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'Geoliteracy', 'Cartology', Cognitive Development, and a Mobile Game

'Geoalfabetización', 'cartología', desarrollo cognitivo y un juego móvil

'Geoliteracia', 'cartologia', desenvolvimento cognitivo e um jogo móvel

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Abstract

Some researches in education science develop educative games on mobile devices for letting elementary school students play outdoor to learn geographic facts, concepts, and patterns. The challenge is about improving their geographic literacy and fluency, or 'geoliteracy', and their map-reading competencies, called *cartology*, before adolescence. There a critical stumbling 'threshold' can impede their geospatial cognitive development, which result in a majority of adults being not geographically literate neither efficient, in real-life context, for reading and using maps. Designing a mobile educative serious game implies applying conceptual and pragmatic methods for both learning and teaching geospatial competencies accordingly to school curriculum. The theoretical framework presented links maps to cartographical semiology, the children's cognitive development stages for geospatial representation, and an experiential learning cycle model. The latter sequentially supports three main cartographic processes of map-making: reflexive visualization, and map-reading, which sustain any geographical reasoning. The mobile game proposed combines components of increasing complexity where the map plays the main role in the course of different activities: scenarios of typical "rounds" and rules of the game within local terrain; types of geometrical and geospatial trajectories to trace and follow while playing; and specific themes relevant to school subjects. Thus, geographical discussions stop worrying about where, to worry about the reason of situations and the occurrence of phenomena.

Keywords

Geographic literacy; cartology; experiential learning cycle; learning threshold; thematic scenarios.

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Resumen

Algunas investigaciones en ciencias de la educación desarrollan juegos educativos en dispositivos móviles para incentivar el aprendizaje de hechos, conceptos y modelos geográficos en estudiantes de escuelas primarias. El desafío consiste en mejorar su alfabetización y fluidez geográfica, o *geoalfabetización*, y sus competencias en lectura de mapas antes de la adolescencia, sintetizadas aquí bajo la denominación de *cartología*, la cual parece ser un umbral crítico que obstruye el desarrollo cognitivo geoespacial de los adultos. Diseñar un juego educativo móvil implica integrar métodos conceptuales y prácticos para la enseñanza y aprendizaje de las competencias geoespaciales, conforme al currículo escolar. El marco teórico que se presenta vincula los mapas con la semiología cartográfica, las etapas de desarrollo cognitivo del niño referentes a la representación del espacio geográfico y el ciclo de aprendizaje experiencial. Este último supone una serie de procesos cartográficos esenciales que sirven de base a cualquier análisis o razonamiento geográfico: creación de mapas, visualización reflexiva y lectura cartográfica. El juego que se propone conjuga componentes de creciente complejidad en los cuales el mapa es protagonista en el transcurso de diferentes actividades: rondas típicas con reglas particulares sobre terrenos determinados; trayectorias geométricas y geoespaciales por trazar y seguir durante el juego; temas específicos relacionados con las asignaturas escolares y con los objetivos propuestos por los maestros, etc. Así, las discusiones geográficas dejan de preocuparse por el dónde para inquietarse por el porqué de las situaciones y el acontecer de los fenómenos.

Palabras clave

Alfabetización geográfica; cartología; ciclo de aprendizaje experiencial; umbral de aprendizaje; escenarios temáticos.

Resumo

Algumas pesquisas nas ciências da educação desenvolvem jogos educativos para dispositivos móveis através dos quais alunos da escola primária aprendem fatos, conceitos e modelos geográficos brincando ao ar livre. O desafio é melhorar a literacia e a fluência geográfica desses alunos, ou sua 'geoliteracia', e suas competências para ler mapas, a chamada 'cartologia', antes da adolescência, quando surge um limiar crítico que pode impedir o desenvolvimento cognitivo geoespacial das crianças. A maioria de adultos não são geograficamente letrados nem eficientes para ler e usar mapas. Conceber um jogo educativo móvel integra métodos conceituais e práticos para o ensino e a aprendizagem das competências geoespaciais, conforme o currículo escolar. O quadro teórico apresentado conecta os mapas à semiologia cartográfica, os estágios de desenvolvimento cognitivo das crianças no que se refere às representações do espaço geográfico e o ciclo de aprendizagem experiencial. Este último supõem uma sequência de três processos cartográficos principais que servem de base a qualquer raciocínio geográfico: criação de mapas, visualização reflexiva e leitura de mapas. O jogo que é proposto combina componentes de complexidade crescente onde o mapa é o protagonista no decorrer de diferentes atividades: cenários com 'rondadas' e regras típicas do jogo num determinado terreno; tipos de trajetórias geométricas e geoespaciais a serem traçadas e seguidas durante o jogo; temas específicos pertinentes aos assuntos escolares. Assim, as discussões geográficas deixam de se preocupar sobre onde para questionar a razão das situações e a ocorrência dos fenômenos.

Palavras-chave

Alfabetização geográfica; cartologia; ciclo de aprendizagem experiencial; limiar de aprendizagem; cenários temáticos.

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Introduction

The scope of some actual researches in education science goes toward the development of educative serious games on mobile devices for elementary school students who play outdoor to learn geographical facts, settings, and patterns (Kaszap, Ferland & Stan, 2013). The challenge is about improving their geographic literacy and fluency, or *geoliteracy*, and their abilities for reading maps, here called *cartology*, before becoming teenagers —a critical turning point. When early geospatial cognitive development goes weakly, adolescence would appear as a critical stumbling "threshold" that impedes them, in their educative progress, to comprehend geospatial concepts, structures, and information, later as adults.

Our didactic research team has focused on both conceptual and applied methods implying mobile media on the terrain as well as real maps in the classroom, for both learning and teaching geospatial competencies. There are daily evidences that a majority of adult population is not geographically literate neither efficient in reading and using maps in real-life context. Consequently, to face the challenge of this societal concern, an urgent educational goal remains to apply such active methods for learning competencies in the domain of humanities, newly renamed *Social Universe*, as prescribed now by many official curricula in modern schooling systems. Then, the objective must be to support effectively most pupils to get over that cognitive threshold before they reach the secondary school (about the 7th degree). That needs theoretical and methodological considerations about educative *serious game* (Kaufman & Sauvé, 2010), cartographical *semiology* (Bertin, 1967), the four *cognitive development stages* for spatial representation by children (Piaget, 1967), and the *experiential learning* cycle model (Kolb, 1984). This kind of cycle supports quite well the sequence of three main cartographic processes of map-making, reflexive visualization, and map-reading, respectively, which sustain any geographical reasoning.

These theoretical references help to consider the appropriate ways to learn how to draw, use, comprehend, and read maps as the fundamental forms of geospatial representation and information that sustain geographical reasoning. That encompasses both concrete display of a terrain on a sheet of paper or on a digital screen as well as having learned a stable cognitive configuration in the mind. Only such mental or cognitive representations allow structuring, interpreting, and recalling on demand from memory geospatial information on location, distance, or orientation, within a situation that occurs at geographical scales, *i.e.* beyond the personal limit of sight.

A promising way to explore would be this methodological framework proposed to the teacher for didactically designing a mobile serious game while preparing the school content that the pupils shall learn as players. The framework links maps, on paper or on screen, to get or draw and to use, with other main components that increase in complexity as the rounds of play (or steps) carry on. They are:

- A scenario of typical rounds within a geospatial environment, telling a progressive plot and the rules of the game.
- Types of geometrical and geospatial trajectory to trace and follow while playing the game.
- Specific themes relevant to school content to teach.

The elaborated prototype mixes these components into fifteen successive rounds of play, in order to engage the abilities relative to the three cartographic processes, along an experiential cycle. Performing that sort of game, one comes to consider a serious question to investigate about the potential characteristics that would compose a hypothetic fifth stage in the cognitive development of the child. This hypothesis emerges with regard to geospatial representation and comprehension that a geoliterate adult might possess to behave autonomously and consciously in present world.

The geographic literacy problem at school and during real adult life

The present research concern is to address the difficult problem of *why so many adults are not able to read and use conveniently a street or road map* (So, it is worse in the cases of topographic or choropleth maps!). Even press and tourist maps are so confusing and misleading to the general public with their graphic distortions and funny pictures… In addition, many adults come to believe that most maps are not only incorrect, but simply lie! (Monmonier, 1991). Most people look at maps as a not-so-special kind of images, being less valuable than photographs (because they seem rarely authored?). Even so, we know maps and other cartographical representations, like toponymy (*i.e.* place names), existed millennia ago in a large array of societies and civilisations, and possibly predated symbolic writings at the core of the first progresses of humanity (Harley & Woodward, 1987). Knowing that, one must hypothesize that there was something probably missing in our children's education for giving so worrying results in the geographical and cartographical capabilities of adults (and so many school teachers among them) today.

The concept referring to this problem of being illiterate face to maps, path finding, feature locations, and geospatial situations that one may call, since more than two decades, *geoliteracy*. This word may mean a set of stabilized and adaptive cognitive abilities and functional competencies to handle, by self, geographical realities and cartographical representations

(Ferland & Kaszap, 2017).[1] In general, one defines *literacy* as "the ability to understand and employ information [in a variety of] daily-life contexts and activities [...] to achieve one's personal goals and to develop one's knowledge and potential" (OECD, 2000). From that, the National Geographic Society (NGS) (2012) reduces it as "the ability to use geographic understanding and geographic reasoning to make far-reaching decisions". According to Edelson (2012), there would be three main kinds of understanding that compose geoliteracy, in order to develop consciousness of geographical *interactions* (links between geospatial human and natural systems), *interconnections* (frames for geographic reasoning), and *implications* (systematic decision-making).

This positivist view that geographic thinking, at its aim, has 'to decide anything' seems very restrictive, potentially misleading and counter-productive for teaching and learning geographical facts and geospatial concepts. Geographic decision-making, like transportation logistics or district land planning, cannot be a main task required from children at school. In comparison, one never say that they must get literate mainly for writing novels, for instance. Everybody may read maps to find the most convenient path to go, that is right, but that does not need reasoning *per se* to follow indications of a *Global Positioning System* (GPS) receiver, what is hardly 'making a decision'. Choosing the best place to go on vacation or to buy a new home are not daily decisions, what implies far more information than reading maps. Nevertheless, the processes underlying geographical decisions, from data gathering to implementation, may serve as a template for both teaching strategies (Catling, 1996) and learning stages, thus developing critical judgments made with respect to complex geospatial situations.

However, the two first kinds of understandings, geographical *interactions* and *interconnections*, constitute fundamental features of geoliteracy, whereas the latter ones can be advantageously replaced by geographic *explanations* in an educational perspective. Instead of 'making a decision', the aim of geoliteracy and the purpose of map-reading would be the capability to 'make one's mind up' in circumstances, then to behave knowledgeably in the real world. That means, to understand on the first try an intelligent geographic explanation, or retrieving ability to ask questions and find appropriate answers while engaged in a critical situation to solve (rather than just recalling answers for a quiz).

In fact, the deep true question in (both human and physical) geography is not only a static "*where is it?*", but more certainly a dynamic "*why and how does this situation occur there?*" (Mérenne-Schoumaker, 2012). For thinking about that question, a previous individual description of geoliteracy, though technology-oriented, looks more convenient for our didactic context of *Social Universe* domain: "the use of visual learning and communication tools [*i.e.* maps] to build an in-depth understanding — or literacy — of geography, geology, and local history" (Ball, 2003). Moreover, a pedagogic claim completes this quote, for defining what is geoliteracy: "Surround kids with geography: study maps, create maps, follow maps, play with maps. The more you develop their spatial intelligence when they're younger, the more kids will understand their place in this world" (Kid World Citizen, 2012). To that, we completely agree: the map stands as the best way to think geographically about the world.

Thus, a geoliterate adult should possess a complete (but never exhaustive) set of stabilized cognitive abilities and functional competencies that are necessary to:

- Read, use, and even detect errors on maps and other carto-geographic representations (at any support, format, and scale or zoom).
- Locate places and situations, find new ways in space (at any scales).
- Understand and interpret geospatial concepts, signs, and structures on a critical, reasoned, autonomous fashion, while discarding misconceptions.
- Determine, delimit, plan, and select best places to install activities.
- Recall modes and patterns of geospatial representation, even without maps at hand (not just from mental images, capitals, touristic metaphors, or evocative pictures to come out from memory, which is necessary but not sufficient).
- Enhance own geographic culture and useful geospatial awareness.
- Elaborate an opinion or explanation regarding daily geospatial situations or circumstances.

What a troubling concern is the multiple evidences that the majority of adult population is not literate neither efficient in reading and using maps, *i.e.* cannot perform most of the precedent list of geospatial abilities and competencies. That is why the Canadian Committee for Geographic Education (CCGE) was formed in 1993 with the purpose "to promote geographic literacy in Canada". Adopting the NGS (2009) geographic literacy goal for 2025, it also identifies two levels that contribute to educational purposes: geographic literacy and proficiency.

Geographic literacy is the ability, effective after secondary school, to apply geographic skills and understanding in both personal and civic lives; the goal to achieve should be 50% of students. Geographic fluency, a higher standard, is defined as the level of preparation to achieve what would be essential for successful university studies in domains that require geographic skills and understanding (*e.g.*, international affairs or environmental sciences).

1 See www.cgeducation.ca/programs/geoliteracy.

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Thus, the educational concerns about geoliteracy span from kindergarten to professional training, starting at home and in the elementary classroom, then expanding to university and distance learning (Nichols, Dobbin & Ferland, 2002). Few years ago, some Canadian geographers, geomaticians, and map librarians with the CCGE adopted the *Declaration of St. John's* [in Newfoundland, NFL] on *Advancing Geographic Education*. As the goal engages to advance geographic education, they affirm that spatially literate citizens are essential to understand and address the economic, social, and environmental issues faced by a rapidly changing world, now and in the future. In particular, there is an urgent need to improve, update, advance, and develop a coherent and relevant geographic education, built upon fundamental concepts.

Improving the geospatial competencies during stages of children's cognitive development implies they understand the relationship between the symbols and networks showed on maps and the features and situations these ones actually represent. That should imply a strong pedagogic training and involvement of teachers into a slow, progressive, and cumulative learning and assimilation process for the children's geoliteracy (Bednarz, Heffron & Huynh, 2013).

A hypothetic threshold on geospatial cognitive development of the child

Plenty of observations on the evolution of pupils' and students' behaviour seem to indicate a declining interest toward many school matters as they reach teen ages (Anderson, 2003). Ferland and Kaszap (2014a) enunciate an assumption that there is a kind of cognitive threshold, a critical step of organized capabilities, by the end of elementary school, at about 12 years old (just a reference point generally accepted for entering to secondary school level). The educational expectation is that students must learn and master these disciplinary matters in order to be able to build on more complex competencies and knowledge while continuing school further in higher grades and then proficiently during their adult life. If a student does not succeed to get over that learning threshold, even the few weak abilities hardly acquired may vanish if interest in them decreases while practical usage disappears.

Later, as a young adult, it will be very hard to restart learning that same matter without the necessary mental frames to organize concepts and relations into an actionable knowledge. At this point, it is uneasy to indicate what would be the characteristics of this hypothetical threshold and its effects: it can be a springboard for some students, but an impediment for many others. This crucial point deserves further interdisciplinary investigation for its formalization within a theoretical frame.

Following Piaget and Inhelder (1947) for good research reasons, this threshold might be placed at the fourth and last stage of the geospatial cognitive development of the child, which is also at about age 12 (or sixth to seventh grade). That stage consists of the abstract capability of drawing on a spatial plan or sketch, a map or a chart, at very large scale (*e.g.*, 1:200), any geospatial situation from above and with the vertical point of view. The four learning stages for looking at places and mapping them grow also in complexity with age (passages are indicative only; of course, many children can read correctly maps and globes by far younger):

1. Elevation topology (psycho-motor) of a sketch with difficulty to show the roof (ages 5-6).
2. Multiple views (front, side) arranged together in same drawing, with hesitation (ages 7-8).
3. Operating concrete assembling of features in represented space with appropriate scale and dimension (ages 9-10).
4. Abstract, deductive, formal vertical view of a full plan or map within a frame with association to some symbolism (as detailed in a map legend) (ages 11-12).

Piagetian theory is based experimentally on first try drawings, which revealed more about perception, memory, and representation abilities by the child, than they expressed geospatial conceptions, comprehension, and knowledge of a situation, even if familiar. This theory lets us believe that this fourth stage would be the complete and final one in cognitive development of geospatial abilities and competencies learned by any child. But nothing there proves that most children effectively reach this stage, neither that it corresponds definitively to any kind of geographic literacy or fluency.

However, recalling from memory some mental image of a home place and mapping it with drawing skills, though necessary, cannot be sufficient abilities. Our research team questions this developmental limit and come to look for other consistent characteristics of a potential fifth stage that would emphasize landscape patterns, road networks, urban frameworks, and multi-scale representation, for instance. This rather structuralist view of an advanced stage should help to teach and consolidate geographic literacy among students toward secondary school levels, to come up to behave as geo-competent adults.

At these stages, a representation of real geospatial settings or situations, without visibility from place to place at geographical large scales, is mostly instrumental and primarily devoted to the local neighbourhood of the pupils that grounds their daily experience. That seems far more important than showing small-scale maps of large countries and continents, what young children's mind cannot encompass. Neither do we recommend to base introduction to cartography on the replication of imaginary or fantasy worlds, due to the risk of definitive misconceptions, too difficult to modify thereafter.

One must point out a difference between geospatial cognition and reasoning. Cognition covers most of the ways by which humans think spatially about places and their organisational locations, distribution or networks, and relationships (Catling, 1978), here and there in the world, and then how they come to some memorization and understanding of it. Geospatial reasoning is rather the fashion for voluntarily reaching a spatially significant conclusion or statement, like a decision (which is a by-product among others), from memory, direct experience, and new information.

Developing a mobile serious game for geography education

Thus, after a research project on mobile serious games, called *GéoÉduc3D* (Daniel & Badard, 2008; Kaszap & Ferland, 2012), our research team joined elementary schoolteachers within a small community of practice named GéoTIC[2] (2012-2015), in order to identify pedagogic needs and to test some game components as exercises. The intent of these schoolteachers had double facets, whatever one thinks of general opinions about gender differences on spatial perceptions and representations.

First, digital mobile devices to support outdoor educative games should help to keep boys' attention on the taught matter, as being a funny way of learning. Second, the progressive structure of the game components must stimulate girls to assimilate more complex than trivial geographical concepts by intense use of maps. From the latter facet —letting apart its gender derogatory allusion, because the map-reading deficiencies strike too many males and females as well, whatever their relative proportion as reported in studies— emerged the project called *Géolittératie* (2014-2017). It was more concerned about the content of a progressive serious game that can improve the pupils' competencies (Kaszap & Ferland, 2017), whatever their initial capabilities, differences, skills, or assessed performances in conceptual geographic knowledge, reflexively with more intensive use of maps (Bednarz et al., 2013, p. 36).

The concept of educative serious game (Ferland & Kaszap, 2014b; Kaufman & Sauvé, 2010) comes from the assumption that in the children's mind, playing is a very important and serious activity; some theories by Huizinga (1955), Piaget (1962), Bateson (1972), and Vygotsky (1967), for instance, support that assumption. In this creative and exploratory activity, a game become serious in two ways: by its set of rules in order to play with a cut-off simulation of determined reality, and secondly, by keeping the fashion and the outcomes of the game as lessons learned into this continuing reality – plus a taste to play it again, for positively affecting their reinforcement. Games may appear as a methodological framework to build a sequence of play rounds with growing complexity of components within phases of a learning cycle.

Our previous exercises and experimentations of serious games in school settings used applications on mobile devices (*e.g.*, cellphone, tablet) in consideration of their potential with regard to augmented reality (AR) displays. Our research and teaching team focused on both conceptual and applied didactical methods to take digital field-notes of different kinds (*e.g.*, textual descriptions, pinpoint labels on map, photographs, voice recordings, etc.). Taking notes about local thematic aspects on the terrain includes referencing them to street addresses, landmarks, or neighbourhood toponymy. Afterward in the classroom, these field-notes had to be compiled and compared with documentary resources and other maps to be reused in following activities (*e.g.*, oral presentation, planning an excursion).

As an intermediate conclusion, the interest for technological media in education does not stand within their capacity to provide fancy and complicated displays that would require a long training of a *Geographical Information System* (GIS). Although many technological applications (*e.g.*: GPS receiver, digital *Google*™ maps) installed on a cellphone assist quite well, they cannot replace a real map or a smart look (a « *coup d'œil* ») at the terrain for triggering some geospatial thinking. There is a concern that they rather induce a decline of current intellectual competencies to locate, find, or determine a place or a route. On the other hand, it appears clearly that the use of mobile devices allows children to gather, combine, and share data from a variety of sources on a quite autonomous fashion. That can easily support the teacher who prepares a theme to learn about, conceives a didactical scenario to manage the matter content, articulates progressive lessons, and controls the results achieved by the pupils.

Henceforth, one has to formalize a conceptual kit for map-games at school that might help teachers both to design fieldworks with data collection on the terrain and to support geographic reasoning thereafter, in the classroom, intertwining geospatial, socioeconomic, and environmental dynamic phenomena. So, let us take advantage of that!

The structured components of a geospatial serious game

A serious game constitutes a methodological framework to prepare phases or rounds of play by increasing practical abilities and analytical knowledge. In the experimental design presented here, the game frames four important components that work together while growing in complexity, step by step. The first one is obviously the map with other pedagogic accessories and devices that help to locate and document the place

2 TIC, in French, stands for: "Information and Communication Technologies". The *GéoTIC* project was voluntary, but non-funded, so despite results were stimulating, they were too partial for publication.

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characteristics, the features related to the theme, and the trajectories of the game. That is the essential cartographic purpose of the game to support its geographic representation goal.

The scenario component provides the didactical basis for successive rounds of a complete play toward a curriculum goal: providing all keys for understanding the aspects and relations of a theme, as selected from the school programme for this grade and adapted to the class pupils. The scenario enunciates the tasks or roles to perform, the rules of the game (what is at stake, who plays which role, how to fix and count the marks, when it is over, who wins what) and its educative intent. It is not just a storyboard; it presents a scene on a starting location, according to the theme, and it identifies the aspects of a situation to locate and describe as it evolves at each step or round.

A scenario may present a series of criteria or questions to answer right on the site while actively searching next spatial or conceptual steps, a story with alternatives to choice for next direction or location, or minimally a rich geocaching plot. While adapted to the pupils' cognitive development and school grade, a serious game scenario requires more than a conventional treasure hunting or a simply commented excursion. To be educative, the scenario must stimulate the mental reflection and avoid confusing statements, trivial yes-or-no answers, and riddles. We identified and designed six types of scenarios that can structure a journey based on cumulative knowledge about geospatial organisation and behaviour relative to the topic (Kaszap et al., 2013). The simplest scenario gives the destination and the characteristics of the successive places to recognize and visit on the way. The harder and more complex scenario ask for players to think about unknown location constraints and to explore a territory toward a solution to a quest.

Third, we find the educative goal. While applying active pedagogic methods, the game has to teach abilities, concepts, instruments and tools (like maps), and both disciplinary and transversal competencies that pertain to an interdisciplinary theme component. In the domain of *Social Universe* (MÉQ, 2001), as prescribed by the official—now quite regular—school curriculum,[3] there is a so large variety of themes to look at on the field, since it encompasses matters in History, Geography, and Citizenship, plus basic Economics, and even Architecture and Botany as seen on the terrain. The topic is supposed to stay the same all along the game, but it may be subdivided in sub-themes or aspects at each step of the learning cycle (or at each round of the game), or progressively mixed or paralleled with another theme. The elements of the topic to be learned may be described extensively in the scenario, like in a text to read in class before a lesson, whereas the purpose of playing the game might be to observe the facts and to recognize the relations between them.

Finally, the fourth component refers to all possible trajectories (Ferland & Mercier, 2004) to follow towards the geographic goal of the game. The various types of trajectory are based on the geometrical dimension primitives: point, line, polyline, polygon perimeter, surface (2D), or multifaceted volume (3D). They compose a kind of cartographic 'alphabet' and syntax with properties like scale, extent, and semiological symbols or signs. Most of these primitives may be combined and seen from diverse perspectives or scopes. For instance, from one place to another: a point and another point (without any interest for the player in between), the close area around each point, the line between two points, one or both sides of this line, direct or reverse orientation of the way, perimeter of a sector of interest, etc. The trajectory serves as a means to observe, note, and build representations of morphological features, settlement landscapes, street grids, or urban forms about which the scenario realistically gets reality in the neighbourhood. The complete trajectory should compose an area of significant locations without visibility from place to place at a glance, what makes their representation as 'geographical'.

The teacher assembles these four components for designing, at will, games of increasing complexity with respect to the didactic objectives, while preparing a sequence of progressive tasks to do in rounds, according to the students' different learning styles and stages. The teacher should adjust the details of the game in accordance with the stages at the level of the tasks, steps, or rounds, not at the whole phases, in order to keep control of the students' learning progress. They will be exposed practically to the process of making some sketches and plans, then a map. They will play rounds of the game many times during a semester, by themselves or as participants in a team, in cooperation or in competition. They will go outdoor on the terrain with pleasure for collecting data on some map to make, building up a framework of trajectories, making sense of all them, and learning more about the entities, facts, relations, and evolution of the suggested theme of the game in their local milieu or environment. Through such a serious game framework, the teacher gets access to the pupils' geographic representation and knowledge in their actual everyday life as well as to the ways they come to use for constructing their comprehension of the world. It works like an instrument to follow their progresses, step by step, identify their learning weaknesses, adapt or improve the next rounds to coming lessons, and assess the results achieved by the pupils (not just by the "winners") thanks to post-tests and subsequent activities in the classroom. With multiple experimentations on the terrain and in classroom settings, the serious game would contribute directly to the identification of the characteristics and conditions of the learning threshold to be demonstrated, and then to be able to get through.

3 See: www.education.gouv.qc.ca/enseignants/pfeq/.

The theoretical and methodological framework for geographic literacy

The expected cognitive threshold within or after the fourth cognitive development stage hinders the comprehension of geospatial concepts, patterns, and information. The objective of developing such an educative serious game is to find effective manners by which most pupils should successfully learn and integrate those geospatial matters before reaching the secondary school (or college) levels. Every teacher's wish might be that teenage students would avoid some cognitive regression due to weakly learned matters, at this moment when they change their scope together with their cohort's interest. Beside considerations about cognitive development stages, relatively to our educative serious gaming (Ferland & Kaszap, 2014b), the constructivist theoretical background adopted by our team (Jonnaert, 2002) comes to refer particularly to the *experiential learning* cycle model proposed by Kolb that structures learned abilities and competencies (Kolb, 1984; Kolb, Rubin, & McIntyre, 1974).

From a methodological view, in order to train adequately a map-reader, the whole game must also integrate both cognitive geography basics[4] and cartographical semiology of visual variables (Bertin, 1967, 1983; Ferland, 2000) for geographical information, representation, and communication. The rationale is that learning how to read maps implies minimal understanding of how to make them (*i.e.*, how good maps are made and do work), and that obligates the teacher to master and introduce some concepts and techniques of good practices in cartographic design, what is not so common.

Here is a warning that maps for cognitive representation of geographical spaces have very few to do with a sort of hierarchical graphs metaphorically known as *cognitive maps* or *mental maps*, in use for completely different and non-spatial purposes, *i.e.* social or organizational networks of entities and linear relations.

A three-layer theoretical and methodological model for experiential learning and cognitive styles (Ferland & Kaszap, 2017) was designed cautiously, with respect to four quadrants of the cyclic experiential model. Each quadrant is dedicated respectively to: perception and concrete observation, analysis and representation, comprehension for conceptualization, and then planning for decision to make and action to take (Kolb, 1984). Any quadrant, loosely determined, brings together dozens of related abilities, competencies, or performances. The author assimilated and used pragmatically this experiential model for two decades, from his graduate studies through professional researches and teachings in cartographic information and geospatial knowledge representation (Ferland, 2007). It is easy to put many other developmental models within this structure; for instance, Piaget's four learning stages, running from topologic perception to spatial conceptualisation, fit quite well over the first half of the experiential model. Despite its similarities in vocabulary and cyclic learning, this model does not match Bloom's well-known hierarchical levels (1994). Over these two theoretical layers (from Kolb and Piaget), our team elaborated a third one as a scheme of fifteen successive rounds in a detailed prototype of cartographic serious game. It goes from data collection on the terrain for map-making to reflexive visualization and map-reading by comparison with the real area displayed on it, and finally, what is called *cartology*.

First cartographic phase

One must teach these geospatial concepts in a progressive spiral manner, *i.e.* in a logical sequence of learning cycles while diverse abilities take turns through all the quadrants (Catling, 1978). The first half of the model applies to notions relative to map-making, adapted to the development stage of average pupils in the class, what the teacher controls by a pretest. As students get exposed practically to the process of making a plan or a chart —then a map—, they must become aware of the necessary elements and conditions that compose a good map and how cartographic information works (MacEachren, 1995). That is neither a simple drawing, nor a sketch to illustrate a setting, but a tool to represent a complete area under a certain theme.

At appropriate moments in the process the teacher has to give cartographic instructions that must support and correspond to both thematic elements to display on already made maps and capabilities of pupils at the normal stage of their class level. That is why the educative serious game scenario begins with simple observation and data gathering on the terrain, in one manner or another: by taking field-notes and photographs, by locating sites on an available map and pointing information on it, or still by identifying the appropriate type(s) of paths that might better represent the suggested theme components.

From round to round, as the scenario of the game becomes more complex, the students enhance their abilities to map trajectories and landmarks of the story on sheets of paper, while also using their cellphone screen or printing digital maps as geographic reference. At this step, making a brief analysis of the data and choosing the way to display them on a plan leads to reasoning and answering the questions of the designed scenario about the object of research. Thereafter, students get prepared for the next round of the serious game. Next versions of the plan will compose a more correct map, with density and structure of cartographic information; that contributes to synthetize and even explain what happened to the situation at stake in the game.

4 See: http://geography.name/cognitive-geography/

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Intermediary visualization phase

After the first half of the experiential learning cycle is accomplished, one can expect to approach the cognitive development stage associated to a threshold of operational comprehension of both cartographic maps and geographic situations. Now, the students know how to describe a spatial situation and to make a map, which is good but not enough. Therefore, the challenge is to learn, from this quite technical knowledge, how to read any map, and get information from it. That is a reflexive, abstract, new open phase called cartographic visualization (Ferland, 2011), a recursive, retroactive (*feedback*), systemic, and intermediate process between cartography and cartology among the complete map-use competencies to be acquired. In the case of children missing this cartographic experience, there would be a sufficient reason to cause the cognitive threshold at this learning phase.

Visualization is "to play with maps" for gaining the deepest comprehension of their potential content. This process comprises any technique for designing, using, and modifying at will visual imagery such as pictures, diagrams, maps, or animations, to communicate and explain both abstract and concrete ideas (Tufte, 1997). It is an effective way to think about the map features and patterns by analysis, interaction, selection, transformation, or simulation on these visual displays, in order to extract information or knowledge from data. Visualization may simply be to place two or more overlays of data on real or digitally built images or 2D and 3D models of the shown reality; or it can be the making of a conceptual digital construct of some real object directly from a mass of collected data. An overlay can be a simple sketch drawn on transparent acetate sheet placed upon a paper map, or the digital superposition of street names on a satellite image of the Earth. Visualization focuses and emphasizes the map content to reinforce cognition, elaborate hypotheses, and reason while dealing with statistical graphics and geographic data abstracted in this schematic form, within an implicit or explicit geometric structure. Among many techniques, one consists to slightly variate ranges of data values to get a more significant appearance or shape of a model, whereas another one extracts questions from the map to search for documentary information or supplement about the theme or the local history, for instance. In the classroom, as a visualization post-test, the teacher may ask to the pupils to read, interpret, and comment hand-made maps by their mates, each other.

Second cartologic phase

The intermediary phase of visualization allows teacher and students to continue towards a third process corresponding to the second half of the experiential learning cycle, which is the complement or a converse of the cartographic one: a 'cartological' process. As a definition, cartology means textually the capability to "make the map talking" even for telling a new story that adds to or differs from what the intent of the cartographer or mapmaker was about, in any details.

This last process starts from a phase of comprehension or visualization of map content. Since the student has learned and now knows how the characteristics of a correct map work, the way is open to ask questions by himself and read on it some information that was not necessarily put there intentionally in advance by the mapmaker.[5]

This second half of the experiential cycle constitutes an active process leading from conceptualisation to methodic planning, formal decision, adaptation, and implementation in real world. In the case of cartology, this process can mean projecting the map upon the view of the place represented on it, while one stands directly there on the terrain *in situ*, and then verifies to what extent both match.

That is "mapping the map on the ground truth". Likewise, a decision made by planning an action on a map should be executed accordingly on the real specific conditions at that represented place. At the last steps or rounds of the game, children would be able to plan with enhanced maps drawn by colleagues, then to go on site with them in hands to prepare and make a wise decision for answering the question at stake in relation to the topic in the scenario.

Since theory says that an experiential learning cycle may begin at any phase, one can organize the steps of the cartologic process into a mobile game other than the cartographic one, with new scenarios and trajectories. Children can gain a better understanding of the power of a variety of maps and atlases for their cognitive structuration of geographical space and patterns (Ferland, 2017). Thus, they will learn more efficiently about a specific topic that requires historical thought (Stan, Kaszap & Ferland, 2017) and geographical thinking and reasoning. A good topic to begin with is toponymy (placenames) of streets and districts in the neighbourhood of the school, completed with some classification of generics (lane, street, drive, road, boulevard, and highway), for instance (Ferland, 2015). One may ask simply the children to find on the *Web* the meaning and origins of some street names in the vicinity.

As everyone can see, that experiential learning cycle follows the same analytic-deductive circular process generally used in scientific investigation, decision-making, creativity, and so on. Thus, the complete experiential cartographic process is seen as a double mapping: after making a map of the area of interest, cartology consists reversely to transpose that representation towards the terrain.

Of course, both aspects (cartographical and cartological) might occur in the same round. But the teacher would surely prefer to prepare, two

5 That is obviously the case for interpretation of a satellite image captured by an automatic sensor, without any intention or preselection of data.

or three scenarios on different aspects of both cartographic concepts in practice and thematic disciplinary matters over the course of each semester in a year, rather than a long and complicated game with many rounds on diversely connected situations.

Conclusion

The conception of an educative serious game on mobile devices for elementary school students, with the purpose of exploring outdoor situations on the terrain, was an opportunity to address humbly a societal concern: the most of adult population is not geographically literate. Among researches in education science about the didactic of humanities, both conceptual and applied methods implying mobile media on the terrain as well as real maps in the classroom should be considered for better learning of geographical facts, settings, and competencies.

The challenge of improving geographic literacy, or *geoliteracy*, mostly passes by map-reading competencies, also called *cartology*, which children must assimilate before becoming teenagers. The reason to point at this development phase, while beginning puberty and entering secondary school, is because many children would face then a critical 'threshold' in their educative progress, impeding their comprehension of geospatial patterns and information as growing up to adult age. Face to this double problem, as a teenager and later as an adult, the educational goal in (both human and physical) geography and history remains to apply active methods for teaching geospatial skills and competencies, instead of abstract concepts and facts to memorize. For all that, teachers must come to master appropriate and efficient ways to teach and learn how to draw, comprehend, use, and read maps, as fundamental forms of geographic reasoning.

Facing the geoliteracy challenge at school, the geographical map appears as the best, powerful, and necessary support or instrument of geospatial knowledge representation. The fundamental interest of cartographic abilities to make and read a map is that it creates information value, builds own mind, structures memory about places and events, and enhances mobility.

To recognize, manage, and get over the hypothetical cognitive threshold, it should be necessary to identify the aspects of the cognitive development phases where it risks occurring, why, and what is missing or lost in the learning process. To address this threshold in geoliteracy, which needs theoretical and methodological considerations, for instance about cartographical semiology, cognitive development stages for geospatial representation by children, and an experiential learning cycle model. We designed such a cycle of learning activities within a mobile serious game as an experiential strategy that supports quite well the sequence of three main cartographic processes: map-making, reflexive visualization, and map-reading, respectively. This conceived prototype mixes these components into fifteen successive rounds of play, or steps, of increasing complexity to develop geospatial abilities and understanding of the pupils, particularly their knowledge about the local milieu, all along cycles of learning, play, and life.

This exploratory theoretical and methodological framework for mobile serious game is based didactically on maps, of course, plus three other components that the teacher prepares for organizing the game in a sequence of rounds, as if it was a series of lessons with increasing complexity. First, different types of scenarios permit to tell the rules of the game and the progress of the play as a chain of typical rounds within a geospatial environment. Secondly, there are various types of geospatial trajectories, which resemble the usual geometrical dimension primitives, as paths one may follow on the terrain while running the game, and then that can be drawn on plans. Last but not least, the teacher chooses the specific topics with their facts and relationships relevant to the school programme objectives and matters.

This game framework has both a learning side for pupils playing on the terrain and in the classroom, and a training side for the teacher preparing scenarios and trajectories accordingly to the topic. Many teachers cannot progress seriously toward the curriculum objectives on humanities because they lack a sufficiently strong geography education background, their own geoliteracy. Educators must develop new enhanced practices based on theoretical or methodological frames of reference already validated by various scientific domains, but not just instinctive neither trivial, like the experiential learning cycle and a taxonomy of learning objectives with levels of complexity. At the ground levels of school classes and boards, it is no more time to devote to surveys and research about what is missing in curricula or should be the best method to reform them.

At this stage, that experiential approach has no pretention to become a standard for teaching active geography in elementary classes. This method for developing geoliteracy by combination of both cartography and cartology within a mobile serious game was used in recent years for teaching 'Didactic of Social Universe', an undergraduate course for future schoolteachers. Practical experiments and teachings must continue in order to strengthen the theoretical and methodological framework as a coherent pedagogic strategy. The real intent is to ease the schoolteacher's work about the best usage of maps for structuring the geographical comprehension of students, from home place to the whole world. For this, that experiential model invokes the argument that "you must think before acting" in an area, at any round. That transversal competency is critical and necessary for assessing the achievement of reasoned solutions or decisions and their intended results in the reality; or, in case they fail, it allows conducting an analysis which can say how and why.

The combination of humanities and cartography strongly supports interactions among the three most important sorts of literacy: geographical, mathematical, and, of course, literary (and some would argue artistic, too, due to the need of developing abilities in graphical semiology). In the field of mathematics: plane geometry, scale, distance, perspective, topology, primitives, and dimensions, all of which concern cartography. Even more, both map-making and cartology need to perform textual literacy in: reading, writing, vocabulary, toponymy, and even syntax and grammar.

Set apart the need of funding for the realisation of an operational version of the mobile serious game and its experimentation with a large set of exemplar components, there are much researches to lead, in the classroom and on the terrain, on three main topics. First, it is necessary to write some guidelines for training teachers about concepts and practice of cartography and cartology in an elementary school classroom, in relation to the four cognitive development stages. In the second part, this guide would describe the serious game framework and the ways to define its objectives and rules, to prepare a scenario of rounds according to the theme selected in the curriculum, and to build the appropriate trajectories adapted to local situations. These guidelines should help teachers to complete and stabilize their own adult geoliteracy, what seems in high demand.

Thereafter, further investigations must identify the characteristics of the potential cognitive threshold impeding the comprehension of geographic situations by students and the performing usage of cartographic maps by teenagers and adults. Finally, researchers have to question if that threshold remains within the fourth and final learning and cognitive development stage of the Piagetian theory, or if there is a hypothetic fifth stage corresponding to teenagers' geospatial cognitive development, with its characteristic components and aspects. It looks like a gap between the cognitive threshold and the geospatial competencies that a geoliterate and mobile adult might possess to behave autonomously and consciously in the present world.

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