MOBILE LEARNING FOR SPATIAL SCIENCES

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Abstract. Initial approaches on mobile learning focussed on delivering learning facilities anywhere and anytime independent from restrictions. In contrast current research on e-learning and web-based education tries to adapt learning material to the user pre-knowledge and learning preferences. Our approaches on m-learning tries to combine them, taking advantages from both mobile technologies and context adaptation. As such mobile learning offers many advantages to education in subjects depending on space, ranging from Geography and the Earth Sciences to Archaeology, Architecture and History. Based on an m-learning lesson on "slope and aspect" initial solutions will be presented how to consider environment while teaching space related phenomena. As such mobile learning also raises research questions on the utilisation of cartographic presentations as communication platform. A prototype of an "open map" shows how to provide collaborative tools for learners and visitors in natural environments.

KEYWORDS: mobile learning, adaptive learning, location dependent learning, collaborative tools, open map

1. Introduction

Adaptive learning platforms and mobile learning (m-learning) represent modern forms of supported electronic learning (e-learning). Adaptive learning searches on compromises between intrinsic learning activities and support from outside. The idea behind m-learning is "to bring the classroom and pedagogic materials into the field" (Armstrong and Bennett, 2005). Additionally mobile learning offers access on learning resources anywhere and anytime. Approaches presented in this paper try to combine these learning methods through "adaptive m-learning".

Adaptation aims to adjust learning content to spatial and temporal contexts as well as to consider the learning progress of the user. The following sub-tasks can be distinguished – automated capture of user knowledge and learning progress; modelling of user activities and context; adjustment of presented learning content and evaluation of mobile learning environments.

The article starts with a definition and differentiation of terms such as mobile learning, adaptive learning and location dependent learning, which can be seen as increasingly specialised cases of e-learning. Different learning paradigms such as behaviourism, cognitivism and constructivism are compared with respect to m-learning. It is shown, that m-learning has great potential to support the independent formation of knowledge by exploration (cognitivism, constructivism) overcoming simple repetition (behaviourism).

The customisation of an m-learning lesson is then described through a three step process. The first step is the determination of user context, e.g. pre-knowledge of the user, preferred learning style and user position. Dependent on the context the adaptation and selection of teaching content will be carried out. Finally the adaptation of content presentation is realised with consideration of output device limitations. Two m-learning applications are then presented and discussed, first an m-learning lesson on slope and second a open map, which intend to build up a common understanding of place through collaboration.

2. Theory on mobile learning and related work

2.1 Definition of mobile learning (m-learning)

An often found definition of m-learning is based on the usage of mobile technologies such as mobile phones and hand-held computers to enhance the learning process. Following this definition a distinction is made between different types of hardware used. If a person uses a desktop computer with LAN connection the work is described as e-learning and if they use a notebook with WLAN a person is engaged in m-learning. A more user centred perspective is taken in the definition of O'Malley (2005), who describes m-learning as "any sort of learning that happens when the learner is not at a fixed, predetermined location". A combination of both allows a more precise characterisation:

> *"M-learning is any sort of learning that happens when the learner is not at a fixed, predetermined location, taking advantage of the learning opportunities offered by mobile technologies."*

In the m-learning literature (Taylor et al., 2006) often the *"anywhere and anytime"* access of m-learning lessons is described to be the big advantage of using this new technologies. From our point of view m-learning offers also the possibility of deliver *location-dependent information*, which is interesting especially for the study of spatial phenomena.

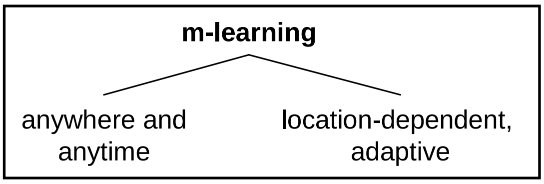


Fig. 1: Two categories of mobile learning

The consideration of contextual information and real-life example within an m-learning lesson can be beneficial especially for applied studies. Armstrong and Bennett (2005) argue in their manifesto on mobile computing in geographic education that mobile computing technologies will allow teachers to bring the classroom into the field. With that a combined study of abstract model theory and real world phenomena is feasible

2.2 Categories of context consideration in m-learning

Schwabe and Frohberg (2004) made a distinction of several context categories within m-learning can have. These included no context (free), and formalised, digital, physical, and informal contexts. Free of context means that there is no context consideration during the learning activity. Formalised context describes learning within an educational establishment at a fixed location and time such as school or university. Digital context describes virtual realities and artificial environments e.g. flight simulators and second life. Physical or natural context characterises m-learning in a real environment. Informal context, finally, considers the learner themselves and their collaboration with other learners as part of context, which allows soft factors and social skill to be developed. In Frohberg (2006) the context categories are ordered against level of complexity and educational impact, see Fig. **2**.

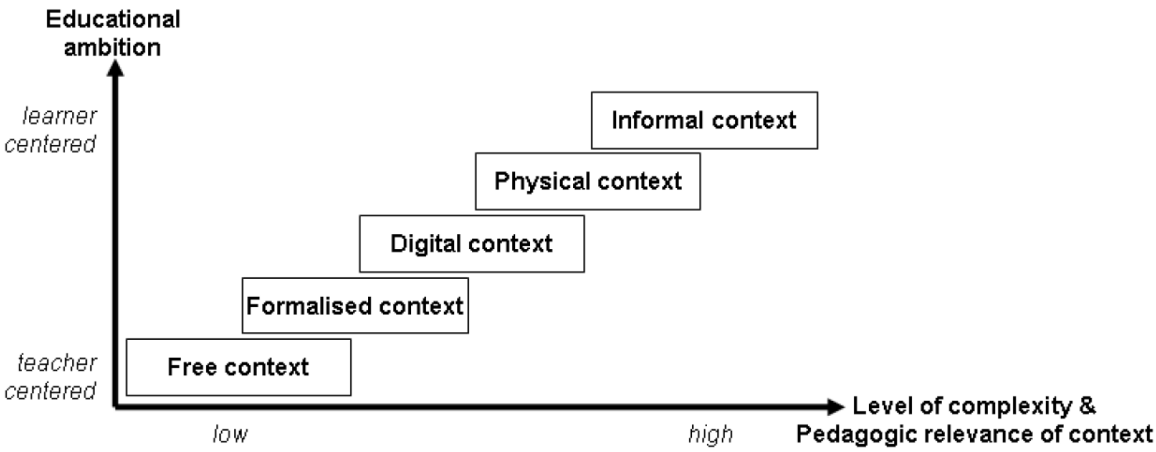


Fig. 2: Categories for m-Learning by Frohberg (2006)

For spatial sciences especially the physical context categories has major importance. The location dependent learning enables an active consideration of physical context, which can be supported by location based services. Such a platform for the delivery of educational information services for tourists in natural and protected areas was developed within the WebPark project (Edwardes et al., 2003).

2.3 Learning theory applied to m-learning

Ally (2004) summarises the contributions of learning theories to the design of online materials as "…behaviorist strategies can be used to teach the facts (what), cognitivist strategies the principles and processes (how), and constructivist strategies the real-life and personal applications and contextual learning". Mobile learning is particularly suitable to implement constructivist theory of learning through exploration and problem solving. Following that m-learning seems to have great potential as final component in a learning cycle with tasks on applying and reflecting knowledge within reality.Holzinger et al. (2005) argues similarly, "mobile technology can enhance the shift from pure instructor centered classroom teaching to constructivist learner centered educational settings". Mobile technology provides a suitable framework to support the application of internalised concepts and knowledge in a practical real-world context. With that requirements of constructivist learning such as free within a given structure are perfectly satisfied. As such, m-learning has great potential to support the independent formation of knowledge by exploration (cognitivism, constructivism) overcoming simple repetition (behaviourism).

2.4 Adaptive learning and web-based education

A number of research articles have focussed on developments of adaptive and intelligent web-based education systems (AWIBES) to make the e-learning courses more intelligent, aiming at activities traditionally executed by a human teacher. A nice summary and categorisation is given by Brusilovsky and Peylo (2003). They made a categorisation of AWIBES technologies in five groups as shown in Fig. 3.

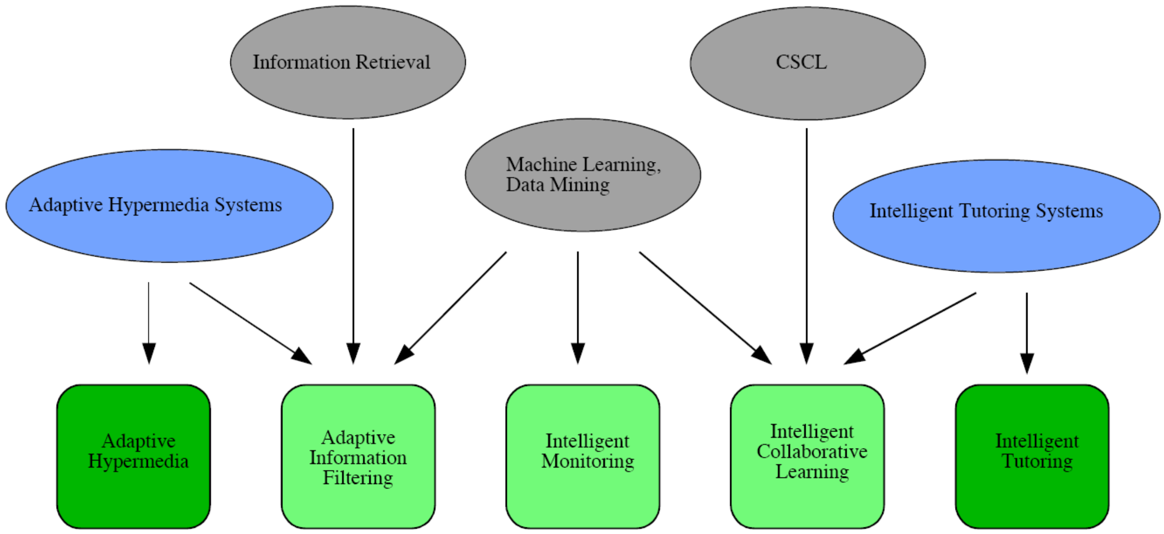


Fig. 3 Five groups of modern AIWBES technologies from Brusilovsky and Peylo (2003)

The first group of *adaptive hypermedia* deals with the adjustment of presentation e.g. switching between language and usage of several multimedia components. This category is highly relevant for m-learning especially when thinking about the effort which is needed to adjust learning material to the small screen size of the mobile devices.
The *adaptive information filtering* category is closely related to information retrieval with the goal of finding relevant information to user interests from large information space. These methods could be partially applied to m-learning especially with a focus on location and context dependent information filtering. Methods of *intelligent class monitoring* are needed both in web and mobile context, because there is no direct feedback about students progress and, related to that, the suitability of learning material. Solutions on tracking of low level interactions such as mouse clicks, keyboard typing, following hyperlinks are proposed in the human-computer interaction domain (Kelly and Teevan, 2003; White 2005), but the transformation of these low level interactions into meaning full information about learning progress is quite difficult.
The category on *intelligent collaborative learning* covers adaptive group formation, peer assistance and collaborative support tools, such as wikis or threaded discussions. Their utilisation in web-based and mobile learning is crucial, because of the limited personal contact time with instructors. A detailed example of a collaborative support tool will be given with the open map application in the next section. The last category of *intelligent tutoring* covers technologies, which provides intelligent help, for example to find out the most suitable sequence of topics to learn, or gives extensive error feedback. These techniques can be useful to m-learning, in cases where the lessons developed do not havesuch a fixed structure for example caused by the location-specific dependency of e-learning.

2.5 Adaptive and location dependent m-learning

Adaptive and location dependent m-learning can be characterised first by the subject of adaptation (what), second through the user context considered for adaptation (where to), and third the method applied for the adaptation (how). The subject of adaptation can be the content of teaching material itself, the degree of complexity as well as the presentation style. User context has been investigated intensively in the domain of mobile information systems for the delivery of context-aware mobile services (Nivala and Sarjakoski, 2003). A rough classification distinguishes between the characteristics of the user themselves and those of his or her environment. In this research the main focus is on the consideration of users' pre-knowledge as well as their location, which is important in the use of real world examples (location based learning). Methods for adaptation were briefly introduced in the previous section, with some remarks about their relevance for m-learning.

A number of early research projects on m-learning have been reported, these include:

- GIPSY, (Geo – Information for Integrating Personal Learning Environments by web and mobile ICT Systems, 2002 – 2004, Netherlands) and the Manolo project (2003 – 2005, Netherlands), http://www.spinlab.vu.nl/manolo. Both projects focussed on integrating electronic, wireless and mobile learning in higher education. Several case studies were carried out, e.g. mobile applications in vegetation science, computer-assisted archaeological field surveys or biodiversity and ecological fieldwork (van Lemmeren, 2005).
- RAFT (Remote Accessible Field Trips, EU funded project in the IST programme, 2002 – 2005, Germany). http://www.raft-project.net. The main scientific and technological objectives of the RAFT project are to demonstrate the educational benefits and technical feasibility of field trips supported by mobile devices (Kravcik et al., 2004). Therefore a mobile learning application called Mobile Collector was developed to enable data gathering and annotation in the field. The data is stored in a way that they can be later elaborated by the learner as well as evaluated by the teacher.

In the following sections a number of experiments carried out by the authors will be described.

3. Prototypes and implementations

3.1 M-learning lesson on slope

The aim of this lesson was to support student excursions by focussing on comparing theoretical models and their limitations in reality. The main theme dealt with the introduction of slope calculation based on digital terrain models with different resolutions. In contrast to the available e-learning lesson (Fig. 4) the aim of the m-learning lesson was not set on teaching theoretical basics but rather applying such the knowledge in reality. Therefore the students had to interact both with the visualised slope-raster on their PDA as well as with the natural context.

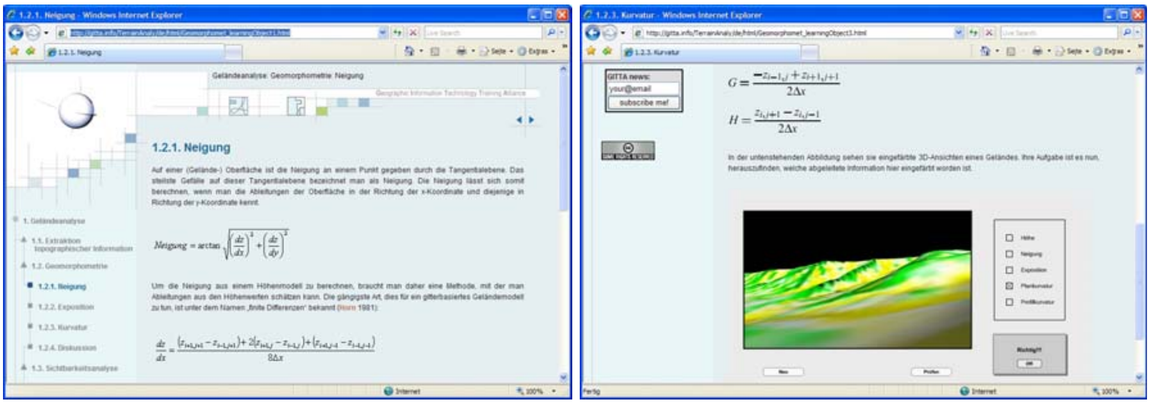


Fig. 4: e-learning lesson enabling the teaching of theoretical knowledge requiring writing on the desk

The lesson was structured sequentially with help of a path and fixed task points as shown on Fig. 5 (left). Starting at any position at the University Campus, the student initially has to read the introduction and the listened index. A special characteristic of this prototype is the consideration of the pre-knowledge of each participant. The reason for an integration of this feature is to compensate for the absence of a teacher through the content adaptation. To determine this pre-knowledge the student has to complete a small test consisting of five questions (Fig. 5 middle and left). In consequence the student is being classified either in a detailed or an abridged course. A student with missing knowledge has to complete therefore more comprehensive tasks.

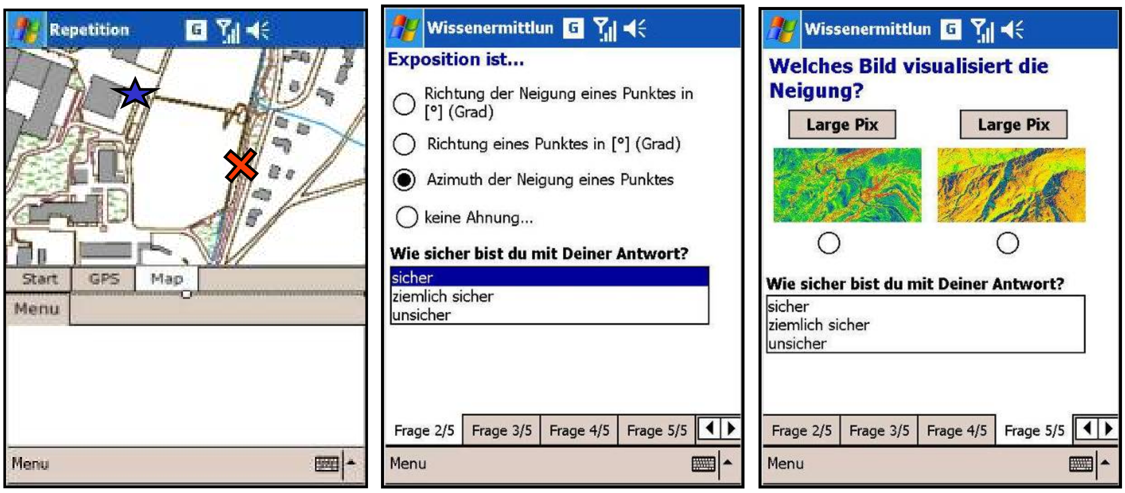


Fig. 5: Map with task points and current user location (left), example of capturing pre-knowledge (middle), example of solution considering limited interaction possibilities (right)

The pre-test contains basic questions about definitions and calculation of ‘slope & aspect’. As mentioned above the following parts of the course are dependent on the result of the test. So, the next part is accordingly aimed at compensating knowledge amongst all participants through theory about ‘slope & aspect’. This knowledge is imparted through texts the students have to read.

Due to the small display size and the limited possibilities of interactions between user and mobile device the presented learning material has to be processed specially. For that the theory part has to be compact and limited to the main points of significant sentences. Furthermore, large entries by the student using the keyboard or stylus pen have to be minimized or substituted e.g. by multiple-choice as shown in Fig. 5 (middle and left).

Besides the texts, the theory part also includes two examples of practical applications of ‘slope & aspect’. For example, one case demonstrates the effect of exposition on land prices. The location where this example is being demonstrated is shown on the map through a task point (see Fig. 5 left). At the moment the students are next to (within 3m) the location of the task, which is automatically detected by the device, they are instructed to look at the southward houses and to think what influences the exposition has on the land prices. The abridged lesson includes only one practical example and less text than the detailed lesson.

After the introduction and the basic questioning, the lesson presents practical exercises that benefit from the natural context. These exercises take place at location which the student is guided to by the device. The tasks have to be solved by the students through interaction with maps on slope and their surrounding context. These maps on slope (see Fig. 6) are raster based and available at three different resolutions: 2m – 10m – 25m. In each cell the slope value is written as a number.

The students has to solve three tasks, they are free to choose the order these are done in:

- Try to orient themselves with help of the available slope maps at each resolution.
- Look at the environment at each resolution: what do they notice with regard to the maximal values?
- Think about the resolution: which resolution do they need for different purposes e.g. for creating a survey map of Switzerland?

By interacting between maps on slope and their surroundings the student is able to compare the spatial model and the appropriate reality while solving the tasks for a more sensitive handling of cartographic material.

Fig. 6: Slope maps with 2m, 10m and 25m resolution

To summarise the characteristics of this m-learning lesson the following points can be mentioned. The lesson was carried out in the natural context of the particular topic to apply and extent the knowledge. The pre-knowledge of the user was captured through a test at the beginning of the lesson to enable adaptation of the teaching material. Limited screen size and interaction possibilities needed adjustments of content and arrangements of the control elements (buttons, textboxes, etc). The presented maps served two functions, first to show the current and the task locations (topographic map) and second to visualize the spatial slope model (thematic map).

3.2 Open Map Sihlwald - building up a understanding of place through collaboration

Open Map Sihlwald (http://www.openmapsihlwald.ch) is the result of a Master's project aiming to consider how providing collaborative tools for visitors to a protected area (a forest called the Sihlwald in Switzerland) might allow them to share their experiences and knowledge about a particular place and so enrich their interaction with it. Initially the project was conceived as a mobile system but owing to the relatively low current adoption of mobile technologies and the need to maximise results the project was largely investigated through a conventional web site. Fig. 7 shows the application.

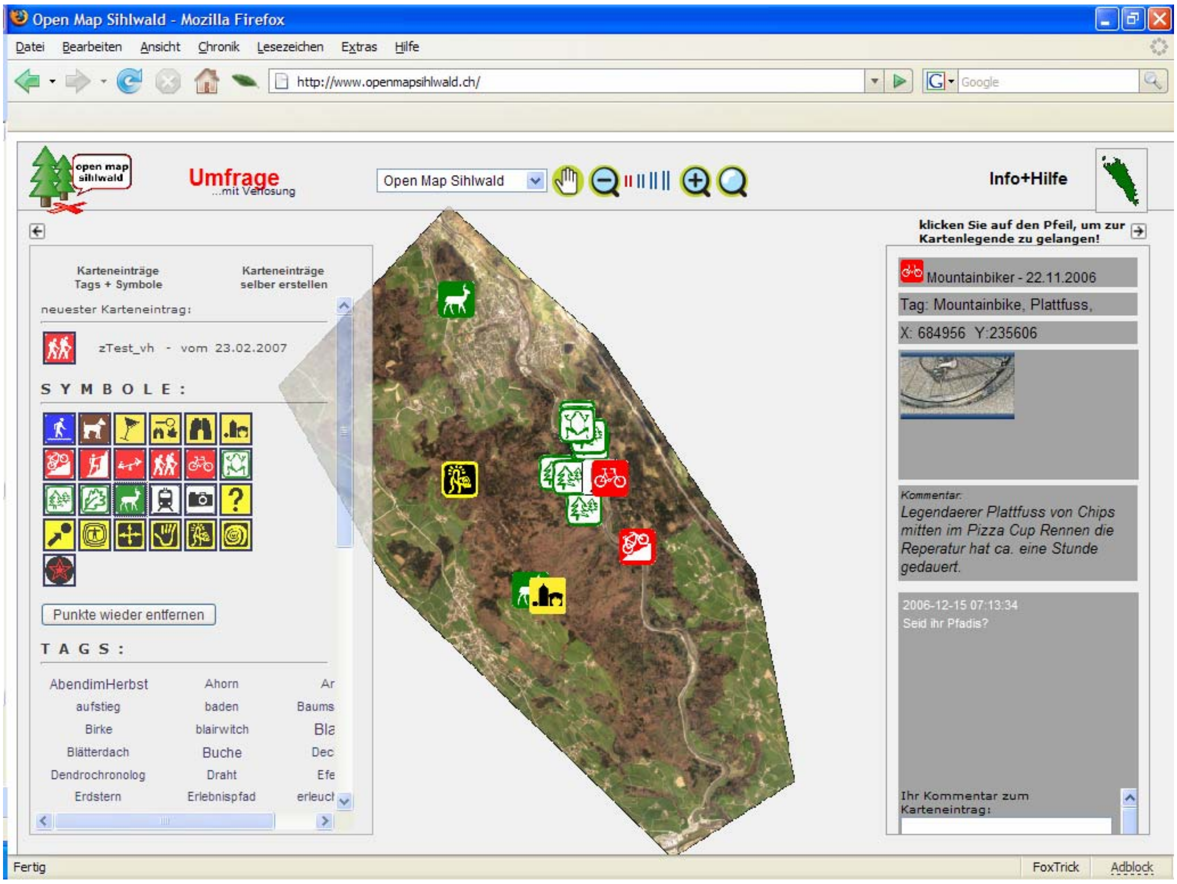
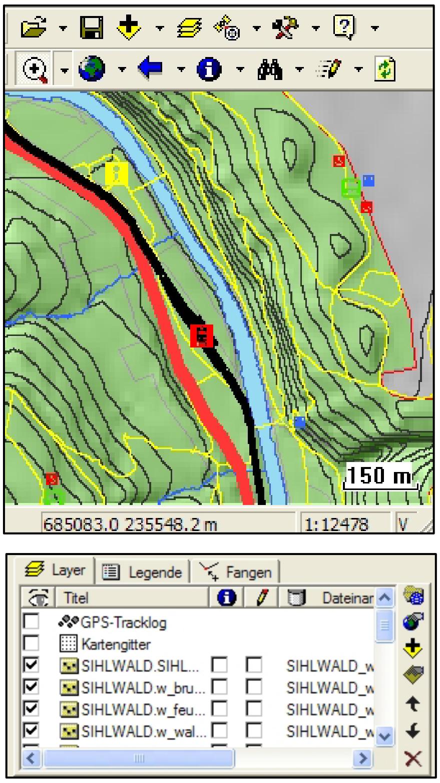


Fig. 7: Open Map Sihlwald website (http://www.openmapsihlwald.ch)

The site is open, in the sense of a wiki, allowing visitors to share content using tools to geo-code and semantically tag messages and photographs to relevant places on a supplied base map. Visitors are also able to communicate amongst themselves through comment threads attached to each content item.

Fig. 8: Photographs left on Open Map Sihlwald

The map differs from the more conventional ideas of a web-map in that its contents are not only highly dynamic, changing in response to both the input of participants and forms of interaction of the map users, but also defined by the contributors to the site. Hence, the form of communication between the cartographer and the map user is not one way, from the cartographer to the map-user, but closer to a dialogue between map-users as well as with the cartographer. The approach can therefore be seen as closer to the idea of a ‘mashup’ (for example using the Google Maps API), and indeed uses similar techniques and technologies, such as tag-clouds and AJAX. However, it also differed in two main ways. The system was able to use highly detailed and extensive base map data collected by the Sihlwald data center (http://www.sihlwald.unizh.ch/). This meant a much richer spatial description of the place could be provided than is typical for base maps used by mashups. Secondly, the focus was on sharing experiences of a particular place that would be known to the contributors and people using the map, rather than to either document a remote place (e.g. http://www.geograph.org.uk and http://www.wikimapia.org) or places to organise information like photographs (e.g. http://www.locr.com). The map therefore does not exist in isolation from the place but as a medium that supports mediation between different individual subjective experiences of a place. In a sense then, the map cannot really be understood without having experienced the place it refers to also, bringing closer to ideas from locative media (c.f. Chalmers et al., 2005) and public participation GIS (c.f. Talwar et al., 2003). This blurring of the line between first-person direct geographic experience with indirect experience through spatial representation (Longley, 2004) also makes Open Map Sihlwald a good candidate for use in a mobile, informal and collaborative learning context (see Fig. 9 and Kravcik et al., 2004).



The map was also made available on a mobile device which a small proportion of visitors were able to borrow. Whilst, the main purpose of this was to simplify the collection information about places, to some extent it also allowed people to explore places that other visitors had left, though this type of interaction was limited and data was not updated in real-time. The version used ESRI's ArcPad software to display the base map data and allow editing. Fig. 9 shows this application.

In such a context students can learn about the how places are used and made meaningful by investigating the places that contributors have found significant, both indirectly through a spatial representation and directly by exploring those places themselves. In addition, such an open map allows collaborations of their own with their fellow students allowing what they learn about a place from their own investigations to be shared.

Fig. 9: Mobile version of Open Map Sihlwald

5. Conclusion

The aim of this paper was to investigate the potential of m-learning for education in spatial sciences. In contrast to context independent "anywhere, anytime" m-learning our approaches focuses on location-dependent and adaptive presentation of learning material. The m-learning lesson about slope engages the learner to compare theoretical models and their limitations through interaction in a physical real-world context. Open Map Sihlwald aims on building up a common understanding of place through the use of collaborative tools in an informal context. Three different aspects of adaptation were considered for the adjustment of the learning material – i) pre-knowledge of the user, ii) adaptive hypermedia

to handle small display size and limited interaction possibilities and iii) location dependency, while interaction with the environment.
To conclude m-learning can only be a supplement of traditional classroom teaching, with focus on combination of abstract model theory with real world examples. Furthermore, m-learning can be seen also as complementary to web-based education. While web-based learning has its strengths in teaching model theory, m-learning supports the application of theoretical knowledge in reality. With that new challenges for explorative, non-sequential knowledge transfer are raised. Open research question relate also to the difficulty of capturing learner progress through real-time evaluation of user interactions.

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