Geospatial Learning @ Primary School

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With the advent of GI Science and Geographic Information in general public (for example via virtual globes and navigation systems), education systems all over the world start integrating them in their curricula including competences like spatial orientation, spatial learning, and spatial thinking. The presented Geospatial-Learning@PrimarySchool project takes up this movement, by introducing a simple GIS application for children between 8-11 to foster these competences. In a case study a prototype for the XO-laptop of One Laptop Per Child is being implemented and tested in Primary Schools in Germany and Rwanda.

INTRODUCTION

GI Science and Geographic Information found their way to the general public. Education systems in many different countries have discovered the relevance and potential of GI Science, and so have developed new strategies to implement the use of Geographic Information as an integral part in their curricula, starting in secondary schools. The general aim is to foster competences like Spatial Orientation, Spatial Learning and Spatial Thinking (Committee on Support for Thinking Spatially, 2006). The use of computers and the awareness of digital maps, i.e. in car navigation systems are emerging at much earlier ages, as well as the cognitive development of a child's spatial integration abilities. According Piaget's model (Piaget, 1948/1967), these skills would begin to appear during the concrete operations stage (ages 7–11). An understanding of how children conceptualize geographic features and information will help promote interoperability and usability of GIS, including distributed information systems (Montello, 2005). Very recent studies proposed "Minimal" GIS for primary schools, in which a pedagogic goal of grade-appropriate concept understanding becomes the driving force behind the GIS, suggesting the structure of an effective support system for spatial thinking (Marsh, 2009).

It is against this background that the 52°North[1], the initiative GI@School[2] of the Institute for Geoinformatics[3] at Münster University and ESRI Germany[4] decided to team up for the project GeospatialLearning@PrimarySchool[5].

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[1]   See http://52north.org

[2]   See http://www.gi-at-school.de

[3]   See http://ifgi.uni-muenster.de

[4]   See http://www.esri-germany.de

[5]   See http://52north.org/GeospatialLearning

The project objective is to develop applications in order to foster geospatial thinking by using novel Information Technologies in form of a simple GIS with GPS connection as a support system. The target group are children from 3rd to 6th grade (8–11 years).

Together with MIT's One Laptop Per Child (OLPC) project and ESRI Germany – both being very active in supporting educational activities in Rwanda – we have the opportunity to include children from Rwanda into the case study. The proposed application will be implemented for the OLPC XO-Laptop, better known as the $100-Laptop, and will be tested in Germany and in Rwanda.

This is a special challenge for the software design, development and data:

- individual children's development stages, different and limited spatial abilities

- limited attention span

- limited experience with computers, especially laptops, and geospatial applications

- cross-cultural use, specific localization of texts, symbols, concepts

- it should not be necessary to know GI concepts in order to use the application

- the XO environment provides limited degrees of freedom for designing user interaction

This leads to the following research goals and consequential short-term objectives for this case study:

1. How do children perceive real space in relation to space representations on the laptop?

2. How is the cultural/linguistic difference of children mapping geographical concepts?

3. Do children learn geospatial thinking by using a simple GIS?

Short-term objectives, covered in this study:

- Are children potential users of geospatial information, and starting at which age?

- Do children have interest in and enjoy map-based activities?

- How must Geographic Information be presented in order to be useful and usable for children performing certain activities?

- How useful and usable are certain datasets in this context?

- How can existing datasets be made more useful and usable for this purpose?

- What support can software provide to make datasets more useful and usable?

To present some first results, our methodology is to focus on a adequate platform, the XO-Laptop, and develop an didactical approach based on its advances and constraints and learning theory. Afterwards we introduce an application prototype and report from first tests in a primary school.

OLPC AND THE XO-LAPTOP

One Laptop Per Child

The OLPC project was started in 2005, when Nicholas Negroponte announced his vision[6] to provide a laptop for each child in developing countries, to bridge the educational gap and also the digital divide between the developing and the developed countries. OLPC aims to be an educational project rather to be a laptop project, meaning not only to deliver an ordinary laptop for each child, but one, designed especially to support children's learning purposes at age 6–12 and the utilization of the laptop in rough (environmental) conditions.

The XO Laptop

The XO-1 is better known as the $100-Laptop. This indication rather reflects Negroponte's vision—it currently costs about $170. The XO-1 went into mass production in November 2007. Today, more than 1,000,000 machines are shipped in over 30 countries[7]. Uruguay is the first country which realized the aim providing a laptop for every child (literally) in October of 2009[8].

However, Rwanda also has ambitions in integrating the XO in their educational curricula. Rwanda strives to become Africa's high-tech hub, as a part of its vision to evolve into a medium-level income country until 2020. In 2009, Rwanda launched the Center for Laptops and Learning, "which aims to serve as the educational and learning needs of countries across Africa." Rwanda has committed to deploy 100,000[9]–120,000 XOs across the country (OLPC, 2010). The project GeospatialLearning@PrimarySchool will cooperate with the Government of Rwanda, performing usability tests in Kigali in April/May this year.

Technical Review

As operating system a Fedora Linux distribution is installed on the XO, with Sugar, an innovative zoomable window manager, on top of it. Sugar provides a learning interface for children through Sugar Activities[10]. An Activity could be conceived as an application, but it reflects the intention to learn something by doing something. Here, constructionist learning comes into play, which states, "that learning is most effective when part of an activity the learner experiences as constructing a meaningful product." It is meant to see learning "as a reconstruction rather than as a transmission of knowledge" (Papert, 1987). The technical advances of the XO lie in its robust design, suitable for outdoor use, the simple child-centered user interface and an ad-hoc network design (MESH) to share internet or activities and data with XOs in the neighborhood. The constraints come with the performance (400MHz, 256MB RAM, 1GB ROM) and the strict activity design principles stated in the Educational and interface guidelines (OLPC, 2010).

In concerns of geoinformation and space on the XO, there is an activity for measuring distances included, based on a spread out audio signal and editable factors like air temperature and humidity. The existing Map Activity[11] allows mapping, measuring and adding media to the map, but only works

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[6]   Actually, the idea is a bit older: See http://www.ibm.com/developerworks/podcast/dwi/cm-int042407txt.html

[7]   The next version, the XO-1.5, went into mass production last year.

[8]   See http://www.olpcnews.com/countries/uruguay/last_xo_laptop_olpc_uruguay.html

[9]   See http://allafrica.com/stories/200901080184.html

[10]   See http://www.sugarlabs.org/

[11]   See http://wiki.sugarlabs.org/go/Activities/Map

with an existing internet connection (maps from Google Maps), which cannot be assured in developing country schools. The XO does not (yet) have a built-in GPS receiver, location based activities need to use an external device.

DIDACTICAL APPROACH

OLPC aims on content and software design for pleasing and self-empowered learning, following the constructionism theory, based on Piaget's constructivism theory of childhood learning (Piaget, 1926/1930). Constructionism is a philosophy of education in which children learn by doing and making in a public, guided, collaborative process including feedback from peers, not just from teachers. They explore and discover instead of consuming prechewed knowledge (Papert 1991).

In contrast to the Constructionism, the Instructionism refers to all of the educational theories based on the idea of the teacher teaching, usually according to a predetermined schedule (curriculum), rather than on students learning from their own experiences at their own pace.

Our didactical approach can be found somewhere in between the Constructionism and Instructionism, as we are aware of the very important impact of "learning-by-doing", but also of the real situation in schools all over the world, where teachers mostly teach, following the subjects curricula. That is why we have chosen the XO as the constructive platform for our application. Additionally we analyzed the primary school curricula in our case study countries (Germany and Rwanda) to look for possible links to geoinformation and geospatial learning. For Germany's primary school (1st–4th grade) we found links in the social studies curriculum, in secondary schools (5th–6th grade) in geography and in Rwanda's primary school (1st–6th grade) in social studies. Exemplary links to geospatial learning and possibilities to use and gain geoinformation are presented in Table 1.

Table 1: Geospatial competences in social studies and geography curricula in Germany and Rwanda

	RWANDA Spatial Competences in Social Studies Curriculum	**GERMANY (Northrhine-Westphalia)** Spatial Competences in Social Studies and Geography Curriculum
GRADES 1+2	- locate his/her home. - locate her/his village - describe the main components of the way to school. - draw the route from home to school - locate his/her school. - identify the main components of the school environment	- explore the way to school and the school environment - explore important facilities in the hometown - orientate along points of interest and traffic signs - draw their way to school
GRADES 3+4	- locate the sector on the map of the province - draw a simple sketch map to show the district and ist neighbouring districts.	- use maps and other media for orientation (city maps, compass, sun) - explore and describe regional structures (agriculture, rural areas, cities, industry) - explore and describe changes in their geographic space on all scales

GRADES 5+6	• locate the province on the map of Rwanda. • use longitudes and latitudes to locate Rwanda on the map of East Africa • draw a map highlighting the features identified.	• have basic orientation knowledge at different scales • are familiar with basic rasters and orientation systems • determine their location in real space with the aid of a map and other aids to orientation • move in real space with the aid of maps and other aids to orientation

Out of all geo-related competences we have chosen several key competences (presented in Table 1), to be addressed with our prototype. Another central focus of the development is based on the spiral curriculum (Taba, 1962), with knowledge building on previous knowledge and organization of content on different levels. In a geospatial activity, this can be applied through the use of scale: for the younger classes we focus on the local scale, the older classes can analyze concepts and key ideas more generalized on the regional, national and global scale.

THE GEO ACTIVITY

To make it possible to focus on a variety spatial competences presented in the previous section, we planned to design an open, extensible activity, avoiding putting all aims into one application.

The Geo Activity is designed as a framework, where game-like activities can be placed in as plugins. The activity is written against the Sugar API, and therefore the programming language Python is used. The framework provides tools for gaming in a map context, e.g. an OpenStreetMap (OSM)/WMS map view, with WGS84 coordinates and GPS connection (if external GPS device available). Furthermore, by using the XO's sophisticated MESH network, it facilitates to share the game with other XOs, so a collaborative gaming is possible. With that functionality—using the promising library groupthink[12]—it's possible to share any data between the XOs, e.g. a player is able to see the other players on the map.

For now, OpenStreetMap data is used to display a base map context, using the so called Slippy Map[13], though, other georeferenced data would be possible as well, e.g. a WMS, OpenLayers within an embedded HTML widget—with that some fancy javascripting would be possible (similar to the Map Activity). Georeferenced orthophotos or local maps could be used for areas, where OSM coverage is bad, i.e. in rural areas or less developed countries.

Geocaching

The application's screen shows a section of the OSM dataset in a typical GIS representation (Figure 1). The user sees his own and the participant's positions marked by colour coded XO-logos on the map. Treasures can optionally be marked with a flag. Pan and zoom functionality are provided for finding the right map area. If a treasure is visualized, the user can start moving and comparing his position in the real world to the representation on the screen. Unlike the "typical" geocaching with

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[12]   See http://bemasc.net/~bens/groupthink/
[13]   See http://wiki.openstreetmap.org/index.php/Slippy_Map

portable GPS receivers, where the search is based on distance and direction to the destination (the geocache), our activity forces the user to orientate himself in his environment and understand his and its spatial representations and their movement on the map. It already covers some of the competences presented in didactical approach and is still following the constructionism approach, as the children explore their environment by themselves with the help of the laptop.
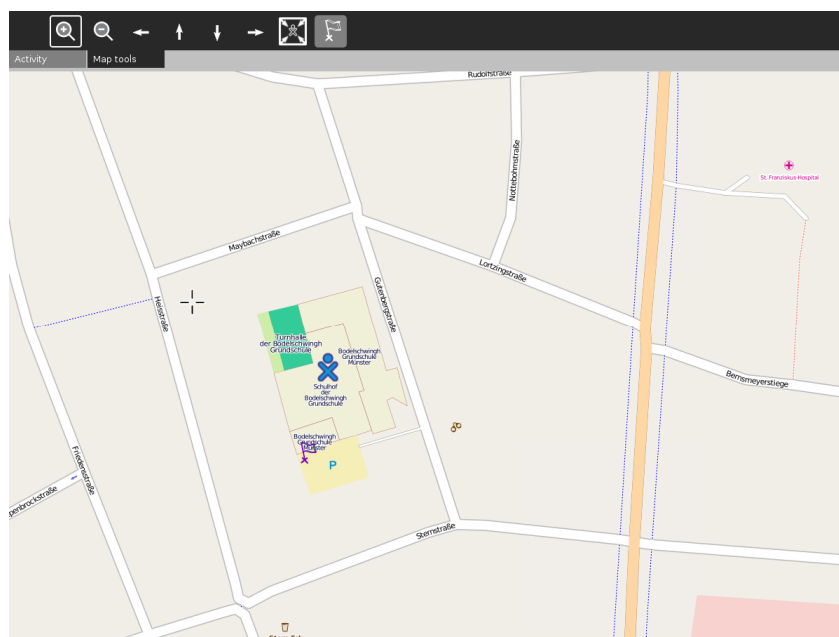

Figure 1: Screenshot of Geocaching activity depicting school area from OSM, cursor (crosshair), XO-Position (XO Icon) and Geocache position (flag)

The Geocaching prototype was already tested in a primary school in Germany[14]. The development accompanying usability tests will not only give a feedback on software usability and influence further development; they also offer first implications on adequacy of the scenarios for geospatial learning. Though, the study's tests on geospatial learning can be conducted during a later stage, where the plugins left the prototype phase.

Usability Test

The test was executed with 16 pupils aged 9–11 (7 female, 9 male) from the 4th grade of a primary school in Germany. The method for the case study is usability testing (behavioral observation while using the application) combined with thinking aloud. The test is followed by some questions evaluating the subjects' experience and clarifying their background.

After a short introduction of the whole class into geospatial information, the laptop, the OLPC project, and GPS, individual children were chosen for the test. In a short briefing, they were told to perform a little treasure-hunt on the schoolyard. They were instructed to look for their position,

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14   See http://52north.org/GeospatialLearning/?p=184

zooming, and displaying the treasure on the map. Then they received the laptop with the application showing a world map (s. Figure 2). The optimal sequence of steps would be:

1. recognize world map

2. recognize position related to the world

3. zoom to schoolyard (recognize own position during each zoom step)

4. let a marker show the position of the treasure

5. correlate own and treasure position with the environment

6. move towards treasure

7. find treasure

All these tasks have to be performed with the touchpad and its two mouse buttons. On the keyboard, only the arrow buttons are available for panning.

Figure 2: 4th grade children during the Usability test on the Geocaching activity

The test was executed on two days. The first day started with the general introduction followed by four runs with individual subjects. On the second day, two subjects worked together (Figure 2) in each of six runs. We switched to this method, to try out if thinking aloud flows more naturally within a conversation.

RESULTS AND CONCLUSIONS

The proposed framework, as an application to foster geospatial thinking, is currently in heavy development along with usability tests in different stages. The first plugin prototype, an adaptation of the GPS treasure-hunting game "geocaching", has been developed and tested.

Remarkable 15 out of 16 subjects had prior experience with Google Maps/Earth or similar applications. This reveals that children are already users of geospatial information, probably even well before the here examined minimum age of 9. All subjects were eager to do the test and reported having had fun afterwards. All would do such treasure-hunting again and would also recommend it to their friends. The enjoyment, however, is strongly related to the functioning of the system. Some subjects quickly lost interest when problems arose, especially in the teams of two, if the partner was currently operating the computer. For geocaching the data must provide enough detail in order to be

suitable for comparing the map with the real world situation. Some subjects had difficulties recognizing their position and orientation from the street network. Nearly all definitely needed the buildings to be successful. They even investigated the buildings for details like jutties and were then able to locate their classroom in a building. Aerial photography would suit the activity as well. The OSM data do not provide enough detail in this respect for the test area. We had to map the whole school area ourselves in order to provide more than a street network. It is an interesting question if and how the position of other surrounding XO-users could help with orientation. Obviously, highly detailed maps with appropriate visualizations are needed for children's treasure-hunting. It will not only be necessary to think cross-cultural, but also in terms of age regarding the visualization of objects on a map. Official mapping agency style might not be appropriate for children. Zoom and pan are basic functionalities for finding one's position and exploring the surrounding area. Apart from some problems with operating the touchpad and recognizing buttons, these concepts were well-understood and correctly employed. But this does not seem to be enough. Most subjects had difficulties with orientation looking at an always north-facing map. There were symbols representing other buildings on the OSM data, e.g. handcuffs for the police station opposite the school, but they were not recognized as placeholders for buildings by the subjects. Probably the fact that the handcuffs were not recognized as such plays a role (being asked, a subject identified the symbol as spectacles), but it remains unclear how big this influence is. It is an interesting question if and how the position of other surrounding XO-users could help with orientation. A parking symbol was recognized without difficulties. In Germany, the "P" is used for the according traffic sign.

FUTURE WORK

A test series in March 2010 in Germany and in May 2010 in Rwanda provides the possibility to look in more depth in the usability issues already identified and to discover new ones. An aspect not explored so far is the display of coordinates and their potential usefulness in orientation. As the time of introduction of geographic coordinates differs in the test countries this could be a possibility to foster the understanding of this concept.

A study on spatial learning, especially effects on orientation abilities, with the Geo activity as support system will be conducted during the upcoming test series. A pre- and posttest will identify the state and the influences of the tested plugins on the subject's spatial abilities.

There are two more Geo activity plugins planned for the XO. The next will be a Geotagging game, where the users create their own maps by geotagging pictures they take with the XO camera and adding texts and symbols. It will be how children use simple atomic geographic concepts like "vegetation", "agriculture", "road" or "building". This can feed back into the visualization issues. This plugin is in the development phase now. A Geosketching plugin will follow, allowing the children to create sketch maps (i.e. of their surrounding like schoolyard or the way to school) and to georeference their maps by fixing map elements on their GPS-position. The aim is to visualize map distortion, and again to help in the development of spatial abilities like orientation skills and distance estimations.

Another important part of the product will be an import-/export functionality for the Geographic Information including pictures, tags and symbols. The created maps, sketches or treasure-hunts could be transferred from/to XO-users, from/to an ESRI ArcGIS-environment for preparation and post processing and analysis or from/to a web geoportal, based on ArcGIS Server technology, so children from different countries and cultures can compare their results.

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