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Augmented Reality in Pedestrian Navigation Applied in a Context of Mobile Learning: Resources for Enhanced Comprehension of Science, Technology, Engineering and Mathematics

JORGE JOO NAGATA
Grial Group. University of Salamanca—Universidad Metropolitana de Ciencias de la Educación, José Pedro Alessandri, 774, Ñuñoa, Santiago, Chile. E-mail: jorge.joo@umce.cl

JOSÉ GARCÍA-BERMEJO GINER
Grial Group, University of Salamanca, Plaza de los Caídos, S/N CP 37008, Despacho 3017, Salamanca, Spain. E-mail: coti@usal.es

FERNANDO MARTINEZ ABAD
IUCE Group, University of Salamanca, Paseo de Canalejas, 169, CP 37008 Solís Building, 1ª floor. Salamanca, Spain.
E-mail: fma@usal.es

This paper describes the creation and educational effectiveness of a digitally-enabled learning module. The module is linked to the implementation of several Mobile Pedestrian Navigation and Augmented Reality features (MPN-AR), which are used to carry out training processes. In particular, the information imparted is related to territorial information on several relevant disciplines like Science, Technology, Engineering and Mathematics (STEM). This is done in a context of digital information about the environment of Santiago de Chile. The research focuses on two main areas, of which the first is the territorial delimitation, in the thematic context of the study area, in order to carry out the design of an MPN-AR application. This includes defining the architecture, functionality, user interface and implementation of the application. A second step deals with the empirical verification of the results produce by the various modes of operation of the application, as well as the comprehensibility and effectiveness of the model. This is done by means of an MPN-AR application, which has been created in the context of mobile learning and ubiquitous learning as applied to territorial or environments systems. The precise context will be students in a formal educational context. Finally, the implication of these results is discussed, determining their effectiveness within the context of m-learning and u-learning scenarios in comparison with traditional teaching

Keywords: computer uses in education; computer-managed instruction (CMI); computer-assisted instruction (CAI)—mobile learning; ubiquitous learning; STEM; augmented reality

1. Introduction

The widespread application of ICTs has produced a large number of new scenarios, and indeed it is affecting one of the most important elements in the development of any society: the comprehension, visualization and understanding of the contents and evolution of territorial and environmental systems. This new scenario makes it possible to work on sites while using different types of information technology, ranging from the simple representation or modelling of spatial scenarios, to even the possibility of generating and structuring spaces from new and complex data structures (Virtual Reality). This is the consequence of the very active development of processing techniques and methodologies of graphical display that is taking place nowadays.

Nature defines the environment, the landscapes and the ecosystems, each with their own characteristics and contexts, and in the current technological stage, a number of tools have been generated for understanding, measuring and modelling. These tools range from the implementation of interactive maps to global satellite navigation systems (GNSS), including the collaborative creation of information about the territory (Neogeography), based on the implementation of the Web 2.0 and 3.0 [1–4].

The field of education is by no means outside this revolution, it being heavily fortified with the creation of new dissemination tools, as well as with the apparition and widespread usage of knowledge creation and learning structures. In particular, new ideas and lines of action have been implemented that are related to the types of established technology. Mobile Learning and Situated Learning (m-learning and u-learning) [5, 6] result from the crossbreeding of different fields of knowledge in these areas, and one can see there is a complementarity of contents, methods and objectives.

Techniques such as Augmented Reality (AR) have been maturing during the last 25 years, in direct proportion to the increase in capacity and

capabilities of hardware. One other aspect that must also be taken into account is the growing portability of mobile devices and applications (in smartphones and tablets). It is now possible to find important new features both for users and for developers of software, features that easy the creation of content for AR-based methodologies. This scenario has led to the implementation of new educational fields of knowledge, one of which is Education, Science, Technology, Engineering and Mathematics—STEM—[7, 8]. This field is converging in a natural way on territorial systems. Indeed, it has led to the creation of thematic content, enabling a new way to display and disseminate information. In parallel, another technology has been strengthened by advances in mobile devices: Mobile Pedestrian Navigation (MPN) [9]. This methodology derives from the use of computer-assisted navigation and map servers, and it facilitates the creation of content on different subjects, which is producing new results through its inclusion in education.

2. Presentation

This research is based on the design, implementation and evaluation of a mobile application that makes use of MPN and AR techniques. It has been used in the context of educational training through the use of technologies (u-learning and m-learning) intending to deliver territorial and environmental information related to Santiago de Chile. The research is conducted in the framework of two major dimensions:

- Establishing territorial scenarios that are to be presented in the application, in addition to the design and development of the platform MPN-AR,
- Defining the architecture, functionality, interface and implementation of the application.

This, of course, implies testing display modes, and understanding the educational effectiveness of the application in a real-world educational scenario, with engineering students and related disciplines as subjects. The application is a mobile computer system that allows appropriate presentation of content on the territory and its various characteristics, framed in a context u-learning and m-learning that goes beyond existing tools.

Our goals include, thus, three major areas of research:

(1) Search, selection and processing of contents related to the environment of one example city
(2) The technological and digital implementation of these contents in a mobile context (m-learning).
(3) The determination of the effectiveness of this tool as a learning process compared to other traditional forms of learning, such as traditional classroom learning or e-learning.

Related to our first goal, we analysed the territorial elements of the city of Santiago de Chile, in order to refine and adapt this information to the context of digital display for mobile devices. In parallel, an MSN-AR application is under development, using computer frameworks that offer Location, Navigation and AR capabilities in programs for mobile devices. Our main aim is to develop this app for tablets, in which to display contents related to the environment and territory of the chosen city. Obviously, these instruments and digital resources are used with an educational role in mind. In this context, the MSN-AR application was developed and adapted to the target architecture and it makes use of a series of frameworks that serve as primitives for the software. Concerning our third goal, we develop a quasi-experimental study, where a group of students are taught in an m-learning context with the application, while the other group works traditionally on equivalent contents with e-learning tools and regular lessons.

3. Discussion

The theoretical context of the investigation is focused on the MPN and AR capabilities of mobile devices and their ability to achieve enhanced educational processes. The themes exposed by the software are related to the territorial scope of existing natural systems (their topography, weather, vegetation, hydrography, etc.). The correct spatial representation and the proper selection of content is a prerequisite in developing the user interface. Further, it is our goal to enhance and facilitate the display of data in a context of MPN-AR [10, 11]. It is expected that our findings could have a significant impact on the final design of the module and its structure, which will be used to teach about STEM disciplines.

On the other hand, from the point of view of educational dimension, the digital implementation is contextualized within the paradigms of u-learning and m-learning, where the learning of contents is defined with real scenarios, particularly in the existing natural-territorial systems in Santiago de Chile.

3.1 Learning through augmented reality

Some digital resources on the environment of the city are based on an aspect of AR that makes use of a specialized version of data display procedures. To be precise, it allows user interaction with elements of the physical real world mixed with virtual and

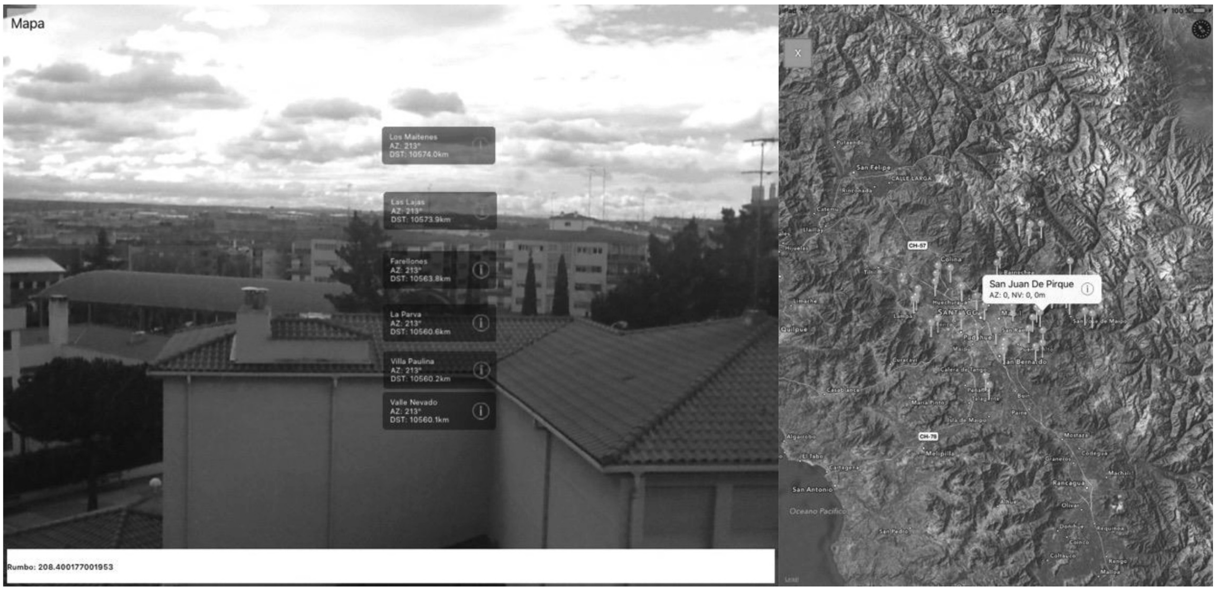

Fig. 1. Augmented Reality model in Santiago de Chile.

digital representations of models in a single display. This presentation of data is complementary to the observation of the actual, real phenomenon (Fig. 1). The user maintains implicit control of the interaction with data presented from digital resources [12–18]. This possibility of mixing digital virtual objects in a physical environment allows users to view abstract concepts, and also to experience events and situations that are impossible in the exclusive domain of the real world [19–23].

3.2 Mobile Pedestrian Navigation Systems (MPNs)

An MPN is a system that supports guided navigation in a context with human scale (1:1). Spatial information is provided by a mobile device with internal location sensors (GNSS), and connected to data provided by maps servers over a digital link. The information displayed on the device includes mapping data, points of interest and even routing, which complements and guides the user moves physically within a given territory [15, 24–26]. MPN systems are implemented through the integration of various complementary frameworks that provide the application with location and maps, running on a mobile device.

Using the device's sensors and the multimedia capabilities of the mobile hardware, navigation is helped along by displaying information on places of interest (POI). POIs can be at hand, or even on another continent; the application controls precisely which ones will be shown. Hence MPN as implemented in this app allows the acquisition of three spatial levels of knowledge that are important in the learning of science: reference medium; sequence territorial knowledge through routes; and contextual survey of knowledge in a general spatial framework [23, 26, 27]. In addition, the mapping used in this mobile context must be understood by the student in order to use it as a tool for scientific education, that is, it requires the user to make a deliberate effort to understand the information that is encoded.

Thus, the digital representation of a territory offers information in various levels [28]:

- It is an informative digital document with added value. Indeed, it lets the student solve spatial tasks by showing environmental information in a territorial context.
- It is a complex structure of knowledge which permits the digital disclosure of its contents. Students can even alter data (add ideas, change information, modify the actual situation of elements, define contexts, etc.) both synchronously and asynchronously by means of a that represents these data as the environment of a location.
- Finally, it is a symbolic representation that needs to be decoded, because it makes use of a mathematical-geometric language (coordinate system, lines, points, polygons, areas).

In this way, an MPN system is actually a cross-content tool for STEM. This system makes it possible to interrelate different kinds of contents shown in the digital representation of regional content, and may well become the basis of complex implementations in mobile applications.

3.3 Mobile learning and ubiquitous learning in a mobile implementation

These technological elements converge in a devel-

opment that implements both u-learning and m-learning, thus establishing an educational process that aims to acquire knowledge from a real scenario, which in this case consists of selected areas with existing natural elements. This context would provide a way to more practical, meaningful and relevant learning. Further, it serves as a tool when the user tries to understand how to solve problems, thus enhancing the effects of the educational process in comparison with other traditional teaching methods [29, 30]. Learning becomes a process based on an existing and concrete situational context (Santiago de Chile and its natural elements). There is no longer a feeling of traditional and abstract learning, but rather the comprehension of a particular context through the use of practical technological tools with very human (portable that is) dimensions [31]. Mobile devices have become ubiquitous in the last decade, and thus learning activities can be carried out anywhere and in almost any context. This has led to new forms of technological structures such as Mobile Personal Learning Environment (mPLE), thus creating personalized learning processes that are offer a unique u-learning context [32].

4. Methodology

We propose the following quantitative general methodology, divided into 4 phases:

(1) Spatial delimitation of the study area and then obtaining relevant information on the environment and territory of the city of Santiago de Chile.
(2) Creation of the environmental thematic content to be shown, taking into account that the scope of this knowledge is its representation on a mobile device.
(3) Implementation of the architecture of the software, creating AR and MPN modules in a context of mobility designed for tablets (the actual app).
(4) Empirical, real world study of the AR-MPN application in real educational contexts.

The early stages of research require solving the usual computer-related problems, as well as creating both the digital contents and their programming-adapted version. This involves several stages of development: data capture, processing, analysis, interpretation and finally dissemination or publication by interactive visualization [32, 33]. The empirical dimension of research necessitates a quasi-experimental design [34–36], including the development of an instrument related to data collection both pre-test and post-test, in order to be able to make use of the data generated by the students who participate in the use of the application. The dependent variable -level of learning-is measured before and after performing the educational intervention in order to measure changes in levels of learning (before and after students use the tool), thus measuring degrees of differences and similarities.

4.1 Spatial delimitation of the study area and obtaining information on environment and territory of the city of Santiago de Chile.

Santiago de Chile has natural boundaries defined by the upper section of the Maipo river, hence they have been used as limits to the contents of our study area. Within this area, elements have been geo-referenced. Three broad dimensions are taken into account in the instrument under development, hence three digital measurements have been used for its implementation:

(1) General ID. This is the element's location, and the description that will be offered for this item: name, type, geometry and magnitude. Geometry includes several kinds of information: points, lines and polygons. Magnitude, in turn, includes area, length and perimeter when applicable.
(2) Scientific background of the element. This is a description of the natural environment, natural features and additional information.
(3) Educational dimension of the datum. This includes educational elements and features that are derived from natural elements in the territorial scenery.

Thus, we have defined 27 thematic layers in an area covering approximately 2312,2 km^2 (Fig. 2).

This set of spatial data has been produced by means of integrated multi-criteria evaluation techniques —MCE—. This is a method wherein various features of the territory are synthesized, thus allowing a weighted display of all analysed elements. Further, elements are chosen depending on their suitability in terms of the objectives of our research [37–39]. We address a number of variables of the territorial dimension, from the perspective of their usage for developing an m-learning/u-learning tool [22, 40–42]. This thematic information is the presented in the MPN-AR application we applied as a tool to measure the educational experience.

4.2 Creating environmental thematic content to deploy, taking into account the scope for mobile representation

A database of urban and purely geographic data is essential for the visualization of information on a mobile device. The database must take two things into account: firstly, deployment is to be done on a Table, and secondly, it must contain the elements previously selected as POIs within the territory. Data structures and file sizes will determine deploy-

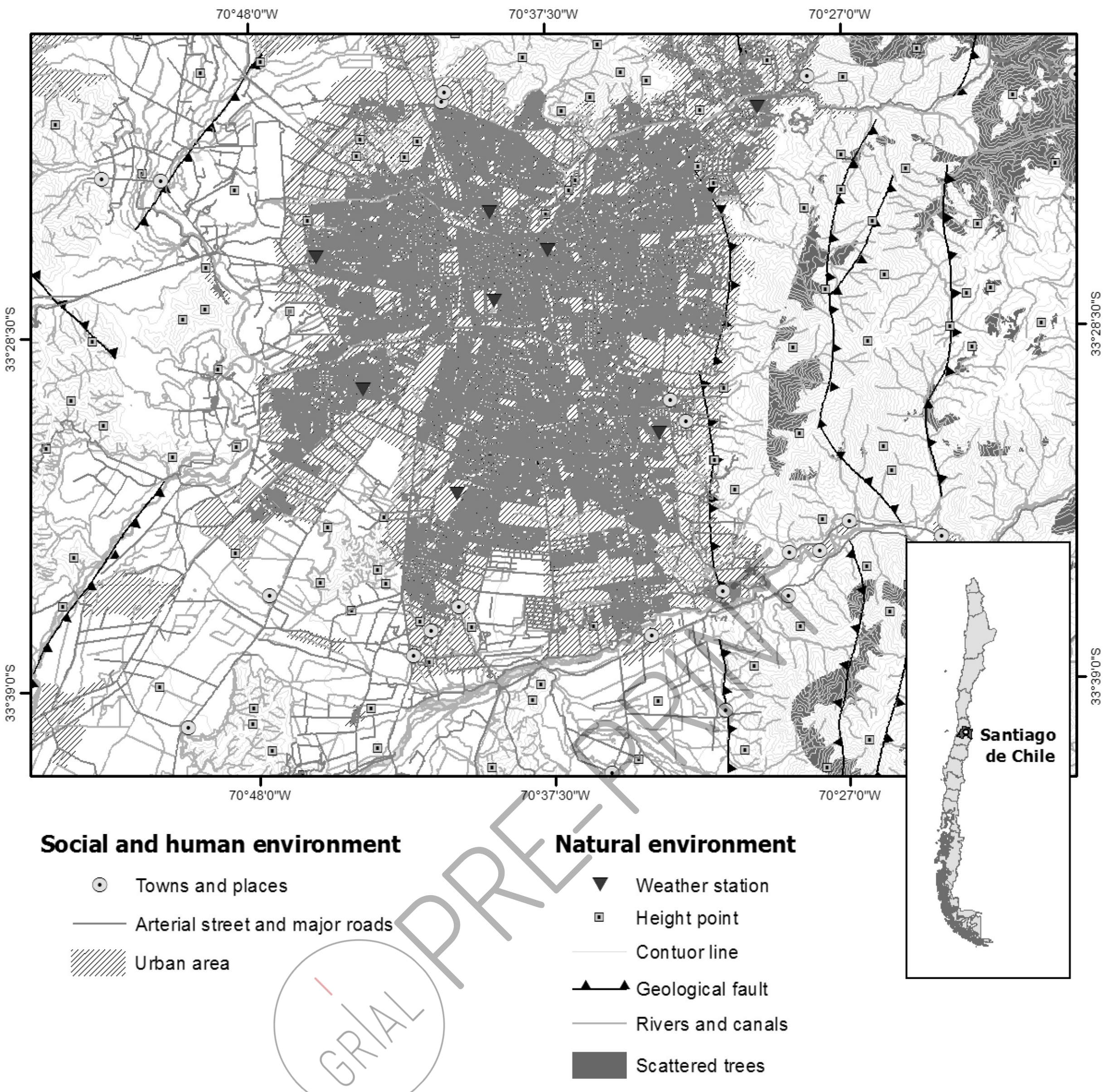

Fig. 2. City of Santiago. Study area and environmental elements.

ment and consultation times on the mobile system, and these are aspects that must be considered carefully from a usability point of view. The construction and population of the database required two main steps:

- *Review of available data on our territory:* a number of databases exists that contain territorial information about the elements present in our study zone. They have various characteristics as concerns their structure, design and access. Databases belonging to public and government agencies make use their own standards for the characterization of spatial information. This information must be selected and transformed in order to use it for the implementation of a system based on mobile technology (Table 1).
- *Definition of a database to be used as a standard for the NMP-AR application*: A definition was created for the implementation of the database. This definition is based on the essential items for the display of information. Basically, the database (including all graphical elements) consists of 27 items organized in 3 tables. Each table contains quantitative attributes plus two additional items with a description of the items displayed (Table 2).

The identifier and the coordinate of each element are used as indicators (token) in order to link the elements stored in different tables. Spatial references are converted to the system of reference coordinates of the Tablet. The size of the dataset created for each item must not exceed 3 kilobytes,

Table 1. Variables used in the MCE assessment for the selection of the study area

Objective	Criterium	Geometry	Description of the criteria and their function (fuzzy)
Background of humanized environment	Human settlements	Polygon	Boolean data coverage: Presence or absence of information.
	Streets and roads	Lines	Standardization of data according to type of road.
	Land and plots	Polygons	Boolean data coverage: Presence or absence of information.
Natural environment	Elevations	Points (Height point) Lines (Contour line) Polygons (slope)	Boolean data coverage: Presence or absence of information.
	Hydrography	Lines (rivers and canals) Polygons (water's body)	Boolean data coverage: Presence or absence of information.
	Weather stations	Points	Coverage of data elements on temperature, rainfall and wind.
	Photo documentation related	Raster	Boolean data coverage: Presence or absence of information.
	Special natural elements (geology, vegetation, etc.)	Points Lines Polygons	Boolean data coverage: Presence or absence of information.

Table 2. Data base definition

Table	Items
General description	ID, Item name, location, date data, geometric structure
Background of humanized environment	Name city, town area, number of inhabitants, road type, length of the street, Id property, area, type of use of the property
Natural environment	Altitude, length of the altitude, magnitude of the slope, type of hydrography, hydrography length, body water volume, weather station name, temperature data, rainfall data, wind data, photo, special element name , spatial extent.

and is stored in a CSV file that has been optimized for interoperability (without pictures and additional information). The tables were created originally by means of an open-source tool, and then exported in order to be used within the application. This simplified the creation process, since the initial order of columns was not known beforehand. Indeed, it was found necessary to reorder, add and join columns. Final results, after detailed inspection, were then exported into CSV. Detailed validation of all fields avoided many errors further down.

4.3 Implementation of the software architecture, creating modules AR and MPN in a context of mobility generated for tablets (Application)

This is the actual implementation stage of the MSN-AR application, which is necessarily intended to work on devices that belong in a portable and mobile ecosystem (tablets[1]). The app is based on several frameworks for spatial visualization and geo-referencing: Mapkit and Location Manager[2] as well as HDAugmentedReality[3] for the deployment resources in AR [44, 45]. The selected operating system is iOS. The contents of the territorial elements are the datasets on the city of Santiago de Chile created in the previous stage (Fig. 3).

Thus, the MSN-AR application was implemented according to the territorial extension defined in

[1] The hardware selected for this experience is Apple's iPad tablet with screens between 7.9″ and 9.7″. iOS software has all the requirements for the implementation of AR software and MPN.

[2] http://developer.apple.com/library/ios/documentation/Core Location/Reference/CLLocationManager_Class/index.html (accessed may 14, 2015).

[3] Software developed by Huis [43].

Fig. 3 Visualization of environmental data on the study area in a mobile environment (Tablet).

each study area and to the characteristics of the environmental information used, considering the factors obtained in the spatial analysis of the previous phase. This allows the interaction with other elements within the previously defined boundary which are necessary for the development of STEM educational objectives. By means of this structure, we generate a proposed navigation experience that guides the user through the educational process about environmental issues in the city. Thus, the application implements several services:

- A general view of the proposed territorial elements displayed on a portable digital.
- An automatic adaptation of the territorial vision based on the location of the device.
- The possibility of generating different scales of spatial representation as the user requires.
- The possibility of viewing and querying other environmental phenomena represented.

The interface of the mobile application displays the geolocation information of the defined environmental data, and the device location (by means of Core Location). The mapping information is obtained by means of the map server implemented in Apple Maps (by means of Mapkit) which is complemented by our territorial environmental information on the chosen city, previously selected and analysed for educational purposes.

4.4 Empirical study of AR-MPN application in real educational contexts

The main instrument for data collection is the software created and implemented on tablets for users and/or students. Invisible to the user, measurements are made whenever the mobile device requires data:

- Unseen, the application registers any activity related to data inquiries performed by the subjects. This includes data transfer, remote connectivity, query of provided data and any navigation that may take place (Fig. 4).
- Plus, direct measurements are produced by means of a test applied to students in order to obtain

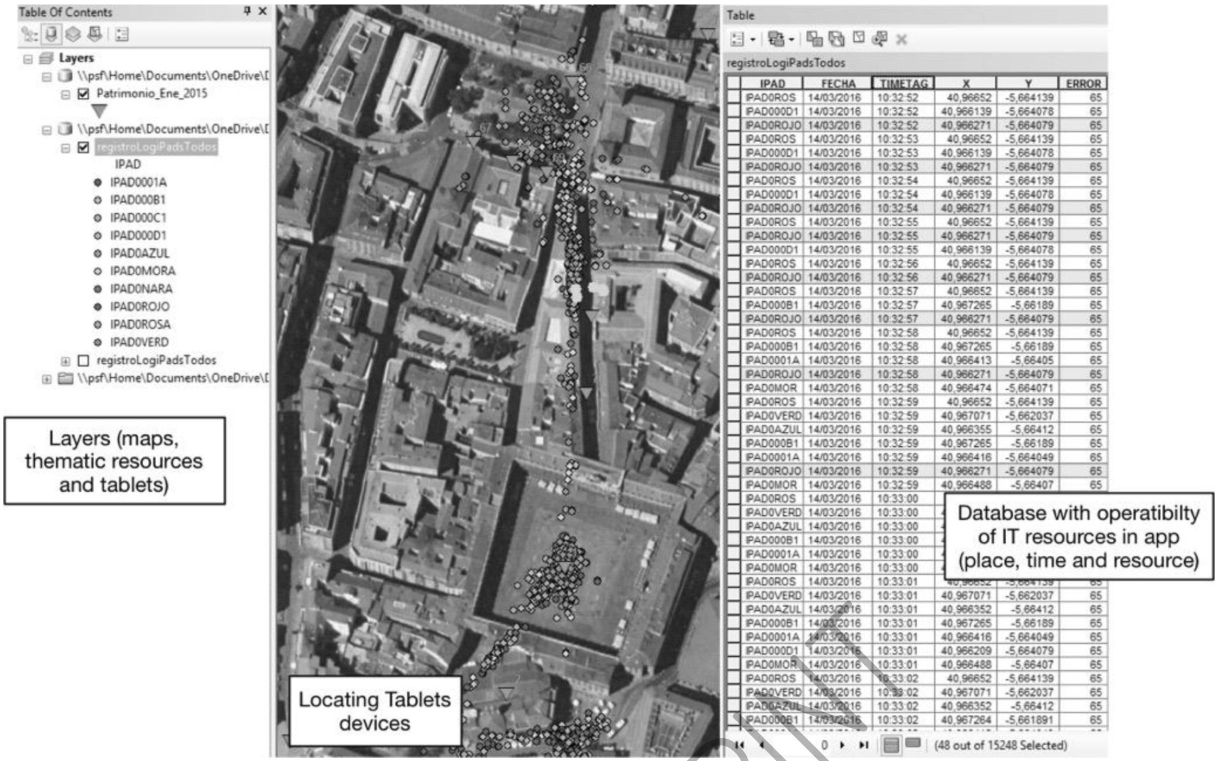

Fig. 4. Analysis of the data obtained with the mobile device.

data on the usability, perception and learning process (effectiveness and significance).

The instrument is built ad-hoc for both levels. It is intended for empirical testing with the respective evaluation of experts and relevant research sources. Further it is built to be used a real educational context: students, plans and programs including the concepts discussed in the mobile application and present in the teaching of STEM. The methodology of case studies is be used to understand the context and meaning of the educational experience with the software, using in-depth interviews with relevant participants. Formal documentation is produced and we use of contents of other related sources: social networks and virtual forums are implemented to complement the process proposed. Empirical testing is set within a quasi-experimental context in which the dependent variable—level learning—is measured before (pre-test) and subsequently (post-test) performing the educational intervention—treatment—with tablets. The dependent variable or the level of learning earned by participating subjects was measured with an objective test that measured the difference in the level achieved in the environmental learning content before and after the implementation of digital resources proposed. The knowledge competence know corresponds to obtaining a body of knowledge which may be general or specific [46–48] and it is measured means of a multiple-choice test, validated statistically and by content. It consists of 25 items with 4 response options. Thematically, the contents of the test are divided into three specific areas:

A. *Environmental-territorial context:* It tries to show the relationship between the land and the elements, taking into account the sense of space as an element that influences the social and cultural aspects, showing its various elements, features and magnitude. This relates to the following areas, allowing the contextualization of the elements and phenomena shown with educational purposes within the field of science.
B. *Mathematical and technological elements:* from this area, we try to achieve a comprehension of the methodological and quantitative elements that one needs to know and also to understand the current and future dynamics of natural systems. It also displays the richness and environmental complexity present in the various layers of the natural structure of the study areas, allowing the user to understand both the element involved, and also its magnitude.
C. *Location and spatiality:* from the local environment in each area, we try to achieve a query-based learning and a visual-spatial understanding through the digital representations of the territory. It is also important to perceive the

contrast of territorial information through existing relationships and the development of spatial reasoning skills [49, 50].

Each of these contents also measured three levels of basic skills of the students. These are [53–55]:

A. *Knowledge Process:* It is the most basic or general level of learning, where one must recover, remember or recognize the contents found in the memory of the students after using the mobile application in an educational context of u-learning and m-learning.
B. *Process Comprehension:* This involves the construction of the meanings of the elements and processes of the natural environmental in the learning experience. Digital activities are configured with territorial representation (maps) and models of AR by explaining and characterizing these data.
C. *Application Process:* This is an attempt to determine the relationships established between the elements and processes, where contents are divided into simpler units. The digital activities employed are maps and models of AR, and this is done taking into account each environmental element and natural process found in the digital representation, regarding the features present in spatial reality (surroundings, dimensions, localization).

Classical Test Theory [51, 52] has been taken as the starting point for a number of statistical techniques that have been applied to the results of the test, both exploratory and psychometric (descriptive, correlational, inferential and multivariate). This is to ensure the validity of the instrument and of the experience as such. Once the selected information has been obtained, we proceed to the processing of data collected through the software for the development of representative spatial models [21, 40]. Values produce by the instrument are entered and coded for statistical analysis. The results will be interpreted and analysed in the context of research, establishing educational dimensions, learning characteristics, patterns and relationships usability of information structure developed in an environment of u-learning/m-learning [30, 53, 54].

From the qualitative point of view, we will conduct in-depth interviews on some subjects who participate in the experience, in order to understand the context and meaning of the educational experience with the mobile application. These interviews contain a set of questions that are set in 4 areas of consultations: (1) socio-demographic information; (2) experience with the technology; (3) educational and personal use of ICT; and (4) opinion and perception about the experience performed with the mobile application. These fields constitute a system of categories for analysis, thus generating a coding around the general concept under consideration. Thus, qualitative analysis is structured as follows (Fig. 5).

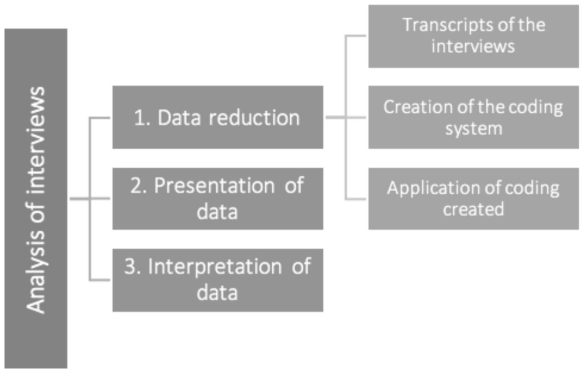

Fig. 5. Structure for the analysis of the interviews

5. Practical aspects and results

We chose Xcode as IDE, with a view to using both Objective-C and Swift. Of course, these languages make heavy use of various frameworks for the generation of software in the iOS mobile iOS [44, 45, 55–56]. Thus, the MSN-AR application was implemented according to the territorial extension defined in the study area and the characteristics of environmental information used, considering the factors obtained in the phase of spatial analysis, interaction with other elements of environmental system within the predefined boundary and educational objectives pursued in the context of the teaching of STEM. With this, the device offers a proposal navigation to guide the student in the educational process about environmental issues in Santiago de Chile. The application interface displays geolocation data of the defined by environments systems, as well as the location of the device (by means of calls to the Core Location framework). The mapping information is obtained from the map server implemented in Apple Maps (Mapkit framework) which is complemented by the information of the natural systems of the city previously selected and analysed for the raised educational purposes. Complementarily, the AR framework presents the resources created for this platform, and based on the location data and on previously defined points of interest. These contents correspond to the 3D models, audio, text and video of each natural item (Fig. 6).

From an educational point of view, the expected result is the construction of adaptive software with a modular structure for mobile devices. It will make good use of navigation and virtual interaction,

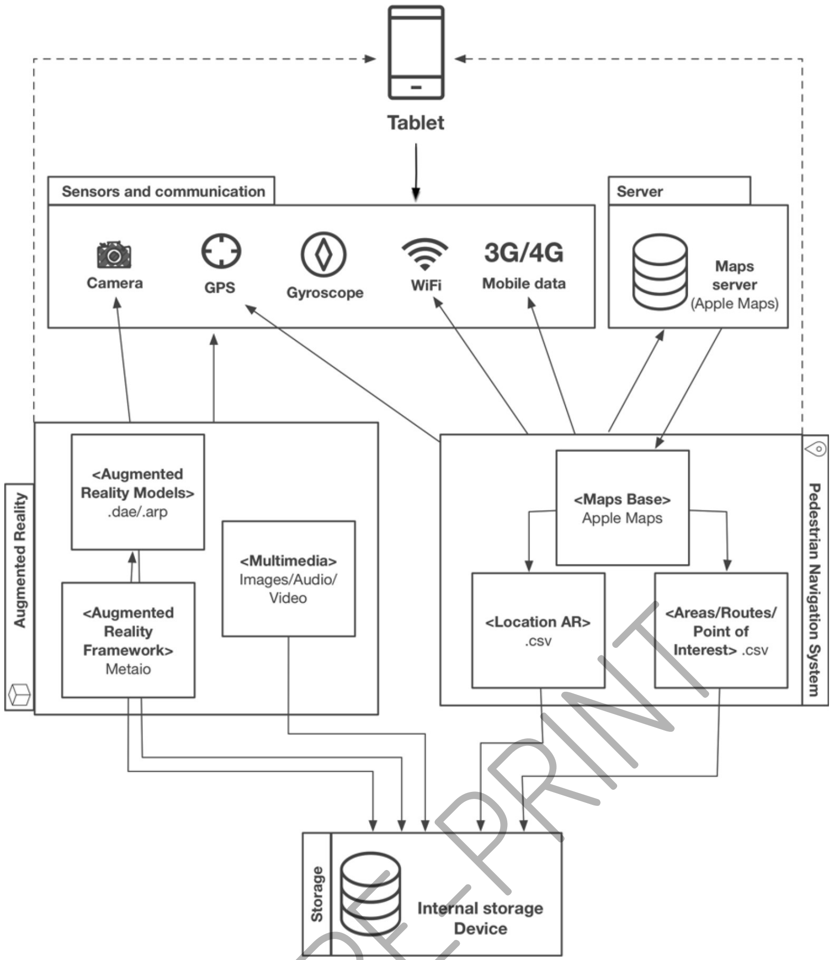

Fig. 6. Diagram of the mobile application. The MPN, AR system and the stored information are shown as parts of the whole.

taking into account educational and thematic reference aspects (teaching of STEM). The improvement of all system components will ease and optimize its digital construction, thus benefiting 4 main areas:

- Developing optimizations related to the advances in requirements needed as an instrument intended for an informal or formal educational context.
- Functionality and educational effectiveness of AR and digital models generated within a framework of resources for education in STEM.
- Understanding digital spatial learning (mapping-location) by means of an assisted mobile system.
- Enhancing the perception of territorial and environmental information by means of the mobility and portability offered by tablets and devices applied in training.

From point of view of education, this research aims to establish the differences between existing educational processes, establishing their efficiency in relation to the contents of the environmental elements shown in a mobile application. Thus, for activities related to m-learning/u-learning, we have assigned an independent variable to the mobile application created with resources with AR and location. This variable is manipulated to observe its effect on the dependent variable or the level of learning of the participating subjects. The control group will be given a similar treatment concerning content, but with traditional teaching methods. For both groups of students, the dependent variable is evaluated in an objective test instrument that measures the difference in level reached in STEM learning content before and after implementation of the proposed contents about environment [48, 49].

The information obtained from interviews applied to students, is used as a framework for obtaining data on subjective elements about the subjects that participate in this study and on their personal experience with the mobile application. This information cannot be obtained by traditional forms of quantitative methodology. The expected result is the exchange of information, with the creation of communication and creating meaning to the context of m-learning and u-learning. From this educational dimension, it would be possible to argue that the developed tool (application MPN-AR) has a greater effectiveness in the field of

education, compared to similar standard methodologies and tools: books, maps and direct teaching. The tool has been used within the context of u-learning/m-learning, establishing that it is a suitable method for acquiring spatial and patrimonial knowledge within an environment, based on the portability of mobile devices such as tablets.

6. Discussion

Resources in AR and NPN in a context of mobility are a promising technology that allows students to face learning processes in new environments, supported by the possibilities offered by mobile devices like tablets. In this way, the use and generation of an application in the context of MPN-AR-themed regional natural systems is one of the many ways to present content in u-learning/m-learning, which gives this form of teaching high flexibility and potential. In this sense, the structure implemented in a context in u-learning/m-learning has had a greater impact with the development of mobile technologies, as far as the dissemination of information and access to data are concerned. Moreover, results point to the benefits of the personalization of content and processes in areas such as the environment and territory, thus proposing an improvement in the learning process, by contextualizing local elements.

7. Conclusions

The experiences and research carried out by means of these tools arise from the preparation of digital resources and from the implementation of software base on those resources, and following strategies for the presentation of contents. From the empirical testing that has been developed, one can see that the implementation of this technology allows for quick and convenient access to specific content and greater personalization in the learning process. Thus, the strengths of this study reside in the possible replication of the contents, territorial areas of study or educational levels depending on the needs of each learning situation. The flexibility of the software allows to adapt the content and functionality for each thematic content, and on the other hand digital resources (maps and AR) provide new tools for their educational application aimed at STEM. The empirical methodology with its quasi-experimental design will make it possible to objectively evaluate the results of learning experiences carried out with these tools.

Finally, the AR-MPN mobile application developed can be a solution for creating new ways of learning with environmental contents, which opens the options to explore new user-device interactions, other territorial scenarios or different content structures, characteristics and forms of expression that can be addressed from these tools and used in educational contexts.

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Jorge Joo Nagata is a PhD candidate of the Program on Education in the Knowledge Society University of Salamanca scope. Grial group, University of Salamanca and has a scholarship of program MECESUP UMC0803 "Improving teaching and learning through the incorporation of methodological strategies ICT in order to strengthen the curriculum in initial teacher training in the Metropolitan University of Educational Sciences (FID-UMCE, Chile)". His research interests are technologies applied to the study of the territory, GIS and geomatics tools in educational contexts. Currently working on his doctoral thesis on Augmented Reality and Mobile Navigation Systems applied to educational contexts.

José Rafael García-Bermejo Giner has a PhD in Physics (1989, University of Salamanca, Spain) and a certification Apple ACTC T3 (Snow 100, Snow 101, Snow 201). Currently developing his academic activity as Professor, Department of Informatics and Automation of the University of Salamanca in the area of Languages and Systems. He has spent periods as professor and researcher at different universities in Germany and Finland. His main research interests include structured programming, object oriented programming, Human-Machine interfaces, user interfaces, mobile devices, and systems management. He is author and technical translator of many books.

Fernando Martínez Abad is Assistant Professor in the Department of Research Methods and Diagnosis in Education of the University of Salamanca. Doctor of Science in Education (2013, University of Salamanca, Spain), he has participated as a researcher in national and international research projects. Co-author in national and international publications related to the evaluation and development of basic skills in education.