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Educational Serious Games Engineering: The Case Of A Mobile Serious Game To Improve Geospatial Representation Skills For Children Aged 11 -12 Years

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Abstract: In recent years, serious games have become more and more important in the educational sphere. Many projects or tools are presented by teachers trying to teach specific knowledge through the use of educational games. What do we mean by educational serious games? How does one build an educational serious game? What learning can we expect from an educational serious game?In this presentation, we address all these issues through an experience we had at Laval University, Canada as part of our doctoral thesis on the design, programming and evaluation of a mobile educational serious game, the case of skills development in geospatial representation skills for children aged 11 to 12 years.Having defined the characteristics of an educational serious game that we have called Geospatial Discovery, we present the problematic that led us to develop a serious game for the acquisition of geospatial representation skills among children aged from 11 to 12 years, then the answers to the questions related to its development. Finally, we try to determine under which conditions our experience could serve as a basis for the development of future educational serious games.

Keywords: *Serious games; Educational serious games; mobile educational serious game; Geospatial representation, Agile Software Development, User-Centered Design*

I. INTRODUCTION

Geospatial representation is a human ability that plays an important role in the way individuals perceive, organize, and interact with space [1].Knowing how to read, write and think space is a necessity to educate young people who live in a modern civilization [2]. For the space learning research center (LENS) at Redlands University in the United States, geospatial representation is “the ability to interpret and visualize things like location, distance, direction, movement, relationships and changes across space [3]. It is inherently transdisciplinary competency transcending from STEM[1]to social sciences and arts.

Spatial literacy is central in primary and secondary school curricula in many countries, and not only possesses the potentials of individual success but also fosters the importance of spatial information use in society[4].Technologies such as GPS and sensors on smartphones have become widely available and young people are very eager to use them.

Despite their omnipresence, they are still insufficiently integrated into current teaching and learning practices.

Spatial literacy is taught in paper and pencil tasks. This is also due to the lack of suitable educational games that provide out-of-the box solutions for teachers [4].In this article, we tackle the issue aiming to close the gap and propose a framework to easily develop educational serious games.This paper aims to answer the following research questions:

- What do we mean by educational serious games?
- How does one build an educational serious game?
- What learning can we expect from an educational serious game and how we evaluate this learning?

Finally, we usethe framework to develop a mobile serious game to improve geospatial representation skills for children aged 11 -12 years. We adopted an interdisciplinary perspective to support spatial representation by fostering very important skills such as orientation, wayfinding, and map comprehension.

II. PROBLEM IDENTIFICATION AND BASIC PRINCIPLE

Our main objective is the design, programming and evaluation of educational mobile serious games to improve geospatial representation skills for children aged 11-12 years. This means that while proposing a generic solution, a framework for the design of educational mobile serious games, we are evaluating more precisely the proposed framework in the case of the development of geospatial representation skills of student’s aged 11-12.

In general, a serious game is a video game designed with purposes beyond pure entertainment [5].Serious games are multimedia tools by nature. As a sub - family of videogames, they combine different types of media (animations, music, text…) to create immersive experiences for the players. Their

Versatilityallows them to be used as tools with many applications in different domains[6]. According to [15], a definition that is not precise or clear often excludes certain development choices that may be useful in the short and medium term. Therefore, when developing a serious game, one needs to take a clear position as to what he builds in order to remain flexible enough, and thereby enable innovation to be realized.

From this point of view, we propose the following definition of a mobile serious game, which start from the definition of the serious game given by [7]and which will be the object of the development of our serious game and its evaluation. A serious game is computer software that has a serious intent, of a pedagogical nature and that uses real and virtual devices, in which:

- Players are placed in conflict position with each other or all together against other forces. They are governed by rules that structure their actions in order to achieve learning objectives and a goal determined by the game.
- Random barriers are integrated into the game according to player’s age and learning style.

[1] STEM: Abbreviation of science, Technology, engineering and mathematics

- Real-time feedback is provided to the learner to help him advance into the game in relation with the intended goals.
- Real-time assistance is provided to the learner in the form of augmented help generated by the game module according to the learner's means.

In the following lines we briefly explain how to develop such a mobile educational serious game and how one could evaluate the different learning following the game.

III. METHODOLOGY

Designing and studying a learning situation is an approach used by many education scientists in transforming learning practices into new forms. This approach examines how learning is done in environments resulting from a design experience [8]or design-driven research [9].We rely on a Design-Based Research (DBR) methodology. It is in particular the iterative and collaborative nature of the approach that distinguishes it from methodologies of the didactic engineering type.Also, it is important to emphasize that this methodological approach has been favoured because of its contribution in the various researches on pedagogical educational game design in recent years.By presenting the main stages of the research and development process, we highlight five major phases that led to designing educationalserious games framework.

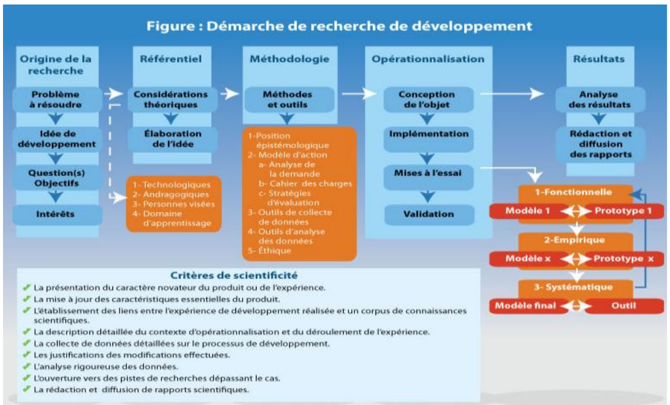

Fig 1. Development Research Approach

At first, there is the origin of the research that led us to determine the problem to be solved, the idea of development, the objectives [16]. A conceptual model of a mobile serious game based on an operational definition of explicit mixed reality devices as defined above will raise the level of students' geospatial skills.In a second phase, there is a repository that includes according to [16] highlighting the theoretical support justifying the decisions to be taken during the development process. It lists all the general theories and pedagogical approaches that we presented in our theoretical framework for the development of a serious game according to the desired aspects in the problematic.We use various theoretical considerations covering a set of fields including: active learning, flow theory applied to serious games, dynamic tracking, instant feedback, geolocation, spatial trajectory, design principles and programming constraints.

The third phase called the methodology phaseproposes the methods and the instruments, the data entry, collection and analysis tools.The fourth phase is called the operationalization phase of the object to develop. It'sall about the articulation between the conception of our serious game, its realization, the different tests and the operational validation.The actual design phase of the object allows to situate the product to be developed, that is to say, its components and the links that lead to the development of a general model of educational games.It will be iteratively refined by the various tests and changes based on the data collected from users. These tests are intended to improve the product in light of the experience of the participants. Finally, it will be possible to validate the product with the population for which the product was created.

An iterative and incremental process was used for the actual development process of the framework, focusing on small and medium development for the educational serious game and basing itself on two lines of research: agile development methodology and user-centered design (UCD) for children from 11 to 12 years. The agile methodology offers a useful option for the development of serious games as it establishes a continuous communication with all project stakeholders - including the end user - throughout the project, while UCD allows the user profile to be known and identified so that the game will meet the needs and match the capabilities, expectations andmotivations of the child.

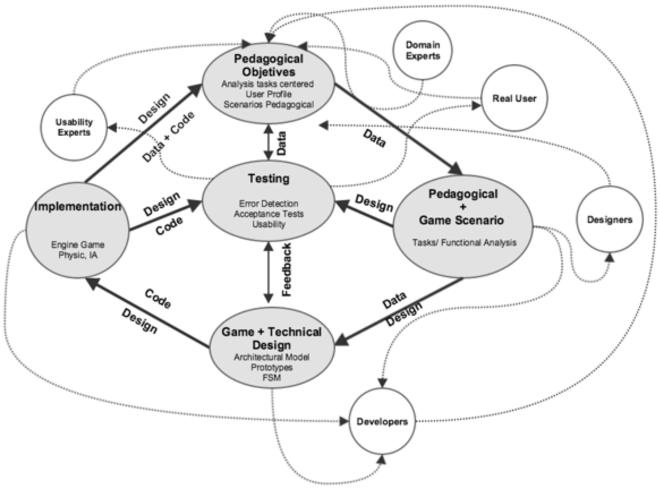

Fig 2. Proposal for an agile development process of a serious educational game

IV. SPATIAL REPRESENTATION TRAINING WITH GEOSPATIAL DISCOVERY GAME

Based on the study results with our game presented above and based on the requirements we draw from curricula, we developed a comprehensive concept of the Geospatialgame that supports the acquisition of better spatial competencies while playing the game through a series of navigation and orientation tasks. The player is equipped with a smartphone or tablet, which provides positioning technologies. The goal is to navigate to a certain location where you have to solve a task. Those routes are created beforehand by the teacher in the inbuilt editor. The following features have been included in the final conceptualization of the game.

Navigation

Two different navigation types can be distinguished: an aided navigation task or a path planning task. In the aided navigation task, the player receives route instructions to the next waypoint. Instructions are given either allocentric, egocentric or landmark-based. Based on the given route instruction, the player has to move in the real environment and find the next waypoint to receive the next instructions which successively lead him to the destination. In the path-planning task, the player receives a map of the environment and the destination visualized on thismap. The player has to locate him or herself on the map and determine the best route to the destination.Once arrived at the destination, the user has to solve a task. This task is defined by the teacher. In principle these tasks can relate to any subject from STEM to social sciences and arts. In the following sections, we describe tasks training orientation and map comprehension. Students solve one task at each destination, but the teacher can define different task for each destination.

Orientation Task

The user has to georeferenced a photo (in more detail: the position from where the photo was taken) and add spatial or thematic data to the map that can be derived from the photo. Depending on the subject and the degree of difficulty, the photo might show different things, e.g. in case of historical photos, the scenery might have changed. New houses might occlude houses that are visible on the historic photo. The photo might show underground supply circuits that are not visible either. This way we can create tasks with different levels of complexity challenging the player's ability to read and interpret a map.

Map Comprehension Task: Cartographic Basics

To make abstract concepts such as coordinate systems more concrete, teachers design tasks that help to experience coordinate systems in practice. For example, students are asked to walk along longitudes, latitudes, certain degrees or angles, or walk to the most northern / southern point of the destination region (e.g. a school ground, a park, a square).

V. USING LEARNING ANALYTICS TO ANALYZE LEARNING OUTCOMESIN AN EDUCATIONAL SERIOUS GAME

Literature research shows that the vast majority of serious games are formally assessed through questionnaires[11], which strikes a stark contrast with current trends in the video game industry. Commercial videogames have been learning from their players through Game Analytics for years and collect data from their players in a non-disruptive way, with tracking systems that go unnoticed by the players [10]. There is a clear need to combine the emerging disciplines of Learning Analytics (LA) and Educational Data Mining (EDM) with the non-disruptive techniques of Game Analytics (GA) to provide reliable, automated and repeatable assessment for serious games. These techniques will allow us to properly answer educational research questions that shed light on the learning processes. In our case, what learning can we expect from the educational serious game we have designed? The data sets come from the traces that students leave when they interact with the educational game we designed. The types of data therefore range from raw log files to eye-tracking devices and other sensor data.

While any assessment designer can attest that the nature of the learner performance evidence that must be gathered rests on a number of factors, including whether the assessment is intended to assist future learning (a formative assessment), to assess individual achievement (a summative assessment), or to assess the quality and effectiveness of an educational intervention (in other words, the assessment isn't really about the individual learner, but about the learning experience itself) [11].

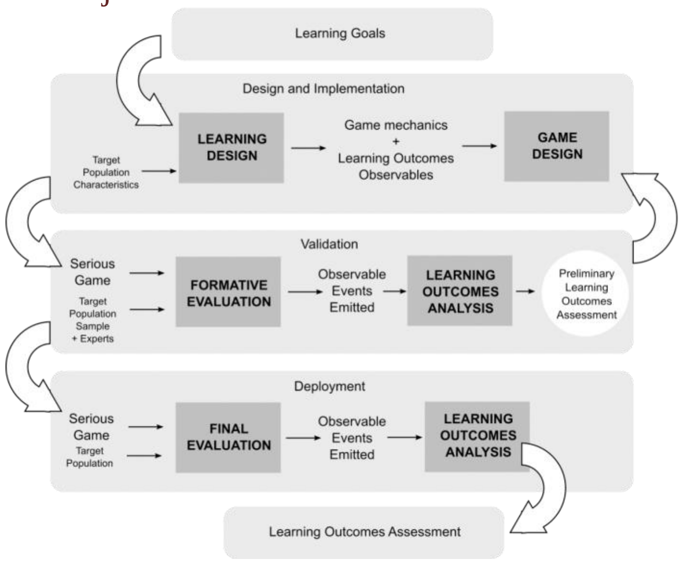

Fig 3. Serious game design and deployment process, with learning outcomes assessment

To summarize, we found research that describes effective analytics-aware serious game design, but lacks concrete methodologies to infer learning outcomes. On the other hand, there is research that proposes ways to analyze serious game learning outcomes, either via general frameworks or ad-hoc analysis, but without addressing the implications of that assessment in the game design. We propose to combine both approaches to define a methodology that tackles all the phases in the developmentof a serious game, from game design and implementation, to deployment and learning outcomeanalysis. As stated by [6], the proposed methodology allowed us to infer players' learning outcomes and assess game effectiveness and to spot issues in the game design.

This methodology allows us to assess our serious games effectiveness using non-disruptive in-game tracking.It's proposes a design pattern that structures the delivery of educational goals within the game. This structure also allows inferring learning outcomes for each individual player, which, when aggregated, would determine the effectiveness of the educational serious game.The methodology pursues two goals: (1) to ease the measurement of serious game learning outcomesand (2) to provide a systematic way to assess the effectiveness of serious games as a whole. To achieve these goals, our approach covers the complete lifecycle of the serious game (Figure 3). The process starts in the design phase, where the learning goals and the target population are the basis to create a learning and game design. These designs combined are used to implement the game, which is then validated in a formative evaluation with a sample of the target population. This process is repeated until the game is fully validated. Then, the game is ready to be used by the target population (deployment).

VI. COLLECTING OBSERVABLES

As discussed in [6], when game players perform different interactions to advance in the game, they make choices, resolve puzzles, take decisions, etc. These events will be the core observables to perform the learning outcomes analysis. The following principles from general game analytics, can facilitate the analysis:

1. Observable's data should be time-stamped events, representing simple interactions of the player with the game [12]. These events should be sent to a central server, where all players' interactions will be stored for later access and

analysis.

2. Events sent to the server should be raw interactions instead of opaque scores [12, 13]. Forinstance, if the mastery phase contains two puzzles, the events to transmit would be theinteractions performed to resolve the two puzzles, instead of just a combined score of thefinal result. This ensures flexibility, since scores can be later recalculated from interactiondata if the subsequent analysis identifies a need to do so.

3.Data collection should be as non-disruptive during gameplay as possible. Ideally, game flowshould never be interrupted to collect data – players should not be explicitly asked to stop their play to answer questions not integrated in the gameplay.Once all interaction events (observables) are stored in a central database, game analysis can begin.

To record and analyze the gameplay sessions of all students who are playing our game, we developed a framework composed by a tracker, bundled within the game itself responsible for sending observables events, and by a collector server, responsible for receiving and storing the events.

The type of events are fully detailed in [12, 13]; here, we only highlight those events relevant for the learning outcomes analysis:

- Events representing bumping an agent. Every time the player bump an agent, respond to a question and the result is incorrect, a new attempt starts.
- The game itself does not make any assessment calculation: only raw events are sent to the server.

VII. LEARNING OUTCOMES ANALYSIS AND RESULTS DISCUSSIONS

For each mini-game we calculate a score between 0 and 1:

Game score (GS):If A is the observable representing the number of attempts to respond to a specific questions or performing any specific actions after bumping an agent,GS is computed using the formula GS= 1 - (MIN (A - 1, AMAX) / AMAX), where AMAX is the reasonable number of attempts needed to solve the problem at a specific agent. The initial assessment will be 1 when the player succeed at the first attempt, i.e., A = 1. The initial assessment will be 0 if the player does not complete any attempt on any agent.

To answer whether the students reached the intended skill level at the end of the game, we calculated the values of GS for each of them. In total, 125 players (85% of players that completed the game) scored more than 0.5 (adequacy threshold set for the game during design) . IA’s mean value was greater than 0.5 in all age groups (11 to 12 years old).

CONCLUSIONS

We started reviewing curricula specifications regarding spatial competency and spatial literacy training in an educational context. We evaluated the state of art for Geospatial Discovery that focus on training spatial competencies and identified a lack of tools fostering spatial competency and spatial literacy for children. Many spatial competencies are studied theoretically in school. Geospatial Discovery allows users to experience many of these theoretical concepts in the real world, e.g. experience map alignment and orientation in a goal-directed wayfinding task in the real world.

References

[1] McGee, M. Human spatial abilities: psychometric studies and environmental, genetic, hormonal, and neurological influences. Psychol Bull, 86, 889-918, 1979

[2] Lebrun, J., Araujo, O., & Anderson. L’intervention éducative en sciences humaines au primaire.Montréal: Chenelière Éducation, 2009

[3] Lens. Retrieved 2 8, 2014 from University of Redlands, Website,: http://www.spatial.redlands.edu/lens/about.aspx

[4] Bartoschek,T., H.Bredel, and M . Forster. GeospatialLearning@PrimarySchool: A minimal GIS approach. in Sixth international conference on Geographic Information Science , Extended Abstracts . 2010. Zürich, Switzerland.

[5] Liu G, Fu L, Rode A V., Craig VSJ. Water Droplet Motion Control on Superhydrophobic Surfaces: Exploiting the Wenzel-to-Cassie Transition. Langmuir. doi:10.1021/la104669k, 2011

[6] Angel S, Borja M, Manuel F, Baltasar F. A methodology for assessing the effectiveness of serious games and for inferring player learning outcomes. Multimedia Tools and applications, 2017

[7] Sauvé, L., Renaud, L., & Kaufman, D. Games, simulations and simulations games for learning: Definitions and distinctions. In D. Kaufman & L. Sauvé. Educational gameplay and simulation environments: Case studies and lessons learned , 1-26, 2010.

[8] Brown, A. L. Design experiments: Theoretical and Methodological challenges in creating complex interventions in classroom settings. Journal of the LearningSciences, 2(2), 141-178, 1992.

[9] Barab, S., Zuiker, S., Warren, S. Situationally embodied curriculum: relating formalisms and contexts. Sci Educ , 91 (5), 750–782, 2004.

[10] S. Santhosh and M. Vaden, “Telemetry and Analytics Best Practices and Lessons Learned,” in *Game Analytics: Maximizing the Value of Player Data*, 2013, pp. 85–109.

[11] Calderón A, Ruiz M. A systematic literature review on serious games evaluation: An application to software project management. Comput Educ 87:396–422. doi: 10.1016/j.compedu.2015.07.011, 2015

[12] Serrano Á, Marchiori EJ, Blanco Á del, et al. A framework to improve evaluation in educational games. In: IEEE Glob. Eng. Educ. Conf. IEEE, pp 1–8, 2012.

[13] Serrano-Laguna Á, Torrente J, Moreno-Ger P, Manjón BF. Tracing a little for big improvements: Application of learning analytics and videogames for student assessment. In: Procedia Comput. Sci. pp 203–209, 2012.

[14] R. Glaser, J. W. Pellegrino and N. Chudowsky, Knowing What Students Know: The Science and Design of Educational Assessment, Washington D.C.: The National Academic Press, 2001.

[15] Becker, K. Distinctions between games and learning: A review of current literature on games in education. In R. Van Eck (Ed.), Gaming and cognition : Theories and practice from the learning sciences. New York: Information Science Reference. , 22-54, 2010.

[16] Harvey. S., Loiselle, J. Proposition d'un modèle recherche-développement, Recherché qualitatives, 28 (2). 95-117, 2009