of such learning experiences according to their specific needs. QuesTInSitu is a mobile application that supports the creation of questions that have to be answered in the real location. Previous research experiments reported educational benefits of carrying out this type of activities and highlighted the requirement of incorporating mechanisms that promote problem solving and students' motivation. Games and educational puzzles are considered interesting and feasible approaches to address these goals. On the one hand, puzzle-based games are especially suitable to feasibly involve teachers as designers of the games. On the other hand, this type of games can promote engagement in the subject topics, while fostering students' problem solving, analytical and memory skills. Therefore, this paper proposes a puzzle-based game metaphor as an innovative way to design gamified *in situ* learning activities. A game design task, completed by secondary education teachers, has been carried out to evaluate the proposed puzzle-based game metaphor. In order to computationally represent and enact the designed gamified *in situ* learning activity following the proposed metaphor, a new version of the QuesTInSitu has been developed. Evaluation results show that teachers are able of using the metaphor to design potentially fruitful gamified *in situ* learning activities according to their educational objectives.

Keywords: game-based learning, puzzles, m-learning, *in situ* learning activities, game design task, gamification.

1. Introduction

The use of m-learning is growing in education since it brings the possibility of creating situated learning activities that take place in physical spaces (Jeng et al. 2010). Benefits derived from this type of activities are related to developing exploration skills and cooperation (Hwang et al. 2008). In this line, QuesTInSitu is a m-learning app to support assessment *in situ* (Santos et al. 2011). The system enables the creation of routes containing geo-located questions that have to be answered with a smartphone in the associated real area. The dynamics of the *in situ* learning activity is similar to a traditional test: students have one attempt to answer each geo-located question. Results of previous experiments showed that, using QuesTInSitu, students put explorative and spatial skills into practice and fosters their motivation, and personal observation. However, students were mainly focused on achieving higher scores than reflecting about the proposed questions (Santos et al. 2011).

Puzzle-based games can engage students in the subject topics, while at the same time foster students' problem solving, analytical and memory skills (Huang 2007; Bottino 2008). Besides, the nature of puzzle-based games seems relevant to consider as potential educational strategy to feasibly involve teachers as game designers (Huang 2007; Crawford 1982). In this line, with the aim of allowing teachers designing this type of learning activities, we propose the use of a puzzle-based game metaphor as an innovative way to design gamified *in situ* learning activities. As a result, a new version of QuesTInSitu has been developed. This version considers traditional puzzles and gamification strategies to improve learning *in situ*. In order to evaluate the potential educational benefits, as well as the most relevant issues of using the proposed metaphor, an evaluation with teachers of secondary education has been carried out.

The paper is structured as follows. Section 2 describes the main elements to consider when designing *in situ* learning activities according to the puzzle-based game metaphor. Section 3 presents the game design process with secondary education teachers to create a gamified *in situ* learning activity. The results obtained from the game design task are reported in Section 4. Finally, Section 5 concludes with the main highlights obtained from the described results and future research lines.

2. A puzzle-based metaphor as an educational strategy to designing *in situ* learning activities

Educational puzzles (also known as educational jigsaw puzzles) are characterized by promoting problem solving. The objective of any jigsaw puzzle is the arrangement of a set of given pieces into a single, well-fitting structure, with no gaps left between adjacent pieces (Williams 1997). Players can try to achieve the solution as many times as they want, and the shapes of each piece are a hint themselves concerning where the piece has to be placed. On the other hand, considering also several research studies that have identified different factors when designing educational games (Fisch 2005; Jones 1998; Kirriemuir & McFarlane 2004; Malone 1981; Sandford & Williamson 2005; Squire & Jenkins 2003), and a broadly recognized approach intended for helping teachers to evaluate the potential of using games- and simulation-based learning (de Freitas & Oliver 2006); a conceptual model (Melero et al. submitted) has been proposed for the design of technology-supported puzzle games including virtual and physical objects. Overall, this conceptual model defines the learning flow of the whole game, the context where the game takes places as well as the puzzles associated to each activity (see Figure 1). In concrete, the learning flow consists of a story structured by levels. Each level of the game presents either a single activity or a group of activities to be performed indoors or outdoors. An activity has associated a puzzle, and players perform specific activities depending on their role. Each puzzle is represented by relating pieces among them or by relating pieces with specific positions (i.e. slots) of a board. Both pieces and slots can represent virtual objects or as computer-recognised physical objects. Finally, different punctuation, feedbacks and hints can be associated to both activities and puzzles in order to scaffold the learning process and guide students to the correct expected solutions.

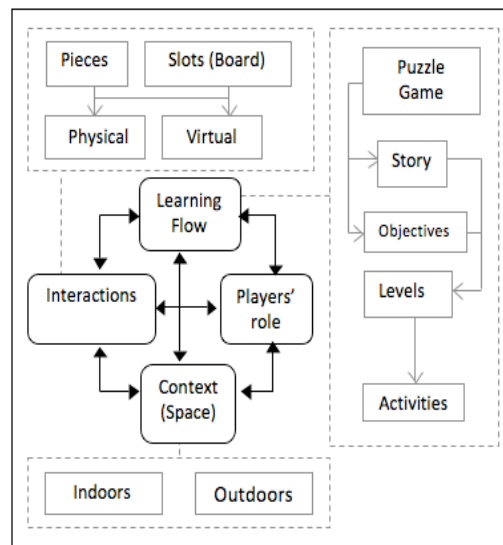


Figure 1: Overview of the conceptual model

Considering this conceptual model, our claim is that this can be applied for creating gamified *in situ* activities to enhance the students' learning experience. In particular, the aim of applying this strategy is to engage students to reflect on the correct solution. Similarly to jigsaw puzzles, players could try to solve the different questions as many times as needed until reaching a correct solution. Following the puzzle-based approach we escape from giving the immediate feedback when solutions are incorrect. Instead we believe that we promote a more reflective methodology in which the answer is not provided to the students right away. In that sense, students have the possibility of finding the correct solutions either by reflecting on their wrong choices or taking benefit of the resources provided not only by the game design itself but also by the information that can be found *in situ* in the environment (e.g. people, buildings, etc.). Besides, the different elements of the puzzle-based game metaphor are described as follows:

- The "board". That means, the map containing the geo-located questions of the puzzle-based game.
- The "slots" included in the map will represent each of the questions designed for the *in situ* learning activity.
- The "puzzle pieces" that are the different options for each question of the puzzle game. Just one puzzle piece can fit in a concrete slot, meaning that there is only a correct option for each of the designed geo-located questions.

- The “puzzle”, formed by a group of questions (i.e. slots).
- The “level”. Different levels can be designed for each *in situ* learning activity. A level contains just one puzzle. It can be defined as many levels as the designer wants. For instance, the designer can differentiate different areas of a map, and associate a level to each place.
- The “points”, defined to express the students’ performance: a) correct answers add points to the overall player’s punctuation, b) incorrect answers subtract points the overall player’s punctuation, c) consulting hints subtract points the overall player’s punctuation.
- The “bonus”. When all the questions for a given level have been correctly answer, students will obtain a bonus that adds extra points to the overall punctuation. The extra bonus is a reward to engage and encourage students to correctly complete the different puzzles.
- The “feedback”. This means, textual information associated to specific range of points in order to show the students how is their performance.
- The “hints”. Hints are provided to scaffold the learning process in order to avoid frustrations and advance forward the gamified activity. Besides, somehow similarly to traditional puzzles, in which the position of the last piece is trivial; when all questions, except one, have been correctly answered, the student will obtain a “free hint”. This means no points are subtracted when consulting the hint of the last question to be solved of a given puzzle.

In order to evaluate whether the different elements are meaningful and understandable by teachers, a game design task for a real *in situ learning* experience has been carried out with secondary education teachers. The evaluation will also give insights whether the teachers are able to use the proposed metaphor to design this type of learning scenarios.

3. Game design process

A group of 7 secondary education teachers, from different subject matters were interested in designing an *in situ learning* activity to help their students to understand better the city where they are studying by solving *in situ* different geo-located questions. As students advance forward the game, new levels of the game are discovered, meaning that new areas of the city can be explored. To this end, we suggested the use of a puzzle metaphor for the design of the gamified *in situ* m-learning activity. Our main objective is to understand the benefits of using a puzzle game metaphor for the design of *in situ* activities, as well as the limitations and affordances of the conceptual model for creating technology-supported puzzle games.

The following methodology has been designed to analyse the teachers’ comprehension about the use of the puzzle game metaphor:

- An introduction is given about puzzle games and the key elements of the conceptual model that has to be understood for designing the activity. Some examples using the elements of the conceptual model are shown as well.
- Use of templates (see Figure 2). The teachers use several templates following the elements of the conceptual model to design the gamified *in situ learning* activity. These templates consist of defining: the general aspects of the game, the properties of each level of the puzzle game, and the slots and their related pieces for each puzzle.

Name of the game		
Game ID		
Feedback	___ points	___
	___ points	___
	___ points	___
	___ points	___

Level X	
Level ID	___
Level introduction	___
Bonus	_____ points
Feedback	___ points
	___ points
	___ points
	___ points

Slot X		
Location	_____	
Slot Content	_____	
Hint	Hint Score	
_____	_____ points	
Pieces		
Piece Content	Correct?	Score
_____	Yes/No	___
Piece Content	Correct?	Score
_____	Yes/No	___
Piece Content	Correct?	Score
_____	Yes/No	___

Figure 2: Sample of Template Game

- Learning design task. First, the different templates are presented, as well as an explanation about how to use them. Then, teachers discuss by themselves the information of each template and expose their concerns. A meeting with the researchers is carried out to discuss and share doubts, worries, interpretations and suggestions of the teachers. Then, the teachers fill out the different templates according to their needs. An example of a complete level designed by the teachers is available as an on-line appendix to this article (http://www.dtic.upf.edu/~jmelero/ecgbl-2013/template_lv1.pdf).
- Finally, the information provided by the teachers in the different templates is used to implement the puzzle-based game for the activity. In this sense, we developed a new version of the QuesTInSitu application. Unlike the former version of QuesTInSitu, where student only have an attempt to solve each geo-located question and no gamification strategies were included; the new version considers the puzzle-based metaphor described in the previous section. This means the application is compliant to the conceptual model and, therefore, its input is the corresponding XML binding, including the different elements of the puzzle-based game (see Figure 3).



Figure 3: Some screenshots of the “QuesTInSitu: The Game” and chunks of its computational representation (compliant with the conceptual model)

“QuesTInSitu: The Game” works as follows. First, the player must enter a group’s name. Then, a gamified route containing geo-located questions should be chosen. Once this is done, the map is loaded as well as the questions of the first level of the game. Also, the player can view at any time the textual information associated with the level. In addition, in order to display the content of each of the

questions, the player has to go to the indicated place. The content then will be displayed automatically. In order to access again to the questions, that has been unanswered or incorrectly answered, the player has to click manually on the icon. On the other hand, the player can always see what your overall punctuation in the game. The punctuation will be updated every time a player fails o answer correctly the questions, access to the hints, or get a bonus for having successfully solved all the questions of a level. To advance forward the different levels of the game, this can be done automatically (if all questions of a level have been answered correctly) or manually (if there are bad questions answered or unanswered). The game ends once the last level of the game has been completed. Once the player reaches this point, will see the ranking scores obtained by the other groups of students.

4. Evaluation

An evaluation was carried out in order to analyse a) the perceived usefulness and educational benefits of the puzzle-based game metaphor by the teachers, and both b) the understanding and c) importance of the different elements to consider for the game design task of the *in situ* learning activity.

4.1. Data gathering techniques

Since different aspects, such as participants' satisfaction or the game design task complexity, have to be analysed; a mixed evaluation method has been followed (Cairns & Cox 2008) combining and triangulating (Guba 1981) the qualitative and quantitative data. Table 1 lists the different data sources: a) Questionnaires to evaluate quantitative and qualitative data about the different elements of the metaphor, and b) observations from the research team during the different meetings. Quantitative data will provide insights into teachers' opinions, while qualitative data will support or reject those teachers' perspectives (Guba 1981).

Data source	Type of data	Label
Questionnaires	Quantitative ratings and qualitative opinions	[Teacher-X] Where X is the number of the teacher, from 1 to 7.
Observation	Observations during the different meeting s by 2 different researchers	[Observation-Y] Where Y is the number of the observer, from 1 to 2.

Table 1: Data gathering techniques

4.2. Results about the educational benefits and dynamics of the puzzle-based game metaphor

In general, when asking the teachers about the educational benefits of the puzzle-based game metaphor, they found it stimulating, encouraging, a good approach to motivate students, useful to structure knowledge in parts and to promote the empowerment of teamwork and collaboration. These were the gathered comments: *"It's stimulating. I think the activity moves away from heavy exercises in the classroom and situates students in a more playful context"* [Teacher-1], *"Motivation and empowerment efforts from teamwork and the achievements of goals"* [Teacher-2], *"The idea is great, it is very encouraging, it is like an updated "treasure hunt" approach "* [Teacher-4], *"I believe it has many benefits as it raises different educational and learning situations, like having to do research and meeting the environment, the heritage, etc. Besides, it is a good teaching tool that empowers collaboration and teamwork"* [Teacher-5], *"The metaphor allows understanding that knowledge is formed by parts that are related afterwards. The game encourages, challenges the student with positive and negative reinforcement, and the student interacts actively in the learning process"* [Teacher-7].

In a 5-rating scale, different answers resulted when asking about having the possibility of solving a question as many times as necessary until reaching the correct solution [Teacher-All]: two teachers completely disagree, while two other teachers agree o completely agree. The rest were neutral on this assumption. For instance, a teacher pointed out that: *"I find the bonus, hints and punctuation more motivating and interesting than trying and trying to reach the correct answer or having a free hint. It is not bad, but I find these elements dispensable"* [Teacher-4].

Most of the teachers argued that the metaphor did not limit the activity design task; applying the metaphor only implied to change the point of view; then the approach is very attractive [Observer-1].

Further comments were: "No, I was not limited at all" [Teacher-1], "I have not experienced any limitation" [Teacher-2], "Yes, but obviously any approach limits the design task" [Teacher-3], "No, it is ideal for working in situ, make different questions, etc." [Teacher-4], "Not limitations, but rethinking and changing the dynamics of the game and its development" [Teacher-5], "No, but I have to formulate the questions differently" [Teacher-6], "The approach does not limit but it extends the possibilities" [Teacher-7].

Furthermore, in order to analyse the correct use of the proposed metaphor, a key point is to evaluate whether the teachers properly understand the meaning of the puzzle-based game metaphor's elements.

4.3. Results about understanding the elements of the puzzle-based game metaphor during the game design task

Overall, the metaphor used to identify each element of the puzzle-based game approach was found appropriate; just the metaphor of the "level" was the most troubled element. More specifically, all the teachers found very or quite appropriate the metaphor of a question meaning as a slot. 4 out of the 7 teachers found quite appropriate the metaphor of the question's options meaning as puzzle pieces. 6 out of the 7 teachers found very or quite appropriate the metaphor of a map meaning as a puzzle board. Different opinions resulted when asking about whether the metaphor of the slots belonging to a same geographical area meaning as a level of the game is appropriate. In fact, 6 out of the 7 teachers quite or totally agreed that they had difficulties understanding what a level means: "*The greatest difficulty was the confusion between area and level. We understood area, while they [the researchers] understood level*" [Teacher-4], "*It is difficult to imagine the design by levels*" [Teacher-3], "*The only thing that I found difficult to understand was the definition of the level concept*" [Teacher-7]. Also, in the different meetings some teachers asked about what a level means [Observer-1], and some asked whether the levels are associated to grades of difficulty [Observer-2].

Furthermore, regarding the meaning, half of the teachers agreed that the elements, "slot" and "pieces", were unclear or difficult to understand. Besides, this difficulty was just at the beginning [Observer-1-2]; once the teachers got familiar with the puzzle-based game metaphor, they did not have problems to correctly perform the game design task. Results show that 4 out of the 7 teachers quite or totally agreed that they had difficulties understanding what a slot means. However, two of the teachers totally disagreed, considering the meaning of the slots easy to understand. Half of the teachers quite or totally agreed that they had difficulties understanding what a puzzle piece means, despite the rest totally disagreed. All the teachers quite disagreed or totally disagreed that they had difficulties understanding what a bonus means. However, a teacher understood that a bonus is only obtained if all the questions are correctly answered at the first attempt [Observer-2]. 5 of the teachers totally disagreed that they had difficulties understanding what a hint means. Different rating resulted when asking about the difficulties the teachers had for understanding what a feedback (associated to either reaching a level or completing the game) means. Some gathered comments were: "*At first understanding the dynamics wasn't easy. Also, because I joined the group later*" [Teacher-3], "*At first it was a bit difficult to understand the metaphor, but once reached the process of the game, it was much simpler to understand the above items. I mean, the difficulty was at first, when the metaphor was described, understand everything and having to apply it later. Once the elements were understood, filling the templates was easy*" [Teacher-5]. Also, during the discussion of a meeting, some teachers argued that at first the metaphor is quite abstract, and it is needed to recall and interpret the meanings of each element [Observer-1]; but once the elements were understood, it was easy [Observer-2].

4.5. Results about the importance of the elements of the puzzle-based game metaphor

Apart from correctly understanding the different elements involved in the proposed metaphor, it is important to analyse which of the elements are considered indispensable in designing gamified *in situ* learning activities, and which of them depends more on the educational situation. In general, when asking teachers about the importance of the different elements of the puzzle-based game metaphor, the most discussed elements were the hints and the punctuation's mechanisms.

Overall, the hints were considered a good mechanism to allow students advance in the game, but not all activities should have associated hints, they should be considered only in those cases that having a hint could be meaningful or relevant to the activity. 5 out of the 7 teachers agreed or totally agreed that the hints can guide the students in case they are lost or stuck. Also, 5 out of the 7 teachers found

important or quite important subtracting points when hints are consulted. However, half of the teachers thought that providing hints to each question was not very important or not important at all. In this line, some teachers highlighted that not all the questions had hints because it was not make sense and it would be very heavy work [Observer-1]. Besides, the design of hints were difficult [Observer-1-2], and not all the hints are designed to promote reflexion because the activity would be too complicated and students could become exhausted if they have to reflect in each of the questions [Observer-2].

Regarding the free hints, different opinions were gathered. Most of the teachers did not recall on the use having free hints nor found them useful. The resulted comments were: "*I think I do not know what a free hint means. I think that no points are subtracted*" [Teacher-1], "*I understand that [free hints] can be a motivation, but perhaps the groups that more achieving them, less they do needed*" [Teacher-3], "*I find bonus, hints and punctuation more motivating and interesting than trying and trying to reach the correct answer or having a free hint. It is not bad, but I find these elements dispensable*" [Teacher-4], "*I do not recall that there were free hints*" [Teacher-7]. Also, 5 out of the 7 teachers found slightly significant or not significant at all the free hints. In this regards a teacher pointed out that, "*The free hint does not seem anything special to me*" [Teacher-1].

Teachers found the different punctuation's mechanisms a good approach to allow students self-reflecting on their performance. They also highlighted the possibility of defining adapted punctuations. All the teachers agreed or totally agreed that the punctuation and feedback give students information about whether their decisions are correct or not. As a consequence, 6 out of the 7 teachers agreed or totally agreed that the punctuation mechanism allows the students to reflect more on the different questions. Also, 5 out of the 7 teachers found very important the adapted punctuation depending on the number of wrong attempts. Regarding the bonus, all the teachers agreed or totally agreed that this element can keep students motivated throughout the activity. But, half of the teachers thought that providing a bonus each time a level is accomplished was slightly important or not important at all. The other half totally disagreed.

4.6. Results about the relevant data to consider for gathering in gamified learning *in situ* activities

Finally, since the design of gamified *in situ* learning activities are still in an early stage in education, it is important to know what type of data would be the most relevant to the teachers as a worthy outcome when students are carrying out this type of learning experiences.

Overall, the teachers found important to gather the data about the satisfaction of the students while performing the activity, the time and punctuation obtained in the different stages of the game, and the awareness about the performance of other groups of students while doing the activity. Also, the teachers highlighted the importance of having a communication module to keep in contact with their students. The gathered comments were: "*The route followed by students. The punctuation. The time required. Degree of fun*" [Teacher-1], "*The time devoted reaching a question and answering it*" [Teacher-2], "*Time elapsed from the beginning. Current punctuation of the other groups*" [Teacher-3], "*Time performing the activity. Allow students to consult where the teachers are at any time*" [Teacher-4], "*I believe that time is a good indicator, as well as the punctuation of other participants*" [Teacher-5], "*Initial presentation of the objectives of the activity. A final evaluation of the game (similar to a 'telephone satisfaction survey'). The overall punctuation of the other groups. The situation of the other groups in the map. Constant contact with the teacher. A forum where the students can describe their experience*" [Teacher-7].

5. Conclusions and next steps

This paper has presented an innovative approach to design *in situ* learning activities with potential of motivating students and supporting them in reflective learning processes. To this aim, a metaphor based on puzzles and game elements have been described and evaluated with secondary education teachers, who have been involved in a design process applying the metaphor. For this particular case, results encourage us to continue working in the proposed direction. The teachers perceived as useful the proposed approach to design gamified *in situ* learning activities, highlighting its possibilities and potential educational benefits. The proposed puzzle-based game metaphor has been found stimulating and a good approach to motivate students. Besides, punctuation and feedbacks were considered good strategies to encourage students during the game. In this line, further work includes evaluating whether similar findings are obtained in the design of other learning scenarios that involve

in situ activities or other gamified activities that are not necessarily *in situ*.

Regarding the understanding of the elements considered in the game design task, results show that only the "level" element was the most troubled (using geographical-related vocabulary as examples improved understanding, i.e. "levels" representing "zones"). Teachers needed a time to internalize the different elements; some problems understanding how to apply some of the elements were detected at the beginning of the game design process. In this line, teachers understood easier the elements related to games (e.g.: hints or bonus) than those related to puzzles (e.g.: pieces, slots). Thus, it is crucial to be careful when presenting the puzzle-based metaphor in order to foster the teachers' understanding. It is important a good initial explanation about the different elements and providing significant examples showing the applicability of them, as well as, supporting the teachers at the beginning of the design task.

From all the elements of the conceptual model, an especial attention deserves the use of hints. In this regards, teachers seem not to appreciate the usefulness or the added value of the free hints and the bonus. All these features will be important to analyse with the students as well. Students are the final users of the designed activities, and they will provide us with useful information about how they consider the inclusion of the free hints or bonus in gamified *in situ* learning activities.

Future research lines also includes to understand the reasons about why the dynamics of answering the different questions does not make sense to some of the teachers, as well as a more clear definition of what elements will be important to consider for future experiments. Also, another research line derived from this study is the inclusion of communication modules and how to visualize and present the data of the elements that are of interest by the teachers.

Different experiments have been carried out in March and May 2013 with groups around 30 students (boys and girls, average of 16 years old) using the resulted designed activity. The teachers' goal is to have the opportunity of involving all the schools and educational centres of l'Hospitalet city (Spain) in a collaborative game-based m-learning *in situ* activity in the future.

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