INTEROPERABLE LEARNING ENVIRONMENTS IN GEOSCIENCES – A VIRTUAL LEARNING LANDSCAPE

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ABSTRACT:

E-Learning has reached the geosciences as well as many other subjects. As in other domains E-Learning has produced high prospects for teaching geosciences in the first instance. Many major research and development projects have been carried out and developers now have a clear understanding of what is possible with which amount of effort. From the technical point of view the implementation of E-Learning functionality has been quite successful. However, from experience we have also learned that conceptual and didactical considerations are very important for the effective employment of E-Learning tools. From the didactical point of view constructionist learning theory fits most of the E-Learning demands. As a consequence action-orientated approaches should be implemented which require high proportions of interaction functionalities. In our case we think of a Virtual Learning Landscape as a data-based interaction environment.

The successful design and implementation of a Virtual Learning Landscape leads to challenges both on the content related conceptual side and the technical implementation side. We aim to address these challenges by providing support for interoperability both on the content and implementation side.

Planning and implementing functionality-intense environments is quite resource consuming. Furthermore, such environments are mostly applied to a certain application and/ or a certain area and are thus restricted to a special application or become obsolete after some time.

This paper describes our approach for building interoperable learning environments. This includes the technical as well as the conceptual side. By focusing on interoperability we want to address different aspects. First, that technically complex architectures or programs may be used repeatedly for different learning scenarios, different datasets or even with different content. Second, that in terms of web-based architectures, the interoperability idea has almost reached the state of standards, although practical adoption still remains limited in many parts. The Open Geospatial Consortium (OGC) has suggested suitable standards for web-based data delivery in the geospatial context. We want to make use of these developments and integrate these technical ideas into E-Learning environments. This paper describes, how established standards like the Web Feature Server (WFS), the Web Map Server (WMS) and the Web 3D Server (W3DS) may be used to provide the data for a Virtual Learning Landscape in an interoperable way.

Conceptual interoperability is another key idea that we address. When different learning contents shall be provided within the same learning environment without much re-construction of the application, we need an interoperable way to formulate the content as well as the concepts of how to teach the task. Ontologies are currently used in many fields to express or define objects, concepts and relations between them. We examine if (and how) ontologies may possibly used to express learning content and introduce the idea of establishing an “EduOntology” for distinct learning issues.

1. INRODUCTION

The great potential has turned E-Learning into a well-discussed issue during the last decade.

Benefits of E-Learning include:

- flexibility of learning with respect to time and space,
- adaptation to individual interest and previous knowledge,
- interactivity and dynamics,
- more effective presentation through multimedia,
- providing access to complex domains, incorporating interaction and simulation for features that are not accessible in the real world,
- increased motivation (cp. educational gaming, edutainment),
- support for different learning styles and learner types, i.e. variety in the conceptual design of materials,
- access to distributed data,
- world-wide availability of education on highly specialised subjects and
- establishing of learning-communities that overcome the isolation of traditional distance education.

With these benefits in mind we give an overview of the situation of E-Learning in geosciences and will deduce the challenges of E-Learning environments especially for this field of application in the first chapter.

To particularize some challenges we will focus on the issues of 3D visualization and interactivity. As the main point we then expound ideas of interoperability and standardization in the technical sense as well as in the contextual sense.

2. LEARNING ENVIRONMENTS IN GEOSCIENCES

Symptomatic for learning in the geosciences is the fact, that many relevant aspects are distributed in the real world.

Teaching those is e.g. covered in field trips, where interaction with the real environments is typically not possible due to environment size, need for reversibility of actions as well as cost and time constraints.

Virtual environments may counter that problem by providing the learners with interaction possibilities to develop an intuitive understanding of a subject. However, the practical application of virtual environments for such purposes is currently hindered by technological constraints as well as the high cost of content production.

Hence much E-Learning content in Geosciences has been produced as web-based "lecture-note"-like materials. Examples of those impressing collections are e.g. geoinformation.net[1] (Germany), GITTA[2] (Switzerland) or the e-Map Scholar[3] (UK). While these collections provide a huge amount of information and many interactive assets they remain rather text-loaded and do not fully use the potentials of the WWW. To create valuable E-Learning experiences and justify the cost of web-based teaching methods beyond initial research projects will require adequate use of the special features offered by the WWW in the future.

Utilization of extended technical but also conceptual approaches are even more needed because geosciences (i.e. geodata-based learning) demand for a special way to present data and information and provide special interaction tools. Thus e.g. the term *learning environment* may be understood literally because a presentation of a natural environment can be provided. We will here speak of a "Virtual Landscape" to emphasize the natural environment as the matter of learning. This implies issues like e.g.:

- requirements of using "real" geographic data (with all its features like e.g. projection, scale etc.) to simulate the "real" environment,
- requirement to integrate data from different sources,
- enabling of reasonable interaction with the geometric, but also thematic level of the geodata and
- possibly incorporating further simulation and / or multimedia techniques to convey special kinds of information (e.g. a process with temporal aspects inherent).

These requirements give a strong argument for the use of the WWW as a means for education.

Some projects have already attempted to go beyond lecture notes and implemented such interactive, explorative learning environments using WWW and multimedia potentials. Examples for such an approach include:

Virtual Field Course (Dykes et al., 1999): The Virtual Field Course (VFC)[4] – carried out at the University of Leicester / UK – was undertaken to address the use of virtual environments and information technology in teaching fieldwork for geologists, biologists, geographers, planners and architects.

Ocean Science Learning Environment "Virtual Big Beef Creek" (Campbell et al., 2002): A collaborative three-dimensional online learning environment for ocean-scientists was provided by the University of Washington. The environment enables users to navigate through a data-rich representation of an estuary on Washington's State's Olympic Peninsula. The learning environment should prepare users for a fieldtrip. Another goal was to provide an online repository for geo-referenced data obtained through fieldwork.

Gimolus (Müller, M., 2004): gimolus[5] provides learning materials for students from environmental science using a complex web-architecture that is largely based on commercial products. Using terminal-client students can log on to an application server that provides GIS 2D-data and software. Using a wide variety of data from distinct area learners can carry out exploration and analysis for several relevant issues within the same area.

These projects give an impression of how the implementation of a learning environment based on geodata-use could look like. Apart from the requirement for the use of web-based learning facilities, another point of view to motivate web-based learning environments in geosciences should be taken up as well: The Spatial Data Infrastructure (SDI) has become a big task in the field of geoinformatics. Much work has been carried out – in first instance – from the technical side. Standards and services have been developed and are – more or less – successfully implemented and accepted. However, practical adoption is much slower than initially expected. Location Based Services[6] (LBS) on Mobile Phones and PDAs provide a wide variety of applications that can benefit from SDI. These include online map-services (e.g. city maps, aerial images, historical maps etc.). Information systems with possibly restricted access, like property search or tools for public participation in planning processes are other applications that base on the technical principles of SDI. While these use cases are well examined they do not yet produce the expected amount of economic impact. The establishment and acceptance of further applications is needed to enhance the use of web-based geodata delivery. Learning environments could be one of such a use case.

3. CHALLENGES OF 3D LEARNING ENVIRONMENTS FOR THE GEOSCIENCES

The projects introduced in the former section illustrate – representative for others – the great possibilities both for virtual reality-based as well as "just" 2D-data-based learning environments. Due to the fact that some of the learning material is not accessible at the moment, it must be concluded that sustainability of complex E-Learning environments remains a big issue. Another issue is the fact that many projects are restricted to either a certain task and / or a certain area. This restricts their application and hence sometimes not legitimates the cost of implementation. Here interoperability (i.e. implementation of standardized interfaces) could provide a solution. The problem of sustainability could probably be addressed in this way as well. Concerning the technical requirements the standards for a web-based-(geo)-data architecture may be derived from the SDI-development and – if necessary – adjusted to the learning application.

Due to the need of an advanced environment, 3D visualisation and simulation are techniques to incorporate. Standards and "best-practice"-examples exist. However, their application for learning is – in most cases – still at an experimental state.

These issues have to converge in the step of (conceptual and technical) scenario-design. Such a scenario-design must provide theory and tools for expressing and implementing the learning objective, particular learning procedures and the learner's interaction possibilities. The special challenge of scenario-design is the requirement of a standardized approach. This is a

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[1] www.geoinformation.net
[2] www.gitta.info/
[3] http://edina.ac.uk/projects/mapscholar/index.html
[4] http://www.geog.le.ac.uk/vfc/index.html
[5] http://www.ilpoe.uni-stuttgart.de/cgi/caya/index.php?id=3&loc=en
[6] (cp. e.g. Gartner, 2003)

difficult task due to the need of abstraction and standardization of conceptual issues. Those conceptual standards still have to be developed. Our current work aims to contribute to this.

Finally the individual requirements in terms of previous knowledge, specific user interests, as well as preferences for special data presentation or interaction techniques could (and should) be met by "individualization". Individualization is another quite challenging issue and of high importance to improve usability and acceptance of E-learning environments. While our standard-based approach has been designed with user specific customization in mind a detail discussion of the topic is beyond the scope of this paper.

The challenges in terms of standardized web-based education in geosciences are:

- sustainability,
- interoperability (use of SDI-standards),
- 3D visualization and simulation,
- interactivity with geodata (application of constructionist learning approaches),
- scenario design and
- individualization.

Within this paper we want to emphasize two aspects. On the one hand we will focus on 3D visualization and interactivity to facilitate the constructivist (i.e. explorative) learning approach. On the other hand we want to look at an interoperable way of scenario design. This point includes interoperability issues in terms of techniques and concepts.

4. 3D-VISUALIZATION

The value of visualization in 3D and perspective presentation in terms of effective communication of spatial content has been generally motivated by many authors, e.g. MacEachren et al. (1999), Verbree et al. (1999), Petschek & Lange (2004), Tiede & Blaschke (2005).

Learning systems targeting environmental phenomena can benefit from the inclusion of 3D content and presentation because of:

- vivid presentation of geo-spatial information,
- immediate visibility and better understanding of results and
- removal of forced abstraction and indirection. (Abstraction is not inefficient in every case. However it is desirable not to be restricted by technology, but be guided by didactical arguments. Flexible change between realism and abstraction may possibly help to bridge between both dimensions.)

While these factors have been the driving force for the development of 3D GIS, 3D city models and the proliferation of 3D visualisation in geosciences in general they can be especially useful in E-Learning for learners because they allow to establish a more direct correspondence to physical reality.

Web-examples of implementations of such environments for learning purposes are e.g. CNN's visualization of a hurricane[7] or the "Nerve Garden"[8] (Damer et al., 1998). These examples show what is technically possible. However, most existing virtual environments stress the aspects of exploring the space and thus act – in case of the display of geodata – "just" as a multidimensional variation of a traditional (topographic) map. Very few of such environments have integrated the textual dimension in terms of additional learning contents.

Two ways are possible to meet that requirement: The first is to *provide* explicit information into the scene, which may then be detected and learned by exploration and interaction. Secondly there is the potential to give the learner the possibility to *gain* (explicit, but also implicit) information by providing interaction / exploration as well as analysis tools.

Systems, offering sophisticated analysis functions for 3D data can be referred to as "3D-GIS". Such software provides useful tools to explore and analyze 3D data but is not especially designed to support learning. The knowledge of how to work with the system and the data must be brought into the process by the intelligent user of the software. Integration of feedback or instructional knowledge etc. is not envisioned.

Approaches to encounter that lack will be suggested in the chapter about contextual interoperability. While many issues in effective application of 3D in education (in geosciences) still have to be solved, the general value has been demonstrated successfully in existing prototypes and further development in concepts is required.

5. INTERACTIVITY

Most action-orientated systems are based upon the constructionist learning method, which is build upon the idea that reality may not be considered as external. Therefore, every learner has to build his knowledge structure by himself starting from his own needs and previous knowledge. Riedl & Schelten (2002) reason that learning without execution of actions remains at the state of a mere mental action and therefore stays distant from real acting.

General theses on constructivism may be summarised as follows (Reich, 1998):

- Didactics should no longer be a theory of mapping, memory and real reconstruction of knowledge and reality, but a constructionist environment of individual learning in reality.
- Didactics becomes an open process of contextual and relational mediation.
- It is not longer considered helpful to prescribe a certain way of teaching or learning, resp. but allow the learner to go his own way of knowledge construction.

The E-Learning pioneer Papert emphasised the constructivist (vs. instructionist) idea by saying: "Well, *teaching* is important, but *learning* is much more important". Papert's constructionist approach relies on the computer for realization.

As stated above interactivity and interaction are essential characteristics of constructionist learning systems. It therefore seems to be worth, to closely look on these terms.

The term interaction comes from social sciences, where it is defined as interplay between two people. "Interactivity" is used in computer science to describe the interdependency between computer and human. In learning programs interactivity constitutes the user's possibility to control and intervene into the system (individually).

Strzebkowski & Kleeberg (2002) distinguish interaction for controlling a (learning) application (e.g. navigation and dialogs) and didactical interactions (e.g. activities for presentation of

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[7] http://www.cnn.com/SPECIALS/multimedia/vrml/hurricane/

[8] http://www.karenmarcelo.org/ng/siggraph/

Interaction	Description of Interaction	Impact on the Learning Process
Interaction with the Data Representation		
Lighting	Illumination changes	low
Viewpoint (“camera”)	Perspective changes	medium
Orientation of Data	Perspective changes	medium
Zoom-in/ Zoom-out & Rescaling	Level of Detail of data changes	high
Remapping Symbols	Clarification of quantitative and qualitative information as well as semantics	low
Interaction with Geometric and Textual Dimensions		
Navigation	Free movement to any perspective/ attribute data is enabled	high
Fly-Throughs	Bird’s eye view is applied to have different perspectives	medium
Toggling	Views on data may be changed	medium
Sorting or Re-expression	Inter-Relationship of values is made clear	high
Interaction with the aim of Comparison		
Multiple Views	Comparison of different areas and/ or different representations	high
Combining Data Layers	Synopsis of different data	high
Window Juxtaposition	Synopsis of different data	medium
Linking	Synopsis of different data	high
Interaction with the Data		
Database Querying & Data Mining	Data Analysis by different techniques	high
Filtering	Data Analysis: Excluding data	high
Highlighting	Data Analysis: Including data	high
Computer-Based Mapping comprising analytical capabilities	Data Analysis: Manipulation, Management, Analysis, Linking of selected Data with external Information, Graphic Redesign	high

Table 1. Preliminary Taxonomy of Interactivity in Geovisualisation (Crampton, 2002). The types are listed according to their (ascending) functional complexity.

information, edit-functions for presented content and possibilities to edit the database). When stressing the distinction between controlling / navigation and textual, possibly didactical interaction, it is helpful to define distinct terms for both ways of interplay. Hence it may be stated, that in terms of software use, interactivity refers to the navigation and application control. Interaction in contrast stands for the interplay with content (Schulmeister, 2002).

To avoid confusion about the terms “interactivity” and “interaction” we adopt this definition for this chapter, in which “interactivity” refers to user actions outside the actual learning content and “interaction” is limited to learner actions within the educational content.

While the provision of interaction facilities in learning processes are generally assumed as an important advantage of E-Learning environments the number of studies to support this claim is still limited. Works about interactivity in geosciences have so far often concentrated on interactivity (navigation in geodata sets) and system control, e.g. in Mach (2005) or Oster (2005). However, initial work to understand the impact and effectiveness of interaction with geodata has been done as well. First approaches tried to categorize content related interactions in a sort of taxonomy or typology. Suggestions were done by Asche & Herrman (1994), Monmonier (1994), Buja et al. (1996) and Crampton (2002).

Due to the variety of definitions Crampton (2002) gives his definition as ‘least common denominator’ by saying that “[Interactivity is defined as] a system that changes its visual data display in response to user input.”

Some years ago some authors added qualitative information (e.g. on effectiveness) into the taxonomies and thus established classification systems. The development of such a categorization of kinds of interaction is motivated by Buja et al. (1996) by saying: „It is useful to develop a taxonomy for data visualization, not only because it brings order to disjointed techniques, but because it clarifies and interprets ideas and purposes behind techniques. In addition, a taxonomy may trigger the imagination to dream up new and as yet undiscovered techniques.” We may extend this reasoning by stating that such taxonomy (cp. Tab. 1) may provide a good structure. Efficiency information in terms of suitability for learning is added.

A discussion on the effectiveness of different forms of interaction has been conducted by MacEachren (1995). However, the demand for a final method to assess the quality and effectiveness of geovisualization was mentioned by Slocum et al. (2001). This situation has not yet changed. Hence the powerfulness of any interaction type may until now only be depicted in a subjective ordinal ranking. However a taxonomy gives the interface designer at least a first impression to assess the usefulness of a special interaction means and thus support designers in the systematic exploration of the available options.

In our virtual landscape we build on these results to provide appropriate interaction functions to facilitate effective learning. Of course the introduced theory on interaction may as well be helpful for the adoption to other environments, like e.g. use cases in the context of Location Based Services, Desktop VR for the WWW or immersive VR environments.

6. THE CONCEPT OF VIRTUAL LEARNING LANDSCAPES

“Hands-on”-learning in geosciences has been hindered in the past both by the difficulty of information access and the lack of implementation of interaction concepts with textual data and thus the impossibility of experimentation. Direct access to information from real-world environments is impossible in most learning situations (except excursions). Abstracted information collections like maps and GIS have traditionally been the main means of work. While it is practically impossible to observe the results of “what-if” – experiments in reality and in traditional maps, GIS may be used in this way. Virtual landscapes take this approach a step further and utilise a perspective 3D representation of a physical environment that is augmented with learning information. Users of the virtual landscape can:

- explore information directly by navigation in the virtual landscape using 3D representations to establish a close link to spatial reality,
- see the results of analysis operation directly in their spatial context,
- manipulate features in the landscape to directly observe the impact of changes, thus enabling “hands-on” learning and be guided by additional annotations or illustration techniques to ensure a productive experience.

7. INTEROPERABILITY

7.1 Technical Interoperability

Learning environments – especially when based on visualisation of landscapes – are very expensive to build. Usually concepts for special scenarios are elaborated. This work is done manually, because the adjustment to the special needs of a learner and a teacher can only be yielded when optimizing a concept. However in many cases the technical implementation will be carried out individually as well. This means that a 3D landscape model for the study area is build. Possibly further thematic data and possibilities for interaction are integrated. This usually requires a big programming effort. The environment then may also just be applied for one special application.

In other fields of applications the same problem is tried to be solved by standardization and toolbox-like systems with standardized components. E.g. for web-based geographical information systems a standardisation process has taken place over the last decade. The Open Geospatial Consortium[9] (OGC) develops technical standards, e.g. in the field of web-based 3D-data presentation. Two specifications in that domain are at the state of discussion papers at the OGC at the moment. One is the Web Terrain Service (WTS)(OGC, 2001). The specification envisions the display of maps in perspective views. The problem of that system is that just raster images will be generated. However, different layers of raster images can not be overlaid. Interaction with and navigation in the WTS is not possible either (Kolbe, 2004; OCG, 2001). An important feature thus is missing. Hence there was another development, the Web 3D Service (W3DS)(OGC, 2005). In comparison to the WTS the W3DS combines all objects in a scenegraph before rendering, which is finally handled by a client, rendering the scene based on the scenegraph description.

We showed in Katterfeld & Sester (2005) how these standards might be applied to provide a technical framework to provide data and functionalities for virtual learning landscapes. However such an environment should be extended to better suit learning- and teaching needs. The required extensions concern primarily the task of interactivity and providing learning information.

7.2 Contextual Interoperability

The importance to integrate content in a learning environment is obvious. Also, the value of interaction was discussed in one of the former sections. But how to integrate those information in an "on-demand"-environment? How to implement such content requirements?

We aim to answer these in our work. Our ideas aim at providing standardized and hence exchangeable descriptions of the content to be learnt as well as standardized descriptions of the kind of interaction needed to convey distinct information effectively. These descriptions can be seen as kind of learning-augmentation. These augmentations could be used in different technical and conceptual versions of a learning system as long as the interfaces are well defined and supported across platforms. In terms of this contextual interoperability we are working on a way to structure the learning information in a kind of "EduOntology". We also want to consider effectiveness of ways of interaction with geodata.

An Ontology is a collection of information and hence represents a part of the reality (a so-called "domain") in a structured way as well as the relationship between the objects in machine-readable form. Within our work we create "Task Ontologies" for special learning scenarios.

Prototype Scenario

The process of planning a railway line requires a set of steps. The student first will be asked to choose the right work steps from a list of options and put them in the right order. The list will be only accepted when the steps were put in the right order. Then the learner has to carry out these steps within the virtual landscape-learning environment. For that appropriate data is provided. The choice of data was done by a tutor who compiled the learning scenario before. (For advanced students the access to the data services could be provided. Thus the choice of data would be a single working step.)

The learner then will carry out the working steps, e.g. exploring the area by using interaction tools of the environment (e.g. pan, zoom, fly, comments/ links on mouse over, etc.) as well as simple analysis tools (e.g. select by attribute, etc.). For analysis the learner had next to assign sensibility indices to every land use type. Based on that areas with lowest sensibility against the intervention are to be calculated. Different weights to the subject of protection have to be assigned to express a valuation of protection needs. For that some basic analysis tools (attribute-based assignment of values and calculation of the total value for ever object) must be provided. Further on the student should calculate buffers to analyse the range of the effects of noise. For that a tool for calculating buffers must be provided. (If the student is interested to learn more about the buffer operation he may switch to a text-based course, where GIS operations are introduced.) Based on the buffer a resistance value can be assigned to areas still much affected by the noise.

Overlaying areas and calculating their resistance should enable learners to identify the respective values of possible routes. Possibly intersected areas have to be investigated in terms of the need of compensation actions. Areas of compensation must be roughly digitized and assigned by attributes about further measures.

The result must be cartographically visualized in the virtual landscape (i.e. the possibility to change graphic variables must be given) and the course of the route may be explored in the perspective view. The final (perspective) map and some verbal evaluation on the route and problems involved in the solution must be submitted as result of the task.

A discussion of the results will be part of a course where every student has actually to be physically present. The commented outcomes will stay available online to be a base for issue-based discussion for the course in the next year.

Figure 1: Prototype Szenario

We want to test the hypothesis that learning information may be deployed interoperable and thus more effective when expressed in a standardized way. Ontologies are a well-known means to structure information and it has to be tested until which level of

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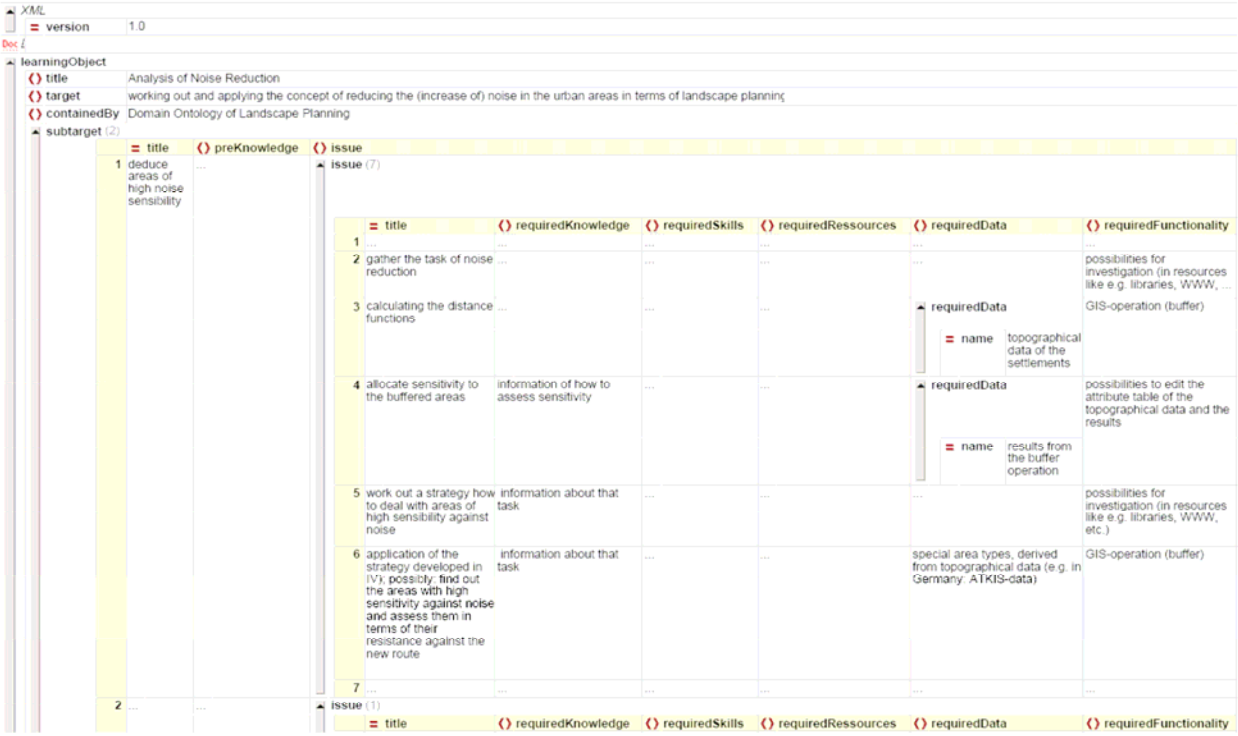
[9] www.opengeospatial.org



XML
= version 1.0
learningObject
() title Analysis of Noise Reduction
() target working out and applying the concept of reducing the (increase of) noise in the urban areas in terms of landscape planning
() containedBy Domain Ontology of Landscape Planning
subtarget (2)

	= title	() preKnowledge	() issue
1	deduce areas of high noise sensibility	...	issue (7)
2	...	...	issue (1)

issue (7)

	= title	() requiredKnowledge	() requiredSkills	() requiredRessources	() requiredData	() requiredFunctionality
1	...	...	...	...	...	...
2	gather the task of noise reduction	...	...	...	...	possibilities for investigation (in resources like e.g. libraries, WWW, ...
3	calculating the distance functions	...	...	...	requiredData = name topographical data of the settlements	GIS-operation (buffer)
4	allocate sensitivity to the buffered areas	information of how to assess sensitivity	...	...	requiredData = name results from the buffer operation	possibilities to edit the attribute table of the topographical data and the results
5	work out a strategy how to deal with areas of high sensibility against noise	information about that task	...	...	...	possibilities for investigation (in resources like e.g. libraries, WWW, etc.)
6	application of the strategy developed in IV); possibly: find out the areas with high sensitivity against noise and assess them in terms of their resistance against the new route	information about that task	...	...	special area types, derived from topographical data (e.g. in Germany: ATKIS-data)	GIS-operation (buffer)
7	...	...	...	...	...	...

issue (1)

	= title	() requiredKnowledge	() requiredSkills	() requiredRessources	() requiredData	() requiredFunctionality

Figure 2. Example of an extract from a domain ontology

Interaction with the Data Representation
…
Orientation of Data
degree of interaction: *medium*
efficiency: *medium*
info: -
Zoom-in/ Zoom-out
degree of interaction: *low*
efficiency: *high*
info: -
Rescaling
degree of interaction: *low*
efficiency: *high*
info: *information on scales, generalisieration etc.*
Remapping of Symbols
degree of interaction: *medium*
efficiency: *low*
info: *information on cartographic issues*
….

Interaction with the Data
…
Database Queries & DataMining
degree of interaction: *high*
efficiency: *high*
info: *information on databases, databasequeries and data mining*
Filtering (Excluding)
degree of interaction: *high*
efficiency: *high*
info: -
…
GIS-Operations
…
Clip
degree of interaction: *low*
efficiency: *high*
info: -
Buffer
degree of interaction: *high*
efficiency: *medium*
info: *information on buffering algorithms*

Figure 3. Extract from the Interaction Dictionary

complexity ontologies remain applicable. Otherwise other frameworks for structuring information (possibly e.g. databases etc.) have to be found.

We are working on a case study, wherein students of the landscape planning subject should use the virtual landscape to learn how to plan a railway line. A possible scenario, how the work within the virtual landscape could look like given in Fig. 1. Our task ontology is derived from text analyses (based on the text in Fig. 1), a method suggested and applied e.g. by Kuhn (2001). It itemizes the whole process into single working steps and assigns further information to every working step. Such further information is:

- working target (the aim of the distinct action in relation to the learning target),
- overall learning target of the working step (i.e. what the learner is supposed to learn with that action),
- ascertained action,
- data needed,
- metainformation needed,
- software functionalities needed and
- possible feedback.

Enhancing the ontology with these information we derive another ontology, which we will call the first-level EduOntology. Such an Ontology could be regarded as script for a learning scenario. Fig. 2 gives an insight how such a scheme could look like.

The second important aspect to incorporate with the domain ontology to derive a mature EduOntology is the evaluation of interaction types in terms of effectiveness for the use with distinct geodata in distinct situations. Approaches to categorize ways of interaction were introduced before.

Based on these taxonomies we establish a so-called 'Interaction Dictionary', which provides for the interaction types attributes on the degree of interaction, the efficiency in terms of acquisition of knowledge and the information a learner should possibly know about this type of interaction. The last point became necessary, because we also understand more complex processes of gaining knowledge as interaction as well. Here e.g. a complex GIS-analysis could be regarded as one interaction. In that case it might be useful to learn more about that functionality, which mostly incorporates different steps, some of them containing algorithms, which's understanding is important for evaluating the results. However this point is very difficult to realize, because the learner should not be confronted with intransparent learning information when he is looking for an answer to a distinct question. The provision of information according to the users needs is another problem to deal with when aiming to improve such a learning environment.

Fig. 3 gives some examples how the Interaction Dictionary could look like. The assignment of the attributes to the interaction types is based upon our experiences. However to quantify and improve the propositions some systematic user tests would be necessary.

The most interesting point now is the incorporation of the Interaction Dictionary into the EduOntology on the one hand and the (automated) transfer of the mature EduOntology into a learning environment, i.e. into software on the other hand. One case could be, e.g. the notion of a buffer – given as a functionality in the first-level EduOntology – would automatically be related to the description in the Interaction Dictionary (which could also be extended with technical information of the buffer operation, as well as the necessary parameters) and derive the suitability of this operation for the current environment, scenario or issue. This issue is subject to further work. At the moment the findings provide principles for designers to mind when implementing learning environment more or less manually. However it would be desirable to develop tools which are able to use such information (e.g. formalized in XML or in the Web Ontology Language, OWL) for semi-automatical or finally automatical implementation of learning environments.

8. SUMMARY

In this paper we discussed the development of learning environments for geosciences in a broad and overall way. We gave an overview of the situation of geodata-based learning and made clear what chances but also challenges exist. We introduced technical standards and identified ways to use those standards for the development of learning environments. We further discussed the contextual side of learning environments extensively. Here we have provided a proposal of how a kind of standardization of structuring learning information could be reached. For that we incorporated and hence investigated the task of interaction.

It could be summarized that E-Learning is valuable, but still has to be improved in terms of applying visualization and interactivity to accommodate distinct learning scenarios and special user demands. We suggested applying structured instructions how to design learning scenarios by developing an EduOntology. However, we are aware that much work remains to be done until those structures can be operationalized successfully. Thus further efforts are needed for the investigation of effectiveness and impact of different interactivity types, for expressing learning scenarios and domain knowledge in a structured way as well as for the operationlization of those structures for software use. The description of learning scenarios in an EduOntology also provides the opportunity to adapt the presentation to a specific learning context (user, knowledge, hardware, environment), an aspect that we have not addressed in this paper and that we aim to explore in the future.

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