DESKTOP VIRTUAL REALITY IN E-LEARNING ENVIRONMENTS

C. Katterfeld*, M. Sester

Institute of Cartography and Geoinformatics, University of Hannover, Germany
(christiane.katterfeld, monika.sester)@ikg.uni-hannover.de

Session PS WG VI/2-4-1

KEY WORDS: Visualization, Virtual Reality, Internet/Web, Web based, Learning, Education, Teaching

ABSTRACT:

In recent years distributing knowledge via Internet and World Wide Web has become standard for universities, institutes and companies. Many of them offer E-Learning-Environments. The advantages seem to be obvious: easier distribution, independence of space and time, potentialities of hypertext and multimedia etc.
In the field of Geoinformation and Earth Sciences a lot of projects have been carried out to use the potentials of the World Wide Web. This paper describes the current situation of E-Learning-tools in the field of Geoinformatics and Earth Sciences with some emphasis on German examples. One of them is the project "Virtual Landscape" of the "E-Learning-Academic Network" (ELAN) in Lower Saxony, Germany. The project aims to develop an E-Learning-Environment for students in Earth Sciences, such as Geodesy, Geoinformatics, Geography, Environmental Studies, Landscape Planning as well as students in Applied Computer Science. By supporting the action-oriented teaching concept the development of a "Virtual Landscape" will provide an interactive tool to explore and work with geodata. Special modules will guide students through the work with the data and give problems to solve. The main characteristics of this project is therefore – as opposed to projects providing only E-Learning material in terms of courseware – the explorative learning approach. Furthermore, the multidisciplinary focus is also unique.
The article gives an overview on the concepts of that E-Learning-Environment as well as to the technical structure of web-based geodata visualization and interaction.

1. INTRODUCTION

1.1 Motivation and overview over paper

Using the World Wide Web for distributing information and knowledge has become standard years ago. Meanwhile also spreading and sharing of learning materials is usual via WWW. However, as "web-based learning materials" not only texts and slides should be considered.
This project is motivated by the idea to provide a learning environment which utilizes the potentials of the World Wide Web, such as interactivity, dynamic and multimedia. By doing so learning may become a more interactive process, possibly even playful and experimental – like the action-oriented approach of learning concepts provides for.
The project is carried out as a cooperation of the "Competence Centre for GIS" at the University of Hannover. ("GIS-Zentrum" der Universität Hannover", http://www.gis-zentrum.uni-hannover.de/). Herein scientists from different disciplines are organised to share their knowledge, experience and ideas, as well as conduct joint research initiatives.
Hence the "Competence Centre for GIS" forms a representation of the variety of Earth- and Geoinformation-Sciences. The Virtual Landscape will on the one hand use this competences to highlight the landscape as diverse as possible. On the other hand the Virtual Landscape may consolidate the relations within the Competence Centre by providing a common infrastructure for provision of teaching materials and data to work within the interdisciplinary scope.

In the presentation, after a review of related work, the concept of the "Virtual Landscape" is described firstly from a didactic point of view. Then, implementation issues are described, with a special focus on the infrastructure to set up the "Virtual Landscape". The main component being a web-service architecture presenting 2D and 3D vector data. A summary and an outlook conclude the paper.

1.2 Related Work

During the last years several projects have been devoted to providing a broad base of E-Learning content for the World Wide Web. Notably, at the MIT the OpenCourseWare initiative has acted as stimulator to similar projects all over the world (http://ocw.mit.edu/index.html).
In Germany there may be noticed different initiatives providing content for the field of GIS: 'geoinformation.net' and 'gimolus' have been stimulated by a governmental program ("Neue Medien in der Bildung") and have recently come to an end.

'geoinformation.net' covers a complete curriculum for a course of study in Geoinformatics. Slides and self-studying-units, enriched by pictures and animations form the knowledge-base. For practical exercise, the so-called "Geo-Café" has been developed. This constitutes a learning- (and discussing-) environment for spatial analysing techniques and methods. In addition an infrastructure for web-based geodata-delivery has been developed as the so-called "Web Portal". The infrastructure is based on OGC-conform services, known as Web Feature Service, Web Map Service or Web Catalog Service (Bode, T. et. al., 2004; Simonis, I. & S. Merten, 2004). Establishing such an infrastructure has a lot of links and inspiration to the project introduced in this paper. Technically 'geoinformation.net' provides high quality by its Web Portal, only it lacks of examples for integrating this technology into E-Learning-scenarios.

'gimolus' ("GIS- und Modellgestütze Lernmodule für umweltorientierte Studiengänge"/ engl.: "GIS- and Model-Based Learning Modules for Environmental Sciences") lays its

emphasis on environmental studies. However, a few units cover GIS-subjects (cp. Weippert, H. & D. Fritsch, 2002) and thus introduce to work with a "Virtual Landscape". This Virtual Landscape is constructed by datasets from different disciplines (e.g. hydrology, botany, landscape planning etc.) of a real-world area. To work within the Virtual Landscape a web-application was implemented. This is an architecture partly based on ESRI-products and partly based on Open Source. Müller, M.(2004) describes the quite complex infrastructure.
The gimolus-project shows an impressive collection of software and web applications. It gives an idea of functionalities and application of web-based work with geodata. However the experiences made in gimolus give also an insight into problems and obstacles encountered when building such a complex infrastructure: they relate to technical issues on the one hand and future support on the other hand.
The project FerGi ("Fernlernmaterialien Geoinformation"/ engl.: "Materials for Distance Learning in Geoinformatics") aims to provide relatively short units of very special tasks. It is targeted at advanced topics that are not yet included in conventional curricula. Furthermore, it also focuses on further education (Schiewe, J. et al., 2004).
Examples of other projects, not further described in this paper are :

- GITTA (Geographic Information Technology Training Alliance) in Switzerland. (http://www.gitta.info/ - cp. Lorup, E.J. & S. Bleisch, 2003)
- LEAP (Learning Effectiveness Alliance Program) at the Department of Spatial Sciences/ University of Curtin. (http://www.cage.curtin.edu.au/leap/ - cp. Metternicht, G. , 2003)
- WEBGEO – development of web-based learning modules for the basic education in physical geography (http://www.webgeo.de) (Saurer, H. et al., 2004)

2. CONCEPTS OF THE PROJECT "VIRTUAL LANDSCAPE"

The project "Virtual Landscape" is carried out within the scope of the joint project "E-Learning-Academic Network" (ELAN), which aims to provide a broadly spread network of E-Learning in different disciplines in the state of Lower Saxony, Germany.
The idea of this project is to represent the landscape virtually in order to provide an intuitive entry point for studying the landscape, its genesis, the spatial processes occurring on it, but also models for describing and analyzing it. The project consists of three main components: a virtual landscape, learning material related to it, as well as modules in terms of applications or scenarios (see Figure 1).

2.1 Action-oriented learning

Using the Virtual Landscape supports the action-oriented concept of learning. The advantages of such a concept are described by Riedl, A. & A. Schelten (2002): Cognition and cerebration will only be a complete action when implemented in practise. Human action is mentally tested before acting, depending on cognition and cerebration. The comparison of the mental plan with the real action will feed back on the mental map of the doer. The back coupling to cognition and cerebration will alter and extend these as well as evolve new cognitive structures. Riedl, A. & A. Schelten (2002) further reason that learning without execution of actions remains at the state of mental action and therefore remain distant from real acting. To counter that danger an interactive environment is aspired.

2.2 Content

The target group for using the developed E-Learning-Environment are students in Earth Sciences, such as Geodesy, Geoinformatics, Geography, Environmental Studies, Landscape Planning as well as students of Applied Computer Science. These students have to learn how the landscape evolved, how the processes in it work and are interrelated, as well as how to make decisions concerning the landscape and how these forms and processes may be represented and analysed in (digital) data. Based on fundamental questions raised during the exploration of the virtual landscape, course material is attached that explains these phenomena or provides the necessary background for them.
The overall bracket in the Virtual Landscape project consists of learning materials for basic principles of GIS. At the moment courses, such as "Webcartography" and "GIS: structures and architectures for the Internet" are under development. Its content is designed for the use in blended-learning-scenarios.

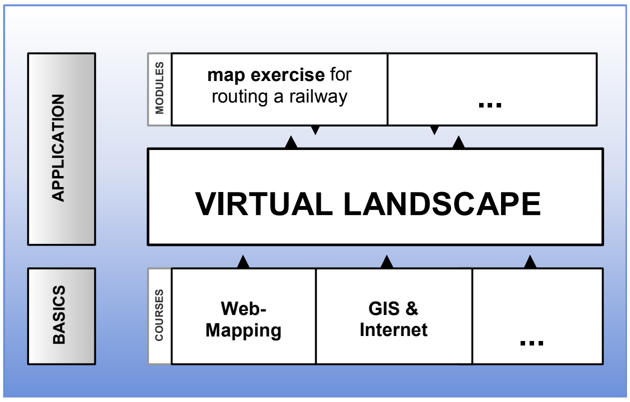

Figure 1: Components of the project.

2.3 Applications

As illustrated in Figure 1 applications of the mentioned disciplines may be integrated in form of text-based units, enhanced by animations, interactive illustrations and tests. They should provide the base for the so-called "modules", which are designed to guide students through application tasks within the Virtual Landscape. A "module" will –visually spoken – be put on top of the Virtual Landscape. To work with a task in a module the Virtual Landscape supplies datasets and tools for exploring and analysing data. For that an infrastructure – described in section "3. Implementation" - will be provided.
An example for a module is a map exercise of a planning process for routing a railway line. This module is developed by the Institute of Regional Planning and Regional Science of the University of Hannover. The map exercise is carried out within a hands-on seminar. There students should solve a complex task by running through the different stages of decision making: from analysing data according to their relevance for a planned project, via deliberating about alternatives unto disputing the decision.

For the developed map exercise the process of planning a railway line in the Hameln-Pyrmont-county was chosen. The routing process takes place within the scope of the extension of a existing route, basically used for freight traffic. The extension is necessary to disburden another route, and to avoid the high-frequented traffic agglomeration of Hannover.

There are lectures that give detailed information and an introduction into the task. Thereby personal attendance is compulsory. In terms of a blended-learning concept the planning process will be exercised within the Virtual Landscape. For this the basic geodata and the data of a landscape framework plan are provided. The latter contains data like different soil parameters, areas of groundwater regeneration, water protection areas, flooding areas, areas of biotope protection, areas of recreation, noise corridors etc. Tools for exploring and analyzing data are supplied in the web-based environment.
For visualization and analysis 2D and 3D-views are used. For many applications, mainly in the field of analyzing, 2D-data is not only reasonable but also better and more easy to handle. However, for many other tasks perspective views are necessary. Such tasks are e.g. visibility analysis, dissemination of noise or visualization in planning processes (Petschek, P. & E. Lange, 2004).

3. IMPLEMENTATION

Due to the fact, that the project aims to establish a dynamic and sustainable web-based E-Learning-Environment, a system based on standards and Open-Source products is about to be implemented.
The learning materials for basic knowledge consists of texts, images, interactively explorable illustrations, animations and tests. The websites are usual HTML, generated by PHP. For the creation of assets PHP, JavaScript or Flash were used. Tests are constructed as dynamic HTML-forms (based on PHP). At the moment we are about to test the use of Macromedia's Authorware for designing tests as well.
The inseparable engagement to a commercial Learning Management System (LMS) has been avoided due to dependencies and high amount of administration. However the developed content may be put in a LMS at every time.
Even though Learning Management Systems offer a lot of reasonable features, those functions did not seem as necessary for the application in our blended-learning scenario as to legitimate the high administration effort.

3.1 Course Material and didactic issues

The developed environment in this project is fit out with a lot of features to make the learning- and communication process comfortable, such as:

- clear arrangement of courses and units,
- linear navigation through the material,
- possibility to skip between the tasks according to personal knowledge and interest,
- tests to check progress,
- references to sources and for further reading - individually assigned to every website,
- generation of personal reference list,
- generation of personal print version in PDF-format of chosen sites,
- contact to a support-person via e-mail.

The materials are build based on common rules for ergonomic internet work (Buchholz, G.A., 2003; Nielsen, J. 1997; Nielsen, J., 1999). These rules take into account, that reading in front of a screen is different than reading a paper article in terms of exhaustion, amount of accessible information and therefore style of reading.
Some of those rules are listed in table 1.

Concern	Rule
avoidance of exhaustion of eyes	- use of light background and dark letters to provide contrast - avoidance of completely white screen as a background due to blinding effects - use of font size at least 10 –14 pt. - use of fonts without serifs, such as Verdana, Monaco, Geneva or New York to avoid squiggly fonts - avoidance of italic fonts
provision of better orientation within the text	- avoidance of complete words written in capitals for better cognition of distinct words - avoidance of underscores when text should not be marked as a link - highlighting of keywords to support recognition of important paragraphs due to the fact that an internet user is rather scanning the text than reading it - avoidance of justification of paragraphs to allow for orientation when reading
assurance of meaningful outline of internet-texts	- inclusion of strong meta-contents, such as headlines, subtitles, labels etc.) - order of text in the way that the important message comes first (and verbose introductions are avoided) - construction of effective texts, e.g. by using prompts, avoiding exuberant use of adjectives and putting further information behind the links - taking in mind that people is able to memorize approx. 7 units (e.g. prompts) for a distinct fact (e.g. not listing lots of prompts) - provision of further reading and links at the end of the text
support of cognition and memorizing the content	- promotion of multi-coding, e.g. application of text and graphics for providing information in different ways - promotion of multi-modality, e.g. graphic - and acoustic signals to allow cognition - through different senses

Table 1: Rules for Creation of Ergonomic Internet Documents (cp. Buchholz, G.A., 2003; Nielsen, J. 1997; Nielsen, J., 1999)

3.2 Technical issues implementing the Virtual Landscape

As illustrated in Figure 1 the Virtual Landscape is laid on the top of the course content. In most cases it may be directly accessed from the learning materials. Depending on a special task dealt in the materials, a distinct view upon the landscape will be opened. When carrying out a map exercise for planning tasks, e.g. data of sanctuaries are provided. Analysis of soil erosion potentials requires e.g. data of soil type, soil texture, description of soil horizons or precipitation.
The infrastructure "behind" the Virtual Landscape is based on a system shown in Figure 2. It has to fulfil the following basic requirements:

- allowing easy data access on possibly distributed data sets
- visualization of data in 2D
- visualization of data in 3D
- basic analysis tools in 2D (and 3D)

An architecture, according to the OGC-conform visualisation process – described by Cuthbert's Portrayal Model (cp. Fig. 3) – was set up (cp. May et al., 2003; Fitzke, J. & K. Greve, 2002).

This infrastructure basically supports the standardized access to geodata via web-services, as well as the adequate portrayal of this data.

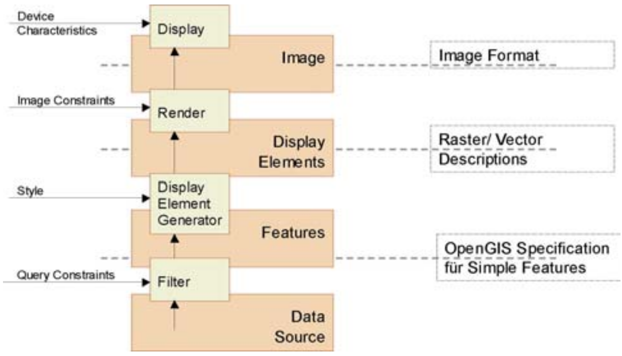

Figure 3: Cuthbert's Portrayal Model – reference for the visualisation pipeline (cp. May et al., 2003; Fitzke, J. & K. Greve, 2002)

3.2.1 Available Data, Data Formats, Metadata and Data access

The (vector) data are stored in a database (Postgis, Oracle). The description of the data is stored in a meta-database. As the meta-database a software developed by the Department for Environment in Lower Saxony ("Niedersächsisches Umweltministerium") is used (http://www.udk-gein.de/). This catalog-software (Umweltdatenkatalog – UDK) stores information such as spatial reference, scale, quality, capturing method, if necessary temporal reference, data type, availability as well as keywords in a database and performs spatial- and keyword-based search.

At the moment the meta-database does not conform to a standard for describing geographic data. However from the next version (UDK 5.0 – to be released this summer) the catalogue software will accord to ISO/TC 211-19115, standard for metadata and to ISO/TC 211-19119, standard for services.

The idea is to connect this meta-information catalogue to the database storing the geodata to allow meta-information-based selection of the geodata.

By using the meta-database's search-feature the data associated to a keyword or an area may be identified and queried from the database. Querying the desired geodata from the database is accomplished by a Web Feature Server (WFS), such as the Open-Source product Geoserver (http://geoserver.sourceforge.net/html/index.php, OGC, 2002b). By adding query constraints (e.g. by specifying filters) this process corresponds to the filter-process visualized in Fig. 3.

The Geoserver-WFS delivers data in GML 2.1.2. The Geography Markup Language is an XML-based language. It was developed for transport and storage of geographic information, including both the geometry and properties of geographic features (OGC, 2002a).

Due to the fact that the GML-specification is concerned with the OGC Simple Features (OGC, 1999) the features' geometry properties is restricted to 'simple', such as point, curve, linestring/line/linear ring, surface and polygon. However unlike the Simple Feature Specification, GML allows for 3D coordinates, but it does not directly support 3D geometry constructs (Dorninger, P., 2003).

3.2.2 Data presentation in 2D and 3D

GML is not concerned with visualization of the data. There is the possibility to add a Web Map Service (WMS), such as Geoserver WMS, which delivers the data in terms of raster maps, so no concern about visualizing the GML delivered by WFS becomes necessary. However, following the aim to have direct influence on visualization, like using special style or displaying distinct data, selected by attributes in a special way, as well as adding further functionality, the visualization process must developed individually.

Due to the fact that GML is an XML-description for geodata, it may be transformed – like other kinds of XML-schema – into a

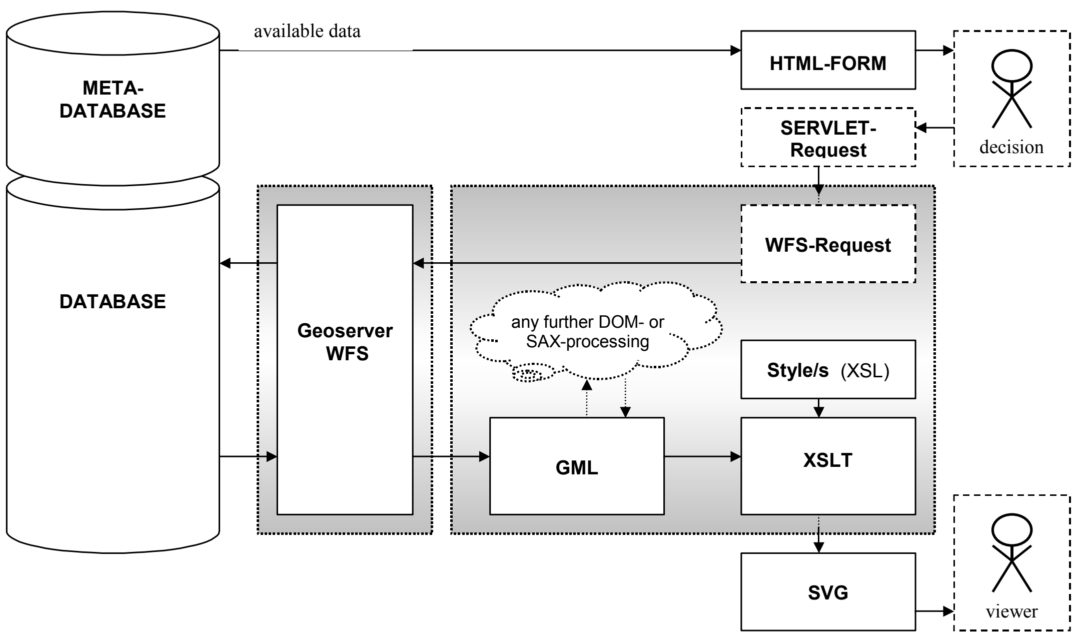

Figure 1: Architecture for the web-based geodata-infrastructure

different XML-structure, such as SVG or X3D – formats used for web-presentation of vector data (Dorninger, P., 2003).
Transformation instructions for the conversion from one XML-Schema into another XML is described in the XSLT („Extensible Stylesheet Language Transformation") 1.0 Recommendation (Lehto, 2001). XSLT is designed for use as part of XSL, which is a stylesheet language for XML, i. e. it includes an XML vocabulary for specifying formatting (http://www.w3.org/TR/xslt). The transformation proceeds when a XSL-transformation engine processes an XML-document (e.g. a GML-document) and an XSL-stylesheet. A list of available XSLT-engines and editors may be found at http://www.w3.org/Style/XSL/.

To carry out the transformation process a serverside Java-application for XSL-transformation has been implemented. At this stage some further processing of the GML data is feasible by applying SAX and DOM.
The Simple API for XML (SAX) is used as a popular XML parsing method (http://www.saxproject.org/). The SAX method may be used for scanning through XML data top to bottom and sending notifications as elements, text, and other items are encountered; it is up to the recipient of these events to process the data. SAX parsers do not store the entire document in memory therefore they have the potential to be very fast for even huge files (Burke, E. M., 2001).
In comparison the Document Object Model (DOM)–API allows in-memory representation of XML as a so-called DOM-tree. (http://www.w3.org/DOM) Applying DOM-methods the manipulation of the underlying data structure of an XML document becomes possible.
Using SAX- or DOM- API even the GML-data could be processed when passing through the serverside Java-programm (servlet). However, at this state just some first experiences have been made in this field.
Using a Xalan–Java XSLT-processor and Java-Servlet Technology (http://xml.apache.org/, http://xml.apache.org/xalan-j/) a serverside XSL-transformation from GML to SVG has been implemented within the transformation-servlet.
Within the serverside transformer-application the GML-data is directly requested from the WFS as a URL, such as
"http://<host>/<webapps-directory of geoserver>/wfs?request=GetFeature&<filter-encoding>.
At the level of the WFS-query the filter may be varied by constructing the URL dynamically within the servlet. By that the filtering-process (cp. Fig. 3) may be influenced. Such a functionality allows to dynamically restrict the delivered data to a subset of object instances (OGC, 2001).
The transformer-servlet also visualizes data in SVG on-the-fly by applying a stylesheet (XSL-file). This step conforms to the "Display Element Generator" in Figure 3.

The next steps according to Figure 3 are carried out by the SVG-viewer, which must be available on the client's side.
Due to that allocation (Filtering and Display Element Generation on the server's side and Rendering and Displaying on the client's side) a Medium Server - Medium Client-Architecture according to Schmidt et al. (2003) is provided. As Altmaier & Kolbe (2003) state, the advantage of medium clients is that plug-ins typically provide functionalities for realtime rendering and navigation and therefore allow high degree of interaction.

Using a similar infrastructure it may be possible to visualize data in X3D, the successor of VRML.
X3D disposes of an advanced syntax which is XML-based. Hence it can be validated against a DTD (http://www.web3d.org/specifications/x3d-3.0.dtd) or a dedicated schema (http://www.web3d.org/specifications/x3d-3.0.xsd).
For X3D six so-called profiles may be distinguished. Each of it covers different functionalities at different stages of complexity. Full implementation of the X3D-specification features the "Full profile". In contrary the "Immersive profile" covers the VRML-standard, for which X3D is downward compatible (Krone, O, 2003; http://www.web3d.org/x3d/specifications/index.html).
X3D has been chosen due to the fact that it is XML-based. Furtheron the idea of profiles in X3D offers extensibility for the format.

The 3D coordinates have to be provided for the generation of X3D either in form of height values for a regular raster for use in the "ElevationGrid"-Node or in form of 3D-vector-data-coordinates for use in the "IndexedFaceSet"-Node of X3D. As already mentioned GML is able to represent 3D – coordinates. Therefore the WFS has to be modified in a way to be able to query 3D data and send it as GML. As Altmaier & Kolbe (2003) state, applications that employ OGC web services for 3D geo-visualization are rare. However, an example of such a service is the Web3D Service (W3DS), developed by the SIG 3D of the DGI NRW (acronym for the German initiative "Geodaten-Infrastruktur Nordrhein-Westfalen"). It is based on the proposal of the Web Terrain Service (WTS) and extends it by the explicit consideration of 3D features (Altmaier & Kolbe, 2003). A client to that W3DS may be explored under http://wmc.ikg.uni-bonn.de/w3ds/. It has to be found out in which way the W3DS-development may support the Virtual Landscape.
Alternatively X3D must be generated from GML applying an XSLT-process (Lehto, L, 2001; May, M., 2003). However in case of vector data the specification of the polygonal mesh has to be carried out, e.g. by implementation of a triangulation. This job could be done either by a (serverside) program or prepend as a DOM-based method before the XSL-transformation.

3.2.3 Analysis Methods

To explore the delivered 2D- and 3D-data functionalities like Pan, Zoom, Select and Query are provided. Zooming and Panning are features included in the SVG- and X3D-Viewers. Queries may be implemented using JavaScript, triggering the database query. Carrying out spatial analysis, functionalities like buffering or clipping are desirable. Those functions have to be implemented after consolidating the architecture.
The Virtual Landscape aspires a lot of functionalities of a Geographical Information System. However it does not aim to feature the full functionalities. Advanced analysis does not have to be carried out in a web-based environment. However, within the educational scope students might not have access to GIS-software at any time or place. For them an introduction into the ideas and basic functionality should be provided, for which the designed architecture is very suitable.

4. CONCLUSION AND OUTLOOK

The complex infrastructure for the Virtual Landscape is partly implemented. However, for some components we still lack of experiences. This deficiency has to be eliminated.
Within the next steps the transformation from GML into X3D has to be carried out. Further the question of how 3D-coordinates via a WFS may be delivered has to be answered.
In terms of providing some basic functionalities for analyzing the geodata it will be challenging to find out whether such functions should be implemented at the level of the database (e.g. using the functionalities of Oracle Spatial) or at the level of the GML-data. For the latter the potentials of SAX- and DOM-processing within the GML-data must be made clear.
Finally these technical components must be composed to a learning environment taking in mind didactic issues. This means that examples have to be provided to illustrate content. Further on meaningful tasks for working and experimenting with the Virtual Landscape have to be assigned to guide students in their learning process. Help and feedback functionalities are essential and therefore must be provided.
After all the application has to be tested and evaluated in a blended learning-scenario.

5. REFERENCES

Altmaier, A. & T.H. Kolbe (2003): Applications and Solutions for Interoperable 3d Geo-Visualization. In: Fritsch, D. (ed.): Proceedings of the Photogrammetric Week 2003 in Stuttgart, Wichmann Verlag.

Bode, T., Devooght, I., Kolbe, T.H., Steinrücken, J. & M. Won (2004): GeoCafé – Kommunikationszentriertes Gruppenlernen von Methoden der raumbezogenen Datenverarbeitung. In: Plümer, L. & H. Asche (2004): Geoinformation – Neue Medien für eine neue Disziplin.

Buchholz, G.A. (2003): The 10 Commandments of Internet Writing. http://www.contentology.com/weblog/weblog_06-2003.html

Burke, E. M. (2001): Java and XSLT. O' Reilly, Sebastopol.

Dorninger, P. (2003): XML Technologies and Geodata. In: CORP-Tagungsband, 2003.

Fitzke, J. & K. Greve (2002): Umweltkarten im Internet: Das Potential von WebMap-Services. In: Kartographische Nachrichten, 6.

Katterfeld, C. & M. Sester (2003): Virtuelle Landschaften für E-Learning-Umgebungen. Contribution to the "web.mapping – Sysmposium 2003", Potsdam.

Krone, O. (2003): Webfähige interaktive 3D-Visualisierung von Proteinstrukturen. Diploma Thesis at the University of Osnabrück. (http://www-lehre.inf.uos.de/~okrone/DIP/Diplomarbeit.html)

Lehto, L. (2001): Multi-purpose Publishing of Geodata in the Web. In: Papers of the Nordic GIS Conference, Helsinki. (http://www.ginorden.org/konf/getpaper.php?ID=67)

Lorup, J.E. & S. Bleisch (2003) : Schweizweite GIS-Ausbildung mit GITTA – Aufbau und Organisation. In: E-Learning in Geoinformatik und Fernerkundung. Wichmann, Heidelberg.

May, M., Schmidt, B., Streit, U. & C. Uhlenküken (2003): Web-Service-basierte 3D-Visualisierung im Umfeld der Raumplanung. In: CORP-Tagungsband, 2003.

Nielsen, J. (1997): How to write for the Web. http://www.useit.com/papers/

Nielsen, J. (1999): Differences Between Print Design and Web Design. http://www.useit.com/alertbox/990124.html.

Metternicht, G. (2003): Expanding Distance Education In The Spatial Sciences. In: Proceedings of the 21th International Cartographic Conference (ICC), Durban.

Müller, M. (2004): gimolus – GIS-und modellgestütze Lernmodule für umweltwissenschaftliche Studiengänge. In: Plümer, L. & H. Asche (2004): Geoinformation – Neue Medien für eine neue Disziplin.

OGC (1999): OpenGIS Simple Features Specification For SQL, Revision 1.1. Document-Number 99-049. http://www.opengis.org/docs/99-049.pdf

OGC (2001): Filter Encoding Implementaiton Specification. Version 1.0.0. Document-Number 02-059. http://www.opengis.org/docs/02-059.pdf

OGC (2002a): OpenGIS® Geography Markup Language (GML) Implementation Specification, version 2.1.2. Document-Number: 02-069. http://www.opengis.org/docs/02-069.pdf

OGC (2002b): Web Feature Service Implementation Specification, version 1.0.0. Document-Number 02-058. http://www.opengis.org/docs/02-058.pdf

Petschek, P. & E. Lange (2004): Planung des öffentlichen Raumes - der Einsatz von neuen Medien und 3D Visualisierungen. In: In: CORP-Tagungsband, 2004.

Riedl, A. & A. Schelten (2002): Handlungsorientiertes Lernen. http://www.paed.ws.tum.de/downloads/hu-rie-sche.pdf

Saurer, H., Fuerst, R. & H. Großmann (2004): WEBGEO – Geographie online lernen ! In: Plümer, L. & H. Asche (2004): Geoinformation – Neue Medien für eine neue Disziplin.

Schiewe, J., Ehlers, M. & B. Grenduns (2004): Fernstudienmaterialien Geoinformatik (FerGI) – Konzeption und erste Implementierungsschritte. In: Plümer, L. & H. Asche (2004): Geoinformation – Neue Medien für eine neue Disziplin.

Schmidt, B., May, M. & C. Uhlenküken (2003): Dienste-basierte Architekturen für die Web-basierte 3D-Geovisualisierung. Münsteraner GI-Tage, 26.-27.06.2003 (http://www.conterra.de/service/presse/archiv/)

Simonis, I. & S. Merten (2004): Die Geodateninfrastruktur des Webportals geoinformation.net. In: Plümer, L. & H. Asche (2004): Geoinformation – Neue Medien für eine neue Disziplin.

Weippert, H. & D. Fritsch (2002): Development of a GIS-Supported Interactive „Remote Sensing“ Learning Module. In: Zeitschrift für Photogrammetrie und Fernerkundung – Supplement, 9.