

Ubiquitous Computing in Children Education: Framework for Georeferenced Multisensory Information

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Abstract: The traditional teaching methods, although very important, fail to explore the potential of interactive group collaboration and multisensory communication. Research has consistently shown that interactive and collaborative group learning, compared to traditional learning, produce greater learning and individual achievement. Learning can be fun, but for that, students need to be on scene and not just spectators.

This paper presents a framework that handles the creation of georeferenced multisensory information, placing the content creation control in the hands of junior explorers – the children. Mobile sensors spread across the exploring area, provide georeferenced environment information such as air temperature and humidity.

Using multimedia (video, image, sound and text) teachers can bring the outside world into their classroom and share it with other classrooms across the globe. Having schools' budgets in mind, when using this framework only content exploration – using Google Earth – requires Internet connection, that is, content creation can be made anywhere without any costs.

Keywords: children, multisensory learning, mobile sensors, georeferenced information

1 - INTRODUCTION

The *traditional teaching* paradigm has its foundations on a teacher-centered model, where students are mainly information receivers. This model is focused on knowledge and comprehension. The teacher has a dominating position, controlling the information/communication flow – not only between the teacher and the students but also between the students and between the students and the environment. The *interactive-collaborative* model changes the way that teacher and students relate. Students become part of the learning process and are encouraged to interact with each other. This model is learning-centered and focused on exploration, evaluation, synthesis and application (Montgomery, 2007).

Research in this field clearly shows that *interactive-collaborative* group learning, compared to *traditional teaching*, not only produces greater learning achievement but also increases student involvement, enhances critical thinking, improves communication and promotes responsibility for learning (Ulrich & Glendon, 2005).

Upon these facts, programs like Carnegie Learning (Carnegie-Mellon University), Wise (Berkeley University) are being developed, improved and implemented. Although these programs have proven that they can improve learning achievement in schools, they are thought for class subjects learning not for exploring the surrounding environment nor multisensory information.

1.1- Carnegie Learning

In this program the teacher's role is different from the traditional one. As in traditional learning, the teacher starts presenting the subject and asks for student's attention. After that, with computer assisted interaction (CAI), each student practices and tests his/her skills – exercises may cover only one or multiple skills. Until a skill is mastered, additional problems that train that particular skill (or set of skills) are presented to the student. He is allowed to advance to the next level only when all skills are mastered. Along the process, several hints are given (if necessary) indicating the path to success.

In this approach each student can learn at his own pace. Moreover, the bars that identify skill mastering level allow the teacher to identify, individually, which subject needs extra help. Students are encouraged to communicate and help each other, transforming an otherwise competitive relation in a cooperative/collaborative one. They learn by doing: trying, failing and succeeding.

1.2- WISE - Web-based Inquiry Science Environment

This program is thought for inquiry (as the name suggests), having activities and steps as its main structure. Information about a particular subject is presented and several hints are shown, guiding student's inquiry and probing connections. While reading, the student is encouraged to take notes – forcing him to think about what he has read. Also, some oriented questions make him think about aspects that are considered relevant.

Some questions go a step further and ask for predictions: the student has to analyze, make connections and formulate his hypothesis. After that, simulation starts running and the student can see how things evolve, either as he predicted or in an unexpected way. Each time the student hypothesis is wrong he goes back and analyses what he have missed and what explains

that result. This way, as with Carnegie Learning, students can evolve at different paces and are generally suggested working in pairs (collaborative), exchanging ideas and sharing knowledge.

2- THE IMPORTANCE OF GEOREFERENCED MULTISENSORY INFORMATION

We explore the world in a multisensory way, i.e., constantly receiving multisensory stimulation. Therefore it is natural to expect that our brain has evolved to develop, learn and operate optimally in multisensory environments. Human memory research shows that multisensory experiences can enhance perceptions and ease the memory retrieval process, resulting in superior recognition of objects compared to unisensory exposure, even when only unisensory information is available for accessing such memories (Shams & Seitz, 2008; Murray, Foxe & Wylie, 2005).

Although smell, taste and touch, in many cases, are difficult to reproduce in classrooms, these senses can be stimulated through additional information such as textual information.

If the same idea is expressed using multiple media to be received by multiple senses, there is a higher chance that students will retain that information (Gardner, 1983). But more than that, each sense gives a different perspective and together provide a richer analysis. Sensors do what our senses are not able to – provide a measurement (quantify) and analyze additional environmental information.

Virtual globes and location-based services can situate everyday activities and multisensory activities in a spatial context. These tools, especially Google Earth (GE) (Google, 2009), have the additional advantage of creating engagement and enthusiasm (Norman, 2006), particularly in education (Silva et al., 2009).

3- RELATED WORK

Schoolsenses@Internet (2008), *Senses@Clipart* (Silva, Hipólito & Gouveia, 2003), *Savannah* (Bristol et al., 2004), *LillyPad* (Lillypad, 2008; Rogers & Price, 2008) and *ENLACE* (Verdejo et al, 2008) are just a few examples of many more existing projects that can be referred as related

work. Ubiquitous computing and georeferenced information are present in all these projects (see Table 1). Multisensory information is explicitly addressed by the first three projects.

Achieving a better end result is only possible when the weaknesses and strengths, of similar solutions, are clearly identified. What is well done needs to be part of the new solution – if possible, improved – and what is not so well needs to be changed or redone. In this section a similar solution is presented and its weaknesses and their strengths are examined.

SchoolSenses@Internet was a pioneer project and the basis for the present project. Its main aim was to improve elementary education, while the platform that supported the creation of georeferenced multisensory messages had an instrumental role.

The platform was built considering that a connection to the mobile provider would always be available; therefore Multimedia Messaging Service (MMS) was a viable option. Using this service to send the content created, any mobile device with GPS functionality and capable of sending MMS to the mobile provider can be used – wide mobile device support. Also, all mobile devices that are capable of sending MMS provide an integrated environment for taking photos and recording sound while creating MMS – no additional software installation is required. Another benefit is that the server only needs Internet connection for content retrieval, avoiding the need to be on the field – activities only require to carry mobile devices.

TABLE 1 - Brief description of related projects

<i>Senses@Clipart</i>	“Senses@Clipart is a library of images, non-spoken sounds and sensory textual descriptions that was developed to be integrated in an environmental monitoring collaborative website.” (Silva, Hipólito & Gouveia, 2003)
<i>SchoolSenses@Internet</i>	“The SchoolSenses@Internet project (...) aims at improving the quality of primary school children learning through the use of information and communication technologies (ICT). [This] project [also] aims to allow children to create georeferenced multisensory geographic messages using not only Multimedia Messaging System (MMS) messages but also some of the project Website tools, such as a multisensory message editor and

	modeling and simulation tools.” (Schoolsenses@Internet, 2008)
<i>Savannah</i>	“The Savannah project is an ambitious combination of games technology, mobile computing and innovative approaches to teaching and learning. Children are given GPS-linked PDAs through which they ‘see’, ‘hear’ and ‘smell’ the world of the savannah as they navigate the real space outdoors as a pride of lions.” (Bristol et al, 2004)
<i>LillyPad</i>	“The LillyPad project is investigating how mo-bile collaborative technologies can be designed to support and augment integrated inquiry processes both indoors and outdoors.” (Lillypad, 2007)
<i>ENLACE</i>	This project developed an educational network that enables the mobile collection and recording of data, including GPS coordinates. To accomplish this task, children are invited to fill a CARD using a PDA. The recorded data can be used to develop analytic reflection in school and (re)used in different contexts and with diverse tools. (Verdejo et al, 2008)

Having a connection to the mobile provider as a requirement implies that the activities must take place in areas that have network coverage. Moreover, each message/packet sent has a cost, that is, activities will always have an additional cost, limiting communications. The communication between mobile devices and the server is unidirectional: content is sent in a MMS but no information is received. Also, multisensory information is limited to MMS constraints (image resolution limit, sound quality limit, video resolution limit and text limit).

Content creation interface may vary depending on mobile device used (even in devices from the same manufacturer). The end user needs to know how to perform the same task on each device he operates.

4- PROBLEM

The project presented in this paper is based on activities that give multisensory information a context, defining where, when and why multisensory approaches are developed.

In each activity, the students explore the environment and are expected to create multimedia georeferenced content (image, video, sound and text) that describes it. Vision and audition are easily reproduced using the current technology, but the other senses are not. Text is provided to fill this gap, allowing the introduction of additional information that otherwise would not be available using these media types only. Also, automatically, the values provided by the sensors are made available to the students. Once all the information is collected it must be transformed in a way that it can be easily observed.

Activities can take place where there is no Internet connectivity, like in the mountains. Moreover, it is required that the system can be used in a field trip – every component must be mobile and carriable. Since there is no place to plug-in each component in the mountains, the system must work for, at least, 120 minutes – accounting for setup time, class duration¹ and a considerable safety margin.

5- PROPOSED MODEL

The proposed model is a solution designed to be used in elementary schools. To minimize the cost of each activity, this solution only requires Internet connection for observation: the cost is zero if the school already has a flat rate Internet access. Moreover, depending on whether the activities take place on school campus or not (like field trips), the network used for device intercommunication can be simplified.

Requirements

This system requires at least one sensor, one netbook (or a mobile device with similar characteristics) and one mobile phone for content creation. All devices must have a GPS receiver for data georeferentiation and a WLAN module for Wi-Fi communication. For increased battery life, several netbooks can be used, each running one or more services. Simultaneous content creation requires additional mobile phones.

For content observation it is required that Flash and Shockwave plugins and GE are installed. Please note that Flash plugin and Shockwave plugin must be installed on the browser used by GE. For offline exploration, due to the HTTP server implementation, support for Ruby code execution is required.

Network

The network has two operating modes – Ad-hoc and infrastructured. Both modes use a DHCP server to automatically configure IP addresses. An Ad-hoc network is created only when no infrastructured network is available.

The infrastructured network operates in a way, similar to the one used in *SchoolSenses@Internet*, but without having its main disadvantages – additional costs and unidirectional communication. As long as the server is in the infrastructure network, only mobile devices and sensors need to be carried around.

The Ad-hoc network provides the necessary flexibility for field trips or for adoption by schools without infrastructure network. Being a multi-hop network is more likely to suffer from the hidden terminal problem (since any node can communicate with any neighbor node) (Yoo & Kim, 2005), leading to lower performance.

Visualization in both modes requires Internet connection. If school network is used, it is very likely that it will also provide Internet access. On the other hand, using an Ad-hoc network, the other nodes will only have Internet connection if an Internet gateway is configured, that is, if one node has a connection to the Internet and shares it.

Platform

The platform, that supports the developed application, is server-centered. All nodes communicate, directly or indirectly, with the server node. Having all the information in one place does not require the network to be set for activity exporting to GE, otherwise all nodes would need to be present for exporting activity information.

¹ Classes in Portugal take no longer than 90 minutes.

To create modular and platform independent environment, with heterogeneous nodes in mind, each functionality (or set of functionalities) is provided as a service – Web Services.

The server node is the place where all information converges. This node collects all the georeferenced multisensory information, stores it and makes it available to other nodes. Since this is the center of information flow, the database must be stored on it.

The database – PostGIS – provides geographic functions crucial for data querying based on node location. Without this functionality, as collected data increases, it would not be feasible to query for nearest sensor information (time and spatial distance). Although not implemented in this project, several other functions could be provided, such as the distance between the mobile device and the nearest sensor or show hints depending on mobile device's current location.

Albeit introducing overhead, compared to solutions based on binary protocols, the creation of Web Services clearly distinguishes between interface and implementation. Furthermore, the use of Web Services provides programming language, platform and operating system independence: a Web Service running on Linux and written in Ruby can provide a service for a program written in C++ running on Windows. Since communication at lower level is made using sockets (no matter what protocol is used), running Web Services and clients on the same or on different machines works the same way, that is, Web Services can be deployed on separate machines – ideal for processing power increase (at the cost of adding more devices).

For Web Services implementation there were only two viable options: REST and SOAP. With the right tools it is easier to implement a Web Service using SOAP but there is more processing and network overhead and it is not clear whether an invocation has any side-effects. On the contrary, REST style, uses the HTTP methods – GET, PUT, POST and DELETE – clearly stating if the invocation has side effects, moreover, stating if the invocation is idem-potent. Since the server is not on a third party host, the four verbs are surely implemented. Because every resource is identified by the representation URI, the action specified by the verb and by the response

format, obtaining a different output format only requires response format change. A Web page, in REST, can be seen as a resource whose output format is XHTML.

The modular nature of Web Services allows the inclusion of new functionalities with no harm – all other Web Services work the same way, only clients that want to use the new functionality need to be changed. For this project, three Web Services were created – GPS, Sensor and Web Page. The GPS service receives, periodically, information about mobile device's location providing, at the end, the group's path for that activity. The sensor service receives georeferenced multisensory environment information, imperative for environment analysis. The Web page service provides an interface for content creation via mobile devices.

Sensors are spread across the exploring area, in order to obtain environmental information. The sensor may change its position, moreover, it can be always moving, because the data sent to the Web Service is georeferenced. Since different sensors, from different manufacturers can be used, all data is sent in the format specified by the Web Service, no matter what the input format was.

A Web-based application was created (instead of a local application) with the goal of having a uniform and easily upgradeable interface across different devices. Mobile devices that have support for GPS and WLAN will likely support browser installation or have a good browser built-in. Albeit, due to Web page access restrictions, taking photographs, recording sound and video, are not integrated in the Web page. Nevertheless, the solution was designed with future in mind, since major players are starting to support Web access to such devices: Nokia Web Runtime (WRT), Palm WebOS, Motorola WebUI, W3C Mobile Web Initiative (MWI) and at embryonic stage OMTP BOMDI. In the near future, it will be possible to integrate all media recording in the Web page, achieving the goal of having a uniform interface across heterogeneous devices.

This way, changing the interface is as simple as changing the Web page. Using AJAX, information about the environment is shown to the user, providing additional dynamically updated data that he can use for content creation. Also, because all devices are using the same page, conflicts from

using different versions will not arise. Moreover, only one Web site needs to be created albeit it is true that the style must adapt to screen size (that can vary), but local applications, even using Java, will have the same problem and will have to deal with platform specific implementations as well.

Computer Exploration

The multisensory information is exported per activity: for each activity a package is provided for offline exploration. Please note that unless satellite images are cached, an Internet connection will be required. Even requiring an Internet connection, since media files are local files, only GE satellite images are downloaded.

Based on all activity information collected, a KML file is generated and the content created by the children (image, video, sound and text) is included in the package. Due to different mobile device's encoding format, all media files (except images) are converted to mp3 (audio) and Flash video (video). Text is placed inside the KML file but the other media are made available as media files. Also, the audio and video players are included in the package.

In order to avoid GE limitations and Flash Security issues, a simple HTTP server is provided in the package – using HTTP requests none of the issues caused by local files access will arise. The HTTP server was built in this work using Ruby providing a platform independent solution².

6- PROOF OF CONCEPT

With the massive Magalhães netbook (a laptop for children based on the Intel Classmate PC) distribution, children in Portugal will have their own. They will likely use it at school and at home, so the exploration was designed with Magalhães small screen (1024x600) in mind. Also, the platform implementation was made to be run on this small netbook: children prefer to use their own computers.

Two activities were developed in one elementary school. In those activities, an HTC TyTN II mobile phone (which has an integrated

keyboard), two Magalhães netbooks and one PASCO PASport PS-2124A sensor (PASCO) for air temperature and humidity measurement were used. It was used the Ad-hoc network model to simulate a field trip and test system battery life and performance – if Ad-hoc mode meets the requirements, infrastructure mode will too.

Constraints

Due to hardware constraints, some adjustments were made to the proposed model. Since the sensor has no Wi-Fi capabilities it was connected to one of the netbooks (through USB) and, because PASCO uses a proprietary and closed protocol, the data was periodically collected from a file exported with DataStudio (PASCO software). To solve the lack of GPS, the sensor geoposition was synchronized with the mobile phone's. In practice, the sensors need to stay close to the mobile phone (ideally they were built-in), so a small approximation error arises only when the sensor feeds multiple mobile phones – not this case.

An application for HTC TyTN II was built because neither the device nor the browser used³ (Mobile, 2009) provide access to GPS location. This application is responsible for letting the server know where the mobile phone is (geoposition). Since the Web server does not have direct access to the user's geoposition, when the user logs in, the Web server sets the mobile phone's geolocation to be the user's.

Activities in School

The Web interface (Figure 1 and 2) was used in the two activities that took place in the elementary school.

Twenty five children participated in these activities, developed in a curricular context. Twelve children participated in the first activity and the other thirteen participated in the second one. Children worked in 7 groups of three and one group of four. They were asked to collaborate in the *Senses@School* game (Silva et al., 2009).

In this game they observed the georeferenced multisensory messages created by other school children, and they were invited to share multisensory

² As long there is a Ruby implementation for that platform.

³ Iris Mobile Browser v1.1.7

information about their schoolyard with other schools. In the first activity, children were invited to create messages with a photo, a sound and a video.

FIGURE 1 - Mobile Web interface – Horizontal layout

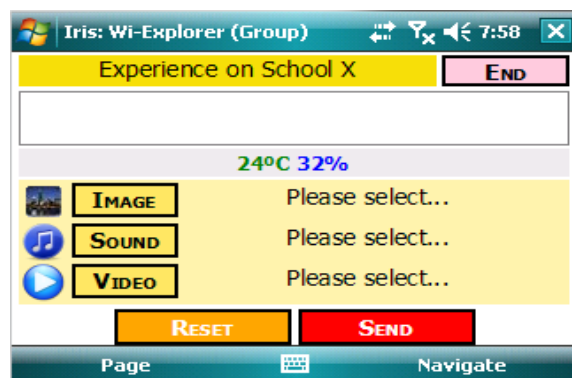
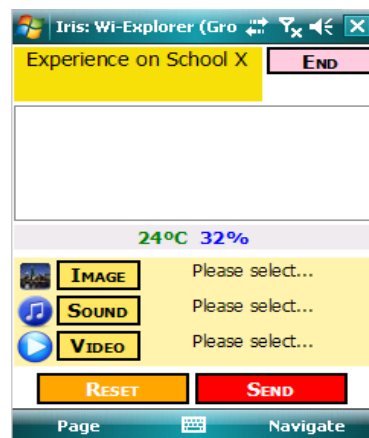


FIGURE 2 - Mobile Web interface – Vertical layout



Due to time constraints, only some of them submitted their creations using the Web interface. Having no information about children's preferred layout, both are provided. This activity was mainly focused on analyzing

children behavior and how suitable the mobile phone and the Web interface were. When these groups were asked about what they dislike, all of them answered: "Nothing". Learning can indeed be fun.

In the second activity, the twenty five children observed, in GE the messages created during the first activity. This time, the environmental information, acquired by PASCO sensors, was being updated (using AJAX) on the mobile phone screen (see Figure 1 and Figure 2). Using this information, one of the groups sent the following message: "When we are under the shade of trees, it gets cooler." Sensors quantify each environmental property providing important information for further exploration.

Google Earth Exploration

When children see their school, and the right place where they created the multisensory information, the all experience gets even more engaging. Each content created has its own placemark (see Figure 3) and when clicked the exhibition balloon shows up (see Figure 4). Figures 3 and 4 images were taken with screen resolution 800x600 in order to provide a fair comparison to Magalhães screen (same height).

FIGURE 3 - Google Earth – Content navigation

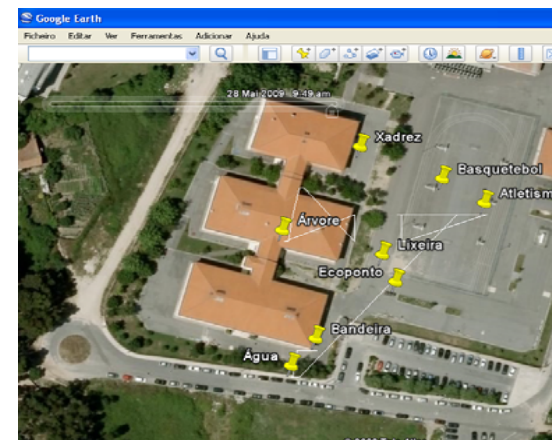
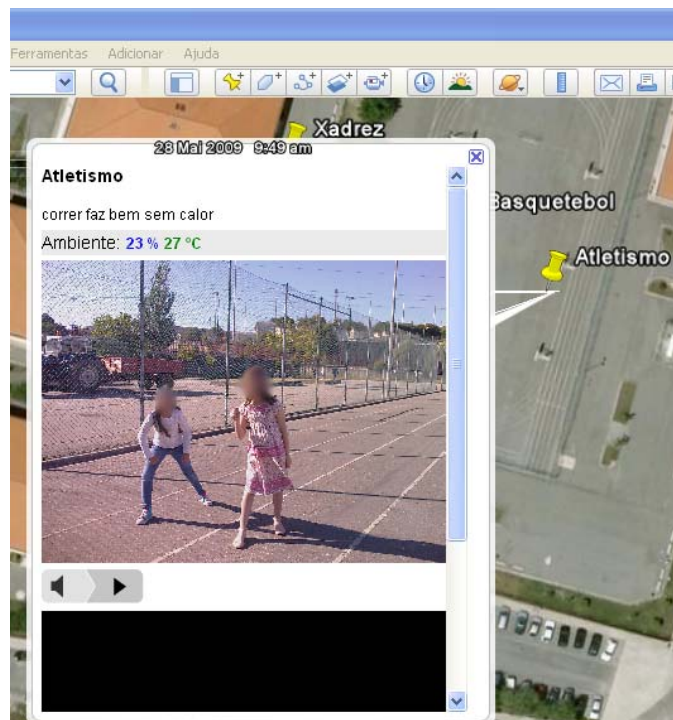


FIGURE 4 - Google Earth – Content exhibition
(text message translation: “Running is healthy when it is not hot”).



As can be seen in Figure 4, the balloon contains, in addition to the multimedia elements (text, image, sound and video), the environmental information: air humidity (23%) and temperature (27 °C). The white lines are the path of each group, obtained by periodically sending mobile phone's geoposition to the server.

7- CONCLUSIONS

The proposed solution works as expected, needing mainly, a GUI for managing more complex parts, such as network and activity management to be performed by teachers (not implemented due to time constraints).

HTC TyTN II mobile phone placed some difficulties in every media creation. The time needed to hold down the button for taking photos or recording video – same interface – was a problem. Sound recording lacks description on the buttons confusing many groups. When it is necessary to write text, children switch layout losing focus and requiring the control to be selected again – on file renaming and message writing. All these problems are easily overcome with practice.

Multimedia recording (image, sound and video) was not integrated into the Web interface, causing the need to identify the created files (through renaming). Some children were lost when there were multiple files to choose from and on directory navigation. This problem would no longer arise if multimedia recording was built-in into the Web interface.

The hardware constraints caused more development overhead having no significant influence on activities. Only environmental data update rate was affected since it was necessary to manually perform periodic data export. Even if this process could be automated, the best update rate, due to device limitations, would be about 30 seconds. In these activities the environment information was updated at request. Since PASCO did not provide a direct mechanism for sensor data retrieval, the simpler solution is to use sensors that provide such mechanism though it may impact the school budget.

GPS solution worked flawlessly but it has the following drawbacks: requires additional software installation, has additional battery consumption and creates the risk of a child accidentally closing the application. GPS locations obtained by GPS receivers may be subject to errors, mainly when working in close spaces or in indoor conditions.

The overall evaluation is very positive, nevertheless, there are two main problems – file selection and file removal. File selection dialog, requires the children to navigate to directories where media is found: images – Minhas Imagens, sound – Minhas Vozes and video – Meus Vídeos. Because of the restrictions imposed to local _les access by Web applications, there was no easy way to clear a file input that was previously selected – Web server cannot specify the input file. Children appreciated the vivid colors used in the GUI and easily identified how to select each media type.

The solution found for offline exploration works very well as long as two conditions are fulfilled: Ruby is installed and if there is more than one activity to explore, they are on the same folder. Ruby has support for all major operating system – MS Windows, Mac OS X and Linux – so only the installation process may eventually be a problem. Since the proposed solution uses an HTTP server it has to be bound to one port. The Web server, which generates the package (including KML), has to use a static port. When different activities are to be explored, they have to be in the same folder because only one server can bind to port 8080 (the one used by this solution). Otherwise only the files, which base path is the same as the HTTP server's path, will be found: all activities' KMLs have links relative to base path.

As new devices come out to the market with technologies that allow access to mobile phone's devices (camera, microphone and GPS receiver) an integrated environment could be built. Due to time constraints, an activity management area for teachers was not built, being a feature that is mandatory for future school adoption.

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Resumo: Os métodos tradicionais de ensino, embora bastante importantes, não são capazes de explorar o potencial da comunicação multissensorial, nem mesmo da interação e colaboração entre grupos. A investigação neste domínio tem demonstrado consistentemente que a aprendizagem colaborativa e interactiva, comparativamente com a aprendizagem tradicional, produz melhor aprendizagem e melhores resultados individuais. A aprendizagem pode ser divertida mas para isso os discentes precisam de ser parte integrante e não apenas espectadores.

Este artigo apresenta uma plataforma que possibilita a criação de informação multissensorial georreferenciada, colocando o controlo da criação de conteúdos nas mãos dos pequenos exploradores – as crianças. Sensores móveis, espalhados pela área de exploração, fornecem informação ambiente georreferenciada como temperatura e humidade do ar.

Os professores podem utilizar elementos multimédia (vídeo, imagem, som e texto) conseguindo trazer para a sua sala de aula o mundo exterior e partilhá-lo com outras salas de aula espalhadas pelo globo. Considerando os orçamentos das escolas, a ligação à Internet só é necessária quando a plataforma é usada para exploração de conteúdo – utilizando o Google Earth. Desta forma, a criação de conteúdos pode ser feita em qualquer lugar sem quaisquer custos.

Palavras-chave: crianças, aprendizagem multissensorial, sensores móveis, informação georreferenciada.

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