Innovative teaching/learning with geotechnologies in secondary education

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Abstract. The development of the use of Geographical Information Systems (GIS) for professional purposes and the success of virtual globes (VG) for personal uses leads to addressing the question of the integration of geotechnologies into secondary education. In this paper, we examine the changes in geography education linked to the increasing use of geotechnologies by the general public. The diversity of teacher practices can be linked to the powerful potential of these technologies for the access and the analysis of geographical and geological information. The characteristics of these tools suit pedagogies based on projects, problem-solving or collaborative work even if it has to be considered that a majority of teachers use them in more traditional ways. Furthermore, the paper underlines the importance of the integration of geotechnologies into the curriculum for the elaboration of the digital culture of the XXIst century citizen.

Keywords: Geotechnologies, virtual globes, Geographic Information Systems, innovation, teacher practices.

1. Introduction

In one of his books about the uses of technology for teaching, Larry Cuban [1] introduced a picture taken in a plane (fig. 1). The picture was published in 1928 by the New York Times. It shows a female teacher and young students during a geography course. The purpose of this picture of an “aerial lesson” permitted by the use of a plane – a very recent technology in 1928 - was probably to demonstrate that technologies had the power to enhance the learning process by allowing the students to have a better access to geographical information. With a closer look at the picture it is obvious that the use of this technology did not really change the way of geography teaching. The teacher is showing the globe of the earth and the students are not looking through the windows. This lesson looks traditional despite the use of recent and powerful technology.

This anecdote shows that the link between the uses of technology and changes in education is not obvious. The changes mostly result from the willingness of teachers. They depend also on the opportunity offered by technology. But technology is only a proposition that teachers can integrate – or not – into their practices.

Fig. 1. An aerial geography lesson

Starting with this point, this paper examines the changes for geography education linked to the increasing uses of geotechnologies by the general public. Therefore we address the following questions:

(a) In which way can these technologies be integrated into the geography curriculum for secondary education? What do the teachers do with geotechnologies?

(b) What are the effects of the uses of geotechnologies for educational purposes in terms of pedagogical setting or its relation to knowledge?

(c) What are the goals and the stakes of the integration of geotechnologies in the curriculum for secondary education?

2. The Development of Geotechnologies

Geotechnologies include both the data and the systems that can be used to deal with these data. The acquisition of data is through remote sensors that can be used to measure different physical and chemical parameters in the field and Global Positioning Systems (GPS) that allow to geolocalise these data. The professional systems that are used for the representation and the analysis of the data are named *Geographical Information Systems* (GIS). Much of these data is available on the Internet for free or at low cost and can be visualized by the general public. This visualization is possible with the use of *virtual globes*. *Virtual globes* permit an access to a tri-dimensional representation of the Earth. They allow the access, usually via the Internet, to different geographical digital data on economic, sociological, cultural or environmental topics [2]. They can be considered as virtual worlds that permit access to a huge quantity of geolocalized information.

The professional uses of geotechnologies are increasing [3]. Many sectors of activity need precise and localised information. It is the case for transports, construction, trading or military domains. It is also true for most other human activities. Therefore there is a need for a qualified workforce in the domain.

There is also an increasing personal use of geotechnologies. Nowadays, more and more cell phones include a GPS and virtual globes such as Google Earth encounter a great success. The success of virtual globes probably results from the fact that they allow access to a piece of information which is, on the one hand, of an individual and personal dimension and, on the other hand, of a global dimension. Therefore, it is possible to look at one's home or one's next holiday destination but also, to give only one example, to locate the villages that have been destroyed during the conflict in Darfour[1].

Another aspect which seems to be taken into account to explain the success of virtual globes is the fact that the frontier between the roles of provider and consumer of geographical information is not clear. Everybody can geolocalize a picture on Google Earth and share this picture with other people on the Web. The virtual globes are virtual worlds that belong to Web 2.0, a digital space which allows the mutual sharing of information. The content is partly user-generated and Turner [4] points out that we are witnessing the birth of *neogegraphy*. The value of the role of this *Volunteered Geographic Information* has been underlined as a potential significant source for geographers' understanding of the surface of the Earth [5].

Geotechnologies give access to a Digital Earth. This term, coined by Al Gore in 1998, is used to name a tridimensional model of worldwide geographical data.

As a consequence, the advent of geotechnologies has revived interest in cartography [6]. In the next paragraphs we examine the impact of this neogeography on geography/geology education.

3. The Success of Geotechnologies in Education

Different experimentations relate to the uses of Geographical Information Systems (GIS) for educational purposes (see for example [7-10]. Nevertheless, little attention has been paid to the pedagogical issues of the uses of geomatics and this question must be explored [11, 12].

Some recent surveys give some information about teacher practices using geotechnologies. Kerski [7] reports different studies that emphasize the link between the uses of geotechnologies and a context of reform for a long term impact [7, 13, 14].

A French study (862 geography and geology teachers) [15] shows that these teachers express a high interest in the uses of GIS material for educational purposes. Beyond the diversity of the tools used by teachers, the *virtual globes* - such as *Google*

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[1] See for example : http://www.ushmm.org/maps/projects/darfur/

Earth or the French *Geoportail* - meet a real success. If a minority uses GIS, 49% of geography and geology teachers use virtual globes such as *Google Earth* or the French *Geoportail*. This success is also attested by the fact that 80% of the teachers express the willingness to use geotechnologies for geography or geology teaching.

The use of virtual globes rather than GIS can be explained by the transfer of personal practices - the use of online geotechnologies to locate a place, to determine a means of public transport or driving itinerary, to look at a holiday destination – into the professional domain. Furthermore, due to the fact that these technologies are recent, most teachers have not benefited from adequate training. They do not master most of the concepts embedded in GIS material and the software applications designed for professional purposes are too difficult to use for the majority of teachers and of course for students.

The French survey also points out that these tools are used in different pedagogical contexts: with the whole class through the use of a video projector, with small groups of students or individual use, a student is alone in front of a computer. Different clues indicate that the pedagogical features that permit Problem-Based-Learning have a positive impact on the use of geotechnologies.

The topics to learn seem to have little effect on the uses. The curricula of the grades that are the most concerned by the uses of geotechnologies include the study of geology or the geography of environment or development. But the survey shows that all the grades of secondary education are involved and the teachers indicate a wide diversity of topics to be learnt with these technologies such as plate tectonics, earthquakes and volcanoes, environment, landscapes, urbanisation, globalization... The diversity of the themes can be explained by the fact that 80% of all our decisions involve a spatial component [3]. These topics can concern local problems close to the school as well as regional or worldwide subjects. The favourite topics indicated by teachers concern regional or worldwide subjects.

The arsenal of geospatial tools available for the educator has greatly expanded. Nevertheless, the uses declared by teachers mainly concern visualization. The teachers express their interest in the fact that *virtual globes* allow access to geological and geographical data. Data gathering or data processing are more uncommon. Nevertheless 7.5% of geography and geosciences secondary teachers in France declare that they use GIS material to carry out field investigations with students. In the next paragraph we examine these different kinds of uses

4. Uses of Geotechnologies for Secondary Education

4.1 Visualization

The visualisation of geological or geographical features is the preferred practice declared by teachers [15]. The power of geotechnologies to give access to geological and geographical visualization is obvious. This interest results from the fact that geotechnologies provide tools for the high-quality production of multiple forms of representation [16]. Geotechnologies give access to a tridimensional representation of space. They allow for the changing of the scale of visualization by using a continued zoom. They also give the possibility to combine different layers of information and, therefore, to identify correlations between data. The diachronic dimension of a phenomenon can be studied by using different functions that allow the creation of animations.

There are many examples of visualization practices in secondary education available on the Internet. MJ Brousseau[2], a secondary teacher, has created a set of data from the Afar rift for pupils (upper secondary school). This set of data has been designed for Google Earth. It encompasses a geological map and layers of data about earthquakes and volcanoes. It is expected that the exploration of this set of data mapped on the digital elevation model and satellite images of Google Earth will help the student to identify different aspects of the forming of an ocean (the geomorphology of the region, the localisation of earthquakes and volcanoes) to understand the functioning of a mid-ocean ridge. Different scientific institutions give access to databases where the data are available in a format which can be visualized with Google Earth. An educational French website[3] gives a list of such databases for geology teaching.

Other functions of virtual globes are used by teachers to promote a better understanding of phenomena. The website, Google Earth Outreach[4], gives the possibility to download different animations such as the changes in forest cover worldwide. The animated overlays show which area has been worst hit. The use of this animation with students offers them the opportunity to visualize a phenomenon which is difficult to observe.

Pedagogies based on visualization are grounded on the idea that "a picture is worth a thousand words" and it is true that geotechnologies give new and powerful tools to access a useful representation of worldwide spatial data for teaching. Nevertheless a risk remains. This risk relates to the illusionary belief that visualization automatically leads to understanding. The vision of the expert can be very different from the vision of the novice and, as a result, this leads to different interpretations. It has to be considered that a good interpretation of the pictures available on virtual globes or GIS implies certain skills. This is due to the choice of semiotic representation for the producing of the pictures. Therefore the teachers should be able to guide the students' interpretation of the pictures by giving them some basic features of the process for the producing of these pictures.

4.2 Data analysis

The *virtual globes* allow some basic processing of data. It is possible, for example, to measure distances or to use different layers of information in order to show correlations. It is also possible to create thematic maps by giving a value to entities such as points, cities, areas or countries. Nevertheless, the virtual globes are mostly

[2] http://acces.inrp.fr/eduterre-usages/ressources_gge/afar/afar.htm
[3] http://pedagogie.ac-montpellier.fr:8080/disciplines/svt/spip/spip.php?article230
[4] http://earth.google.com/outreach

designed for visualization and only GIS systems allow for performing functions by manipulating the structural relations of spacialized data sets.

There is a wide variety of software applications used by teachers. These include desktop GIS, mobile or handheld GIS, server-based GIS tools, and embeddable GIS [16]. GIS applications present a large variety of functions. Some of them are used by teachers as illustrated by the following examples.

A well-known example of data analysis was conducted by secondary school pupils who were asked to investigate the location of coffee shops in their city, The Hague, [17]. The students mapped out schools and coffee shops by using public data, produced maps which were combined and drew buffers around the coffee shops. The result of this study carried out by students was that the law which states that a coffee shop should not be located within 500 meters of a school is infringed by numerous coffee shops and the students wrote a report for the local newspaper.

The work carried out by Peter O'Connor, Head of Geography in a UK school is also a good example of map producing[5]. His pupils produced a map of land use in their city. The realization of the map implied the use of advanced functions of a GIS: data geolocalization, choice of the symbols and attributes for the data, combination of different layers of information, measure of distances, data aggregation… Therefore, the students had to handle the different tasks of the process of digital map-producing from the gathering of data during fieldwork to the different digital treatments with a GIS application.

These examples illustrate the power of GIS for modelling activities. The process implies choices of data and variables to produce a digital representation of a system.

4.3 Data gathering

The databases are an important part of GIS and the gathering of data is a central step in geography or geology studies and fieldwork can play an important role for geography or geology education. As a result, different surveys have identified the use of geotechnologies during educational fieldworks [7, 15].

There are numerous examples of the uses of geotechnologies for data gathering. In most cases, the pupils use a Global Positioning System (GPS). The GPS can be used to identify waypoints or to register an itinerary. Some examples relate to the use of Personal Digital Assistant (PDA), tablet PC or netbooks. Coupled with a GPS, these devices allow for using a portable GIS and for having access to digital maps. The use of remote sensors to measure parameters such as temperature, pH or light is less frequent.

Sébastien Cathala, a geography teacher, reports different projects[6] that he carried out with upper secondary school pupils. One of these relates to the waste management for a school. The students had to create a digital map of the dustbins of the school and to propose new implantations. This teacher reports also the realization of a database

[5] http://www.geographyteachingtoday.org.uk/fieldwork/info/teaching-technology/using-esri-arcgis/

[6] http://eductice.inrp.fr/EducTice/projets/geomatique/Journees_etude/intervention_cathala

by pupils on the pollution of a river. The chemical measures were located and the values represented on a digital map created with a GIS.

The work of François Cordelier is another example of Project-Based-Learning with geotechnologies. The project[7] relates to the diachronic study of the vegetation in an estuary. The digital map of vegetation created by pupils was based on the data gathered during fieldwork. The map was compared to a historical map in order to identify the evolution of the environment.

Research into the uses of geotechnologies for fieldwork [18] emphasized the role of these technologies for learning. The benefit of technology does not result from the fact that it facilitates the work of the learner but from its capacity to mediate the interactions between the learner and the data collected on the field. The next paragraph is devoted to a discussion about the changes that occur with the use of geotechnologies for educational purposes

5. New Relations with Geographical/Geological Knowledge

One of the more obvious consequences of the use of geotechnologies for educational purposes is a better access to geographical and geological knowledge. This consequence results from the development of databases for geolocalized information. This information is often available for free *via* the Internet. As a result, the teachers have the choice of a wide range of topics for integration into the curriculum. The availability of worldwide data gives the opportunity to carry out studies at different levels. The relatively easy access to information allows for the implementation of new local studies or the improvement of former practices by giving access to new data. It is also possible to obtain remote or global data and to widen the pupils' viewpoint. Nevertheless, the question of the quality of the data and the validity of the information remains. The pupils are generally not able to detect and assess the accuracy of the source of data.

The use of "real data" is a source of motivation for students. The studies carried out by students can relate to the "real world" and, sometimes, as seen above, can have an impact on the school or the city. The availability of data gives the opportunity to study the complexity of systems and phenomena. Therefore, the learning relates to embedded knowledge and it facilitates the linking of conceptual models to empirical evidence. The access to the process of information gives the possibility to understand the nature of knowledge.

It has been pointed out that geotechnologies facilitate the implementation of Inquiry-Based-Learning [19] and open-ended projects for teaching [7]. It is probably partly due to the fact that GIS allows implementing different classroom procedures that are close to professional procedures. The reasoning can encompass modelling or simulation [20]. The implementation of such procedures addresses the question of the accuracy of the methods used by pupils and their validity for the discipline. The second question relates to the training of teachers who need to be able to understand

[7] http://appli-etna.ac-nantes.fr:8080/peda/disc/svt/sig_port_lavigne/index.htm

the core concepts of geotechnologies. Pairform@nce[8], a French online training course for teachers, tries to reach this goal.

The modification of the relation between students and knowledge also results from the properties of geotechnologies. As the content can be user-generated the students are encouraged to participate in the process of knowledge production. They can shift from the role of consumer of information to the role of provider of information under the guidance of the teacher. Geotechnologies also allow for aggregating information from different sources. Therefore, geotechnologies also offer the opportunity to implement collaborative work in the classroom.

The changes that can occur are not intrinsic to these technologies. GIS and Virtual Globes can be used in a very traditional way. Geotechnologies are only propositions that have to be adopted and adapted by teachers. These changes depend on the willingness of teachers to change their practices. It depends on their acceptance to change their roles in the classroom. It depends also on their agreement to being involved in open-ended projects in which they can face difficulties in solving problems. These points are probably the critical dimensions to be taken into account to support the introduction of geotechnologies in secondary education.

6. Conclusions: Goals and Stakes

There is an increasing use of geotechnologies that are mostly adopted by teachers to give their students a better access to information. Geotechnologies offer new opportunities for teaching/learning geography and geology. These opportunities relate to the subjects, geotechnologies make it possible to deal with embedded knowledge by taking into account the complexity of the world. Therefore these technologies are adapted for education in sustainable development. These opportunities relate also to the type of teaching that could be practised with the use of virtual globes, GIS and mobile devices such as GPS. Fieldwork, Project-Based-Learning, Inquiry-Based-Learning and collaborative learning are fostered by the uses of geotechnologies.

One of the most important goals regarding the use of geotechnologies is the improvement of the capacity of students to handle the geographic information as a part of their digital culture. Geotechnologies such as *virtual globes* or itinerary information websites meet a real success and it is necessary to give citizens basic knowledge about digital geographic information. This can be easily illustrated with the reading forums devoted to exchanges about artefacts in Google Earth. Some people find a boat in the middle of Greenland and others a “flying car” [9]. This lack of knowledge about how digital geographic information is gathered and processed leads to widespread misunderstandings: the satellite digital pictures become photos, there is a confusion between the scale of study allowed by the use of the zoom and the scale resolution which depends on the quality of pictures. The capacity to handle digital geographic information should be a part of the digital culture of the XXIst century citizen. The stakes of the integration of geotechnologies into the curriculum consist of

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[8] http://www.pairformance.education.fr

[9] Different examples are available on:
http://comenius.blogspirit.com/archive/2008/01/01/betisier-geomatique.html

a better understanding of geographical/geological concepts and the development of the capacity of the students to develop relevant uses for these tools (e.g. critical reading, interpretation or production of cartographic display). The awareness of the source and the quality of information - to avoid disinformation - and the knowledge of the domain of validity of these tools for the processing of data are also dimensions to take into account.

A recent study emphasizes that the development of new habits of young people with digital technology must be taken into account by educators [21]. The uses of geotechnologies for gaming or the uses of virtual globes as virtual worlds that give access to geolocalized information are examples of such habits. Furthermore, it has been claimed that young people are *digital natives* as they have grown up with digital technology [22] but the general uses of technologies are not necessary valid due to the lack of criticism by non-educated people. The frontiers between real and virtual worlds, between the models implemented in the software applications and the reality are blurred, tools and data are used outside their domain of validity. The integration of geotechnologies in the curriculum should contribute to helping the students to localize these frontiers, to distinguish between models and reality and to understand the relations that connect these two dimensions.

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