Usability Engineering for Educational Web GIS

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Abstract

This work introduces concepts from usability engineering and user centered design into software development in the educational context. As most WebGIS on the educational market are based on classical GIS principles made for professionals there is a need for usable tools that fit the needs of children, teenagers and teachers. A prototype WebGIS application for schools to present various geospatial datasets with an intuitive user interface will be presented. The used technologies and user interface elements are described. A usability test with secondary school students is described and used to assess the performance of the prototype web application in a realistic environment. Implications from this test give insight into design rules for usable WebGIS for educative use.

Keywords: Usability Engineering, GIS, School, Education, Human-Computer Interaction.

1 Introduction

Geographical Information Systems (GIS) have become part of our everyday life in the past decades. Today almost 50 years after the first GIS has been invented in Canada [14], it has become subject of educational standards regarding the material taught in schools and can support “students with personalized instruction and interactive animations, games, and simulations that can make complex concepts and systems more understandable” [19]. While there are some established commercial software vendors, who provide GIS software for professional and business use, there is also a large and growing number of GIS applications on the Internet for non-professional users. Several frameworks and APIs for the construction of web applications are available, as GIS are no longer only of importance for professional use, but also for non-professionals. This makes the research field of Human-Computer Interaction (HCI) a key aspect in designing GIS applications. HCI has always been an important aspect of GIScience as coined by Goodchild [5], and it only gained importance with the growth and broad availability of the Internet. Designing a GIS application now requires a deeper understanding of spatial cognition, spatial ontologies, and geographic visualization [6].

In this paper the focus lies on a mapping application specially designed for educational purposes. The age of the users ranges from 12 to 16 years, these are the students in the classes 7 to 9 in the German school system. In these classes the pupils have to learn how to use GIS software, they need to know how various spatial processes work and what their spatial consequences on other fields are [8]. The targeted audience consists mainly of pupils, who are casual users. This type of user only uses a piece of software from time to time, thus the applications needs to provide a steep learning curve and the users need to be able to remember how the system works very easily [9]. Off-the-shelf geographic information system software as used by specialists requires a deeper understanding of database systems, geography and cartography, which makes these systems hard to use and understand for non-specialists [15]. The underlying system architecture and the actual processes required for a GIS to work must be hidden from the users in order to simplify interaction with the software. Aspects like these have to be considered when designing a web application for students. There are several WebGIS applications available in Germany especially designed for the use in school. These applications often are out-dated in terms of design and do not satisfy the demands set by modern standards of usability engineering and similar web applications used by teenagers. In order to further assess the requirements needed for a WebGIS to work in an educational environment with children, teenagers and teachers this paper reviews existing WebGIS applications (section 2) and points out reasons for usability engineering in this context. A prototypical WebGIS is described in section 4 and tested with secondary school students (section 5). Conclusion and an outlook follow in section 6.

2 Educational WebGIS in Germany

In Germany the term WebGIS used in an educational context describes web applications providing capabilities for creating simple thematic maps with predefined curricular data. These WebGIS applications merely need to fulfil the demands set by the educational guidelines and would not meet common definitions of WebGIS. It the context of this research we will keep the naming WebGIS.

Currently there are five major WebGIS applications that are being used for teaching in German schools. Two of them are provided by traditional textbook publishers, which are very popular in German schools. DIERCKE1 provides a WebGIS together with assistance for teaching geography and GIS. The GIS provides thematic geo-data based on the geography curricula and has other valuable features such as a good function to print the created maps. The main view is complex and bulky menus surround a small map. Some of the visible menus do not apply to any mapping function and can be distracting for users. Nielsen [10] states that pixels used for website navigation should be kept under 20%. Figure 1 shows the Diercke WebGIS. Approximately 25% of the website are used by the map, the rest is empty, navigation or the banner.

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1 http://diercke.webgis-server.de/
The legend on the left-hand side is also the layer management menu. If a user wants to classify the given data there are small icons within the legend that open a pop-up window for creating individual classes and assigning colours to them. The other WebGIS by a book publisher is provided by Klett. Two other WebGIS applications are provided by German federal states and another available WebGIS is made by a University. All of them are designed in a similar fashion; one provides panning and zooming in an intuitive fashion as in the popular mapping services. These WebGIS applications also utilize bulky menus, small icons out-dated designs and make heavy use of pop ups. They copy elements from professional GIS solutions, thus raising the usability barrier considerably for teachers who do not have additional time in their everyday work-life to get involved with the demands of such software. Although teaching with WebGIS is mandatory, the usage in schools is in fact a rarity. The benefits of these WebGIS for teaching are that there is no need for installations; they work on any machine featuring an internet connection and a modern web browser. Teachers also do not have the troubles of acquiring data and other materials. This can also be a disadvantage, as it is mostly not possible to add new data. The available WebGIS applications also make use of basic desktop GIS concepts such as layers, a spatial database and map interaction.

While the existing WebGIS may help fulfilling those goals, they are not build with the user in mind. It is not possible to work with these websites without acquiring additional knowledge. Nielsen defines usability as consisting of learnability, efficiency, memorability, errors and satisfaction. This means the software needs to be easy to learn, efficient to use, easy to remember, should not allow users to make errors and be satisfactory to use. Haklay and Zafiri state that there is a “lack of research into the way GIS is used at the workplace, in schools, and at home”. Designs such as the Diercke WebGIS are acceptable, but there is room for improvement. Traynor and Williams suggest to use participatory design as an approach to building new software, Traynor and Williams also state that a program, which is usable by non-specialists, should be free of technical terminology, independent on the software architecture, and expressed in terms of the users tasks. It is also an important aspect to know your user. For this paper the targeted user group mainly consists of teenagers of the age from 12 to 16 as this age range is the most prominent in the targeted school classes where GIS are taught. This age group has to be distinguished from children, whose age ranges from 6 to 12.

Children and teenagers have very different habits of using technology. They have a different conception of how things work. Although it is said, that modern teenagers are well connected with the internet, using social networks, owning smart phones or using the web for personal or school tasks, it is a common misconception, that teenagers are efficient and skilled when it comes to technology. Studies show that teenagers have very individual issues in web usability. A study conducted by Nielsen shows that teenagers like “cool looking graphics", modest and clean designs and most important of all no boring sites. For children and teenagers the first impression plays a big role, both prefer bigger font sizes and less text to read as their attention span is shorter than the attention span of adults. Nielsen also states, that interactive features work very well with teenagers and can be used to keep their attention. There is a need to put more effort

3 Usability Engineering

In the German school system the use and application of WebGIS is mandatory in geography classes in secondary school. These guidelines specify that students should “know how to gather data from sources such as GIS (WebGIS or geo-data viewer)” and be able to design thematic maps.

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2 http://www.klett-gis.de
3 http://webgis.sn.schule.de
4 http://webgis.bildung-rp.de
5 http://www.webgis-schule.de

Figure 1: Diercke WebGIS. The original is shown on the left-hand side. On the right-hand side website elements are marked as follows: Green shows the content of interest, yellow marks the space used for navigation, red shows content that is not affiliated with the map, the white space remains unused.
in usability engineering and research towards the use of software by children and teenagers. Especially in times where computers, software and teaching are inevitably coming together more and more as Ortmann [13] predicts and classrooms are becoming digital.

4 WebGIS Prototype

In this work a prototype is used for a usability study. The design approach is adapted with the aspects of usability engineering as mentioned in the last section. The website is designed to be intuitive, interactive and self-explanatory.

Figure 2 shows a prototypical design. The map, which is the main element of interest, is expanded over the whole browser window, thus using the maximum space made available by the browser as demanded by Nielsen [10]. All control elements are within the map. The zoom slider and the scale are on the left side and the icons used to bring up the menus are on the right side. The menus can be opened by clicking on the icons (upper right); this triggers a slide animation to draw the user’s attention to it. While animations in general are good, they should not be over-used. They can be used to focus on something that has changed [10].

Especially for the users from the age class of teenagers it can be advantageous to have a high degree of interactivity and some animations [11]. There are four icons in total, one for the layer menu, one for the classes menu, one for the legend and one for adding a second map view.

The existing GIS solutions for use in an educational context, which are described above, all utilize the classical layer model to visualize data. This makes it very difficult to directly compare two or more data sets. Cinnamon et al. [3] describe the advantages of the ability to compare two maps directly: “The ability to compare any of the maps on a single screen almost instantaneously via the use of the split-screen was a benefit for most respondents”. They also state, that split screen visualization is an effective way to compare variables in an interactive manner. The prototype makes use of this feature in an intuitive way. Once the icon for split screen mode is clicked, a second map view is opened. If the user pans or zooms within one of the two maps the other one is rearranged accordingly. It is possible to configure each view independently from the other one. The layer menu provides 5 different thematic layers and several background maps. Behind each thematic layer a small “i”-icon gives information about the data on mouse-over. The classes menu is divided into two folding sub-menues. Here users can style the map using automated class (with color ramp) breaks or individual breaks. The whole web site is constructed with responsive web design in mind (RWD) to fit all resolutions and most conventional web browsers and most Android and iOS tablets.

5 Usability Test

We conducted a usability test with pupils to assess the usability of the prototype. This test served solely the purpose of usability testing rather than testing how effective learning with the given set of features proves to be. The aim is to establish a WebGIS that reduces the usability threshold for teachers and pupils and will be used more frequently, thus the test concentrates strictly on usability issues.

The test was construed to be a formative evaluation of the prototype, to help improve the given software interfaces [9]. Test candidates were teenagers between 16 and 17 years old from a German secondary school. In 100 minutes of time we were able to test the prototype with 9 testers, 4 of which were female and the remaining 5 were male. The given number of test users is sufficient as described by Nielsen [9], who states that for revealing usability problems a low number of testers suffices, because the count of findings gained through larger numbers of testers levels out very quickly.

The test was set up following tips and procedures described by Nielsen [9] and by using the thinking-aloud method. The test was set up in a common classroom at their school with a desktop computer. A camera was placed to record all tests. The testers were asked to think aloud while working on the given tasks. The tasks were focused on creating a map out of the data and using some specific functions (i.e. split screen). Immediately after completing the test tasks, the testers were given a questionnaire, in which they were asked to give some

![Image](http://www.webgis-westfalen.de/...westfalen.png)

Fig. 2. The prototype GIS: Comparing two maps. All available menus are shown; they can be slid away by pressing the icons on the right-hand side.)
information about themselves such as prior knowledge about GIS or experience with computers and about personal opinions about the design. Most questions used a semantic differential scale to gain insight into the tester’s attitude towards the concepts to be evaluated [9].

One half of the test candidates estimated that their computer experience is slightly above average, the other half specifies their computer knowledge to be slightly below average. When asked what they use a computer for in their everyday life all pupils answered “for social media and school”. Two male candidates stated that they use a computer also for games and one female candidate used a computer for work outside school. All candidates use web applications for mapping purposes such as Google Maps or Bing Maps from time to time, but not on a regular basis. And although it is a requirement in the German school system to teach with WebGIS or geo-data-viewers [9] only two of the testers stated in the questionnaire, that they have used a WebGIS in school before.

5.1 Observations and Implications

During the test session problems and major issues with the tested prototype became apparent. Figure 3 shows details captured in the usability test. The comparison of the total number of clicks needed by the users to complete each task and the needed time in seconds shows the correlation of these two parameters, as well as that there is no identifiable significant trend in the data that shows a difference between male and female. Figure 4 confirms this and adds that whether a test user was experienced or inexperienced did not matter regarding their actual performance during the tests using the prototype. The tests showed that pupils tend to miss subtle interface elements. When asked to change the background map in the application some candidates found the appropriate sub menu very fast without detours to other parts of the interface. Most other testers looked for several minutes and clicked on everything they could see. The required menu to change the background map is in a folding menu as shown in Figure 2. Many candidates instinctively clicked on the appropriate icon as a first action, but then tended to overlook that it said Background Map at the bottom. When asked after the test most candidates wished for a more obvious placement for this function or suggested to not have folding menus which are closed initially. One other issue was the color picker needed to give a classification of the shown data some color. The picker uses a text field containing the visualized color and the HTML color code such as “#FFFFFF”, clicking into the field opens the color picker. The initial state of this text field is being white and the field is labeled “Color range from/to: “. When asked to give a colored classification to the shown thematic layer, almost all testers found the appropriate menu very quickly, but upon inspecting the

![Fig. 3 Scatterplot showing the number of clicks and time in seconds the users needed to complete the tasks faceted by task. The regression line shows the correlation between both parameters. The legend shows the user number and color along with the user’s gender.](image)

![Fig. 4 Bar plot comparing the total click-count of all male and female users with their self-assessed level of computer experience.](image)
menu did not find anything with colors and dismissed the menu to keep looking somewhere else. Some functionality still remained unclear for a few test users. Not all users found the possibility to display diagrams in the map. Providing additional help is required, this help could come in the form of messages whenever a function is enabled that needs further explanation. The tests have also shown which parts of the interface work good. The mouse-over help icons were a success, as well as the split mode to compare maps. The split mode button was easily found by almost all testers when asked to compare two maps and some of them stated afterwards that they liked the intuitive nature of this function. Most test users also stated in the questionnaire that they liked the overall design and button placement. While most testers answered that they liked the button sizes the opinions about adequate fitting symbols differed. Some found the icon symbols confusing, and others liked them. Combining purely symbolic icons with text is a suggested approach by [9], this approach is also backed by studies that show the improved performance and memorability of such icons; this shows that there is room for improvement.

6 Conclusions and Outlook

The presented WebGIS prototype tries to improve on the existing solutions available for teaching in schools by using modern technologies. To answer the question which requirements are needed for a WebGIS to work in an educational environment, the interface was changed and adapted according to key aspects regarding web usability as described in the literature and discussed in this paper. By using various usability-testing methods the interface has been tested in a real world environment to evaluate the changes made. We confirmed the hypothesis described in Section 5 that it is possible to implement a usable WebGIS using currently available technologies in the use case with pupils.

These key points are the main implications for the prototype derived from the usability tests:
- sub menus in folding menus should not be folded as an initial state or made more prominent
- Hide obfuscating elements such as HTML codes
- It needs to be obvious which elements can be clicked (i.e. the color picker)
- Hover-over help icons are a good concept but additional help is needed for some features

This shows, that in addition to considering basic design concepts recommended for the target audience, it is necessary to heavily rely on usability testing and engineering when it comes to implementing software for young users. Future research has to go into testing an interface, which is more complex with some more features as the presented ones. The prototype merely provided basic functionality to test basic design concepts. Also especially in an educational context it is important to include the teachers in the research process with additional usability tests, questionnaires or by letting them take part in the design process as it is them who have to use the software to teach. Teachers can be the bottleneck when it comes to software used in classrooms; if the application is not usable for teachers they will not use it.

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References


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