

# **Studienlandschaft Schwingbachtal: an out-door full-scale learning tool newly equipped with augmented reality**

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## **Reply to the Editor after open discussion period (HESD, 12, 11591, 2015)**

Dear Editor,

We thank you, the anonymous reviewer and Rolf Hut for comments on our manuscript.

We have addressed the reviewers comments, in particular trying to focus on the “first way” suggested by R. Hut, i.e. on the tool development, rather than on its evaluation. Indeed, we fully agree that this “second way” needs to be addressed specifically. However, we unfortunately have to admit that such evaluation with students could only be done in the next summer semester 2016.

We hope to meet your understanding and support regarding this comment. In case you think the evaluation is necessary for a final (potential) acceptance of the paper, we would need to withdraw our manuscript.

Hereafter, you will find detailed response to the reviewers ‘comments.

With best regards,

On behalf of all co-authors, Alice H. Aubert

Anonymous Referee #1

Referee comment	Response to comment	Change(s) made (marked manuscript)
Does this paper introduces an app or just content for AR Browser (Wikitude)? It is confusing to call the tool as an app through the paper. It should be clearly mentioned in the paper that this learning tool is a content or project on an already existing AR App (Wikitude), if that is the case.	Wikitude calls content for the AR-Browser “App”. Hence, we would like to stay with the wording. To clarify the different meaning, we included several statements saying that this App is hosted by the AR browser and is not a native App.	1.22 (abstract) 1.171-172 1.123 1.172, 1.182
Some of terms in the paper needs explanation for readers (e.g. JSON, QR code, etc.)	To simplify the understanding, we have removed terms not necessary for the paper (JSON) and explained the needed terms more thoroughly	1.204, 1.211, 1.254, 1.281
Android is not an information system by an operating system (page 11604, line 1)	Corrected.	1.318
There are typos or foreign language terms in the article (e.g. technics)	Reworded.	1.321
The URL for the app ( <a href="http://fb09-pasig.umwelt.uni-giessen.de/sbappdescription">http://fb09-pasig.umwelt.uni-giessen.de/sbappdescription</a> ) does not have any source code as mention in the paper. The page just have links to Wikitude app on iOS and Android app stores. There is no source code or link to actual app itself.	Concerning the link to the App, the Wikitude AR-browser is the skeleton of the App, with this AR-browser downloaded on the phone, the end-user of the learning tool can explore the content of the Schwingbachtal App project (stored on servers at University of Giessen), going on the field in Schwingbachtal. To give the reviewers and interested readers access to the source code,	

	we added a link to the URL given in the text.	
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### Rolf Hut, Referee #2

“In my opinion, the authors can go any of two ways”	We have chosen way 1, for the reasons mentioned in the letter (i.e. temporal constraint with student semesters for a proper evaluation).	
including the reasons behind design choices made	This is discussed in part 2.2. Technical design.	
refraining from making claims on the effectiveness of this tool in either communication or education, since that is not what has been researched	Sentences have been added to refrain this claim, and emphasize the need of a thorough evaluation.	1.315, 1.326
The authors can point to other research (in other fields, for example using augmented reality in museums) to hint at its effectiveness and claim they are the first to bring this approach to hydrology. They should then leave the question whether this tool is effective to future research, that should be well designed, with a control group.	We have made it clear that the part discussing the education relevance is based on literature work from other disciplines.  Reference to museums development of AR is done in the introduction, as basis to our work (for instance Mannion, 2012).	1.23-26 (abstract) 1.135 1.321 1.327-328 1.367-370 (conclusion)
They can explain the specific problems they encountered (outdoor localisation, sufficient mobile coverage).	This is discussed in part 3.1. The trail whose reality is augmented by virtual objects.	

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## Abstract

This paper addresses education and communication in hydrology and geosciences. Many approaches can be used, such as the well-known seminars, modelling exercises and practical field work but out-door learning in our discipline is a must, and this paper focuses on the recent development of a new out-door learning tool at the landscape scale. To facilitate improved teaching and hands-on experience, we designed the Studienlandschaft Schwingbachtal. Equipped with field instrumentation, education trails, and geocache, we now implemented an augmented reality App, adding virtual teaching objects on the real landscape. The App development is detailed, to serve as methodology for people wishing to implement such an education tool for geosciences, in particular hydrology. The resulting online application, that is run in the ready-made augmented reality browser Wikitude, namely the Schwingbachtal App, is described as an example. As it was proven in other communication field, we conclude-expect that such an App is useful for communication and education purposes, making learning pleasant, and offering personalized options. The benefits of the tool should be verified next semester.

## Keywords

Hydrology, education and communication, augmented reality, education trail, geo-cache

## 1. Introduction

### *Studienlandschaft Schwingbachtal: an out-door full scale learning tool*

Learning by doing is an old concept. At the university, education includes practical work, commonly when the topic allows it, and field excursions, more seldom due to travel financial and organisational constraints. Water sciences, and environmental sciences in general, are topics for which learning in the field is necessary (Nash et al., 1990): observing landscapes already tells a lot about the water cycle. Field learning also allows better understanding of measurement devices. Keeping this in mind, we decided to create an interdisciplinary landscape-based teaching facility that includes many different learning methods (Wagener et al., 2007). A further aim was to involve science-based projects in the landscape to facilitate a discussion between undergraduate and graduate students on the one hand, but also allow science to go public (Nash et al., 1990; Seibert et al., 2013).

In 2008, we established the study site Studienlandschaft Schwingbachtal. The goal was to create an education tool for the students of environmental sciences of the Justus Liebig University of Giessen, Germany. The chosen site needed to be in reasonable distance to the University and easily accessible with large group of students. It should be a headwater catchment, which size allows touring in a limited time (half day). Human impact such as settlement and agriculture should be present to raise awareness about their impact on the environment, as partly targeted by the majors in environmental sciences. The Schwingbach catchment, located 20 minutes' drive away in the south-west of Giessen met the above-mentioned criteria. A potential outlet stood as evidence with the existence of a retention basin, which offered facilities for further instrumentation (secured bridge above a regular straight stream section).

The Schwingbach catchment encompasses the Schwingbach and several small tributaries, of which the Vollnkirchener Bach is the largest one. A retention basin defines the outlet of the overall study catchment (Fig.1). It covers a total area of about 23.5 km<sup>2</sup> (Fig.1). The Schwingbach catchment is covered by forest (36.9 %), arable land (39 %), and grassland (10.5 %). The Vollnkirchener Bach flows through the small village of Vollnkirchen, while the upper headwater of the Schwingbach is free of settlements. Humans have modified stream networks with drainages to dry up arable land, a combined sewage overflow, and partially channelized stream reaches. Soils are diverse: Cambisols (mostly in the forested area), Gleysols (along the streams) and agricultural Stagnosol, making the catchment a good case

study, and reflecting a complex geology. The climate is temperate. Further information particularly about the hydrology of the catchment are described in Lauer et al. (2013) and Orłowski et al. (2014).

[Figure 1. Map of Studienlandschaft Schwingbachtal showing land use, digital elevation model, points of interest (POIs) along educational trails.]

The Studienlandschaft Schwingbachtal project includes various educational approaches from the start, all considering the principle of learning by doing. (i) Excursions with large groups of students, subdivided in smaller groups, are organised as part of lectures: many monitoring techniques, orally described with supporting pictures during the seminars are turned into gestures. For instance, students measure discharge using the salt dilution method, the speed of the water, by flumes (RBC, Eijkelkamp, NL). (ii) Three educational trails (Fig. 1), consisting of informative boards on hydrology, ecology and soils are installed in the catchment. Both students and locals can read them autonomously (though some locals commented that some boards were too technical). Thus, ~~these~~ trails ~~are~~ also a communication tool, informing locals of the University's involvement in the catchment. (iii) Since summer 2014, the trail hosts a geocache (<http://www.geocaching.com>, “ Studienlandschaft Schwingbachtal”), introducing game and challenge to motivate the strollers to go around the trail. Indeed, geocache principle is to reach a final point, through various stages, where hints about geographical coordinates are given. In this case, finding the hints requires the participant to read the boards. (iv) To deal with the collected data, assure coherence, and no loss of data a database with an online interface was created (Institute for Landscape ecology and resource management, 2012). The web frontend of the database is designed to assist students, researchers and technical assistants from planning the maintenance tasks, to quality assurance and data analysis, over the data collection in the field. Users can upload manually collected data, like groundwater level with electric contact gauges, discharge using the salt dilution method, as well as lab results, using spreadsheet templates. Data collected from automatic data loggers can be imported directly into the database and calibrated with the manual measurements from the same site; invalid values due to instrument failures are masked by the database manager. Users can export the time series, stored in a structured database, using filters for sites, instruments and dates. However, time series can also be plotted and transformed with the web ~~application~~interface. Specific data sets, like online available meteorological data, can be viewed by the public. (v) The Studienlandschaft Schwingbachtal

also hosts many diploma works, from Bachelor to Doctorate. Since 2008, over 30 theses were conducted in the study area, requiring students and PhD candidates to install measuring stations according to their research questions. As a result, the study site database counts over a hundred sampling points e.g. for discharge, groundwater level, surface- and ground-water chemistry, trace gas emissions, meteorology, etc. While several dynamic parameters are regularly measured (e.g. discharge, groundwater table depth, instream nitrate concentrations), others parameters are only measured once to improve the spatial coverage of information (e.g. infiltration, saturated conductivity). Student jobs and internships are the backbone of routine measures. This is also a mean for the students to explore their interest in academic studies (helping them to orientate towards their best interest).

All these ways of learning are well-known and nowadays commonly used. Students' feedbacks to such approaches of hydrology are positive. But, as technology is continuously developing and part of our daily life (i.e. smart phone and the set of sensors they contain) and, as students presently entering the universities are part of the so called y-generation (Keith Macky et al., 2008), defined as "technologically sophisticated", new approaches need to be implemented. One of the most promising is augmented reality.

#### *Augmented Reality: the new learning equipment*

Augmented reality (AR) can be defined as any system that fulfil the three following requirements: It "combines real and virtual [world], is interactive in real time and is registered in three dimensions" as stated by Azuma (1997). Milgram and Colquhoun (1999) refine this definition assigning AR in a *reality-virtuality continuum*. AR is thus part of the domain of mixed reality, in which the real environment is the baseline and some virtual objects are complementing it. From the start, AR has been used for training in military context or in medicine. Thanks to the spreading of smart phones, AR has appeared in museums over the last decades as Apps to enhance visitors learning experience (for instance, Mannion, 2012). Indoor AR benefits from the infrastructures (e.g. access to Wireless Local Area Network (WLAN), constant light conditions). By contrast, outdoor AR remain challenging to (i) determine the user's position and orientation with sufficient accuracy to align properly virtual objects with real world; (ii) overcome constant changing environment (e.g. variation in light, moving objects, seasonal vegetation changes) and (iii) benefit from constant available network.

Since Azuma's review (1999), outdoor AR improved (for instance: Langlotz et al., 2011; Veas et al., 2012) and some native AR-Apps are nowadays available on the market, such as enhanced trail road in natural parks or touristic city guided tours (Guttentag, 2010; Jung et al., 2015). Native Apps are those developed for use on a particular platform or device, using smartphones specific hardware and software. They often use multiple tracking as to overcome the above-mentioned issues, i.e. they combine Global Positioning Systems, reckoning trackers (rate gyroscopes), passive optical trackers (video sensors, line-of-sight), electronic compass, and tilt sensors (inclinometer).

The present paper focuses on the development of an AR-App [built on existing software](#), for the Studienlandschaft Schwingbachtal. First, the concept and technical aspects of the development will be described, as a methodology to develop such a tool, then, the resulting application will be depicted. To finish, [expectations of](#) the use of such AR tool for teaching hydrology will be discussed.

## **2. Development of the Schwingbachtal App**

### **2.1. Conceptual design of the Schwingbachtal AR-App**

"Mobile learning" means learning with mobile media (e.g. smartphone, phablet, tablet) (Kingston et al., 2012), i.e. learning whatever the situation and whenever. Thus, mobile learning is not a substitute to a more classic form of learning, but an extension. The benefit is to allow spontaneous learning, when a stimulus provokes an urge for learning, in particular learning something small, in a short time. The Schwingbachtal application lays in a restriction of mobile learning as it is meant to be site-dependent. However, the content should be accessible without a predefined order, warranting as much flexibility and spontaneity as the user wishes. The technical aspect of the use of AR should not be a barrier to the learners and thus should be intuitive.

The target audience needs to be defined as it conditions the level of prior knowledge and the scientific concepts to explain. In the case of the Schwingbachtal App, the audience is meant to be the same as for the educational trail and for the outside teaching lectures, i.e. undergraduate students. However, there might be other interested visitors (public audience, local people, school classes) who wander on the trail and are wishing to learn more. Thus, the new App should take into account that the educational trail was reported to be not so accessible for the locals, i.e. content should be made more accessible..



The points of interest – POIs, where to provide knowledge – also needs to be defined. We decided that the App will mostly be a technological update of the existing written static information of the educational trail. It should keep the interdisciplinary theme “Soil, Ecology and Water”, adding video and audio contents, as well as interactive contents to enter the domain of active learning: (i) real-time picture recognition (AR component) to guide visitors around the trail (visual tracking); (ii) see “inside” devices (in a tipping bucket for instance); (iii) games such as memory cards for plant recognition complementing ecology panels; (iv) flow calculation after reading the water level on the scale of the RBC flume complementing the discharge measures panel), (see results for a complete description of the App content).

## 2.2. Technical design

### *Choosing the AR-browser and App structure*

Every AR App needs to provide a common set of features, (i) to detect the reality to be augmented, like reading the absolute position in space using the GPS and gyro sensors or interpreting the actual camera picture etc., and (ii) to display content that augments the reality. While specialized technical knowledge is needed to provide the infrastructure, domain knowledge is needed to provide the content. So-called AR-browsers are native Apps which provide location and recognition techniques to show content, as web browsers have the ability to open and display web sites. Publishing content for an AR-browser, which is what we have done, is very similar to creating web sites. Then, the end-user only needs to download the AR-browser from a store (eg PlayStore, AppStore) and install it on the smartphone. At the time of development of the Schwingbachtal App three different AR-browsers were available on the market: Layar, Junaio and Wikitude. To our understanding, the Wikitude App-browser (GmbH, Salzburg, Austria), most used worldwide, offers advanced image and location recognition, full assistance for site-specific service and image recognition. In addition, a wide range of content types including super-imposed videos is available. ~~Also, we decided to construct an App which codes are accessible to the community (Supplementary Material) and which is free to download. Thus, we chose the Wikitude App (GmbH, Salzburg, Austria) as AR-browser.~~ Within this browserApp, sites —so-called “worlds” or AR-Apps by Wikitude - are stored, including our Schwingbachtal App. When the world is loaded in the Appbrowser, the user browses the augmentation of the reality, not by entering web site names and using search engines, but by moving through the real space and real objects. Since the content is loaded live from a web server, a constant mobile internet connection needs to be available in

the area of interest. For rich content, like video and audio services, a 3G connection, or better, is needed. We checked the 3G- and 4G-reception in the Schwingbach. Given the four mobile network providers in Germany, it was observed that the study site is in general well-covered with 3G- and 4G-reception, apart local exceptions.

#### *Location-dependent tracking*

The augmented reality ~~App-browser~~ offers location-based services. Depending on the current position of the user, points of interest (POI) are displayed on the basis of predefined geo-coordinates. All information of a POI (coordinates, descriptive text, title, images, links) are stored on a server. POI locations are marked at their geographical coordinates (latitude and longitude). Clicking on a POI makes information of the POI appears on the right-hand side of the image together with a link. This way, before getting the scientific content, the user can decide to access this information or walk to the next POI. The implementation used in this work originates from a template provided by Wikitude (2014~~5a~~).

To assist the user ~~to-in~~ orientatinge, a radar – small compass showing the location of the POI –, a map view, and a help button are added. The radar adjusts the visible POI according to the user's location and his/her distance to it. The radar and range-restriction are implemented using a Wikitude template (2015~~a~~, see ~~Appendix I~~). The map view, from Google Maps, shows the POI (in JavaScript, stored in an Hypertext Markup Language (HTML) page). It also marks the current user location (using a HTML script). The help button is integrated over a continuously displayed i-Button at the bottom of the App. Linking the help button to the help page browser is done via integration in the index-HTML.

#### *Visual tracking, or image recognition*

In addition to the location-based tracking, the AR-~~browserApp~~ offers image recognition. Tracking visual objects are required, i.e. recognizing images. These can include for instance images displayed on the boards or Quick Response (QR) codes (Denso Wave Incorporated, Kariya, Japan). For image recognition in Wikitude, a tracking file (.wtc) is needed. The images to be recognized are uploaded to the server of Wikitude as .wtc-files in a “target collection”. The tracker code aims at examining continuously the camera image from the smartphone and compares it with the images stored in the target collection specified in the program code (in our case the Studienlandschaft Schwingbachtal target collection, JavaScript code).

#### *Image overlay*

Once the image is recognized, i.e. visual tracking performed, a linked virtual object can be displayed on the screen, augmenting reality. This act of adding an image to the real world is called image overlay. This is done in Wikitude (2015<sup>b</sup>) by the target manager tool. Each image of the “target collection” are linked with the content to overlay, either image, audio or video files, for image-, audio-, video-overlay, respectively. When the image is recognized, the linked content is allocated in a virtual place holder. Both the camera image and the place holder are then combined into a Trackable2DObject, which results in what is displayed on the smartphone screen. In the Schwingbachtal App, a quiz on self-propagating plants in agricultural fields, a discharge calculator and the access to subpages are realized using the image overlay.

#### *Video overlay*

Video overlay works similar to image overlay and is started when the triggering visual object is recognized and stop as soon as the object leaves the camera picture. Videos for the Schwingbachtal App have 960 x 256 pixels resolution (in H.264 / MPEG-4 AVC compression standard) and a frame rate of 15 frames per second. Therefore, the size of a two-minute video file is about 2-3 MB. This reduced size speeds up the transmission and optimizes the smartphone data volume used. For an educational App, like here, a lecturer popping out of an installed information board, is a nice effect. To realize this, the background of the lecturer needs to be transparent. Few video formats support transparency natively, the only format supported by the Wikitude AR-browser (H.264) is not an exception. However, it is possible to split the video into two screens: the original video and a moving transparency mask. These two screens are merged together by the browser to show only the lecturer and not the background. The mask video can be extracted using any professional video cutting software with a chroma-keying. To this end, the lecturer is recorded in front of a green wall, and the software detects the green background and can transfer it into the mask screen.

#### *Audio overlay*

Audio-only overlays are not supported by the browser. However, a complete transparent video without any visual content is effectively stored as video codec, making this a valid alternative approach where audible information is needed. In fact, the resulting file size is, due to the modern audio compression in modern video codecs, usually smaller than an MP3 file of the same audio quality.

#### *HTML overlay*

HTML overlay works similar as image overlay. The HTML information is given in a JavaScript code, together with previously created images and link buttons. These elements are combined into a Trackable2DObject by the tracker code. In the Schwingbachthal App, current climate data of the weather station, transferred by the University server ~~as JSON file~~, are called by the HTML overlay.

### 3. Results and discussion

#### 3.1. The trail whose reality is augmented by virtual objects

The user is now able to connect from his smartphone to the AR-browser. The App forwards the user's request and location information to the Wikitude server. In turn, the Wikitude server then forwards the request to the university IT-infrastructure where the content of the App is stored. Then, the Institute server sends the data back to the Wikitude server, which forwards it to the user: the POI appears on its mobile with a proper style sheet.

Twenty-five POIs compose the Schwingbachthal App (Table 1), among which three types are identified: static information POI (providing HTML links), live data POI (continuously providing data that were just measured) and rich information POI (including video and audio content, as well as games). The trail is now composed of the landscape elements and information boards (reality), complemented with the virtual objects from the AR App. Two sets of videos were shot and cropped for the AR (video comments) and 25 web pages written (textual comments and links). The POI are presented in Table 1 and snapshots of the App in Fig.2. A video is available as online supplement. Points can be reached in any order as they bring independent information.

[Figure 2. A few snapshot of the Schwingbachthal App: (a) how the AR navigation looks like, the blue label indicating a point of interest (POI), (b) the preview of the POI, (c) one of the super-imposed video: the lecturer explains the water cycles in the forest.

]

Different navigation options are available for the App user. First, one can use the map representation. The overview map shows the location of all 25 POIs. The map can be zoomed in and out, and also used for navigation when the current position is marked. Second, when using the AR-browser-view, the POIs are marked by blue labels on the viewed landscape. These labels are defined by their latitude and longitude and are downloaded once, at the start

of the App (~~via JavaScript Object Notation~~(JSON) file). The navigation is supported by a radar view, small compass on the left upper corner of the screen, which indicates the limit of sight and the POIs with small dots. The number of POIs in view sight and the coverage, can be ~~reached~~-adjusted by a “range” button, the user can decide how far the displayed POIs are. At any time, the navigation mode can be changed.

We would like to emphasize that explaining complex concepts within the limits of small smartphone display was challenging, in particular due to the screen size. For future similar project, we recommend to focus on the use of larger screens such as tablets or phablets. However, one needs to be aware of the trade-off between comfort of the user and size of the App, i.e. download speed. Offering a fluid entrainment is a topical concern for AR App (Tönnis, 2010). Indeed, the propagation delay between the tracking system, the conversion of the data, and the rendering explain the un-smoothness. This could be improved either by reducing the data size of the content (for instance of the video) or by creating an offline App. Our current solution is optimised for smartphones to facilitate download, using a quality of the visuals not suitable for bigger screens. At the moment, a good in-situ connection is necessary: it is currently not possible to pre-download the content and recall the already-downloaded content on the field. This latter option would also be questionable, as it is not expected that a user wish to read from all the POIs, and thus pre-downloading everything would just be memory consuming.

During tests, mistakes in localisation of POIs occurred. This is certainly due to shadowing of the signal and the rather low quality sensors that compose our smartphones (Langlotz et al., 2011). Location and visual tracking are still research topics (Veas et al., 2012). In our case, thanks to the preview (map-view), the user can understand if there is a location tracking mistake, and then, look for the right location changing navigation mode. This location tracking mistakes being expected, we decided to offer many POIs linked to image recognition. However, for a performant visual tracking, images should show prerequisites (i.e. showing high-contrast, large structured areas and angular elements (“Wikitude,” 2015~~4a~~)), which was not always the case, as the trail was pre-existing. Light effect and mirror effect of the Plexiglas are also reasons for incorrect image tracking (Tönnis, 2010).

A last point to be discussed is the fact that, as such, the Schwingbachthal App is energy consuming. All sensors need to be continuously activated for the tracking (location and

image) and for the data download. Incorporating in the App scripts for activation/deactivation of the sensors would optimize the energy used, and warranty longer exploration.

### 3.2. Is the Schwingbachtal App educationally relevant?

As preliminary evaluation of the Schwingbachtal AR learning tool, A group of 12 students (B.Sc. and M.Sc. with major on environmental and resources management, biology, nutrition and medicine, aged 20-30 years old, using their own Smartphones (all with Android ~~Information-operation~~ system)) said they experienced “joy of discovery” and “surprise”, particularly facing the super-imposed videos. They felt involved in the trail. The AR fascinates the user, and this fascination for the technical aspects is transferred in fascination for the content. As it has been shown by others, The learner is motivated and wishes to explore and learn more (Radu et al., 2010; Tönnis, 2010). This positive emotional state also makes the experience memorable, helping memory encoding and learning of the content (Fredrickson, 1998). However, when AR will be a common experience, research will observe whether this emotional benefit is sustainable in the long-term.

Other expected benefits from learning with the Schwingbachtal App can be ~~discussed~~suggested, based on literature work. A proper evaluation of the learning tool to verify our expectations still need to be performed. First, it is an intermodal tool, using imaged, audio and textual contents. Intermodal learning helps to keep learning for longer time and is more efficient (Barron, 2003; Bitter and Corral, 2014). Second, it is a kind of active learning, thus, it develops self-training skills, and it was observed during the preliminary test that the autonomous search for POIs raises the curiosity of the user. Third, we think that the Schwingbachtal App displays intuitive navigation and object manipulations, thus, presenting low learning costs and limiting cognitive loads. Cognitive loads happen when activities require working memory and thus reduce learning potential (Radu et al., 2010).

The AR tour is a supplementary tool that add to the existing others. It is developed following the concepts of “micro-teaching” module (Brall and Hees, 2007), aiming at keeping the users stimulated and actively thinking . The Schwingbachtal App ~~addresses~~addresses mostly students who have to learn, but is expected to meet the curiosity of strollers eager to learn. Adapting the contents to the target public significantly reduces displeasure to use the App (Herber, 2012). To check if the App is adapted to our scholar target, a thorough evaluation of the App will be carried on in the summer semester of 2016: is the App an effective complementary

learning tool? In addition, the App brings the understanding that processes happens on the field, at any moment the user is standing there, as well as before (for instance by providing instant measures but also whole time series). It therefore enhances the local and temporal aspect of the processes that can be hard to otherwise explain (Herber, 2012).

Of course, a limiting point to the use of the Schwingbachtal App is the necessity to ~~owe~~own a smartphone – but as it is optional resource, we do not consider it as discriminating. Another limit worth-mentioning is the workload for keeping contents up to date. The future use and success of the App rely on a good communication/advertising on the tool from the University-site, but also in local media, a task which remains to be done.

As a whole, we consider the App as a clever way to use a smartphone for teaching purposes. As stated by Teacher et al. (2013), “the phone in our pocket deserves better application as a collector and handler of data, while its inbuilt links to the internet reveal the potential for real-time information flow between collectors, databases, interpreters, and users of information. These technologies provide an unusual opportunity to link science with society [...]”. We are likewise thinking how to use smartphones not only as a “top-down” link between science and society, but also as a bottom-up link, where any users could actively participate e.g. as data collector and provider, in other words, how to implement the use of smartphone in Schwingbachtal in a citizen science project.

#### 4. Conclusions

The Studienlandschaft Schwingbachtal is an out-door full-scale study site since 2008. It deals with hydrology in an interdisciplinary approach and enhances active learning by various means (field monitoring, education trails and geocache). In order to adapt to the change in students habits and to suit better as a communication tool for the locals, it is newly equipped with augmented reality which adds virtual objects on the real landscape. The development of the augmented reality learning tool was discussed in details, as guidelines for future similar projects, and expectation concerning the benefits for learning are suggested, awaiting full evaluation during the summer semester 2016. Such an App is useful for communication and education purposes, making learning pleasant, and offering personalized options.

#### Supplementary Material

The source code of Schwingbachtal App can be downloaded from the following server: [fb09-pasig.umwelt.uni-giessen.de/sbappdescription]. The Augmented Reality browser Wikitude

374 can be downloaded via the app-store (in accordance to the smartphone operating system).  
375 A video showing the use of the Schwingbachtal App is available as an online supplement.  
376



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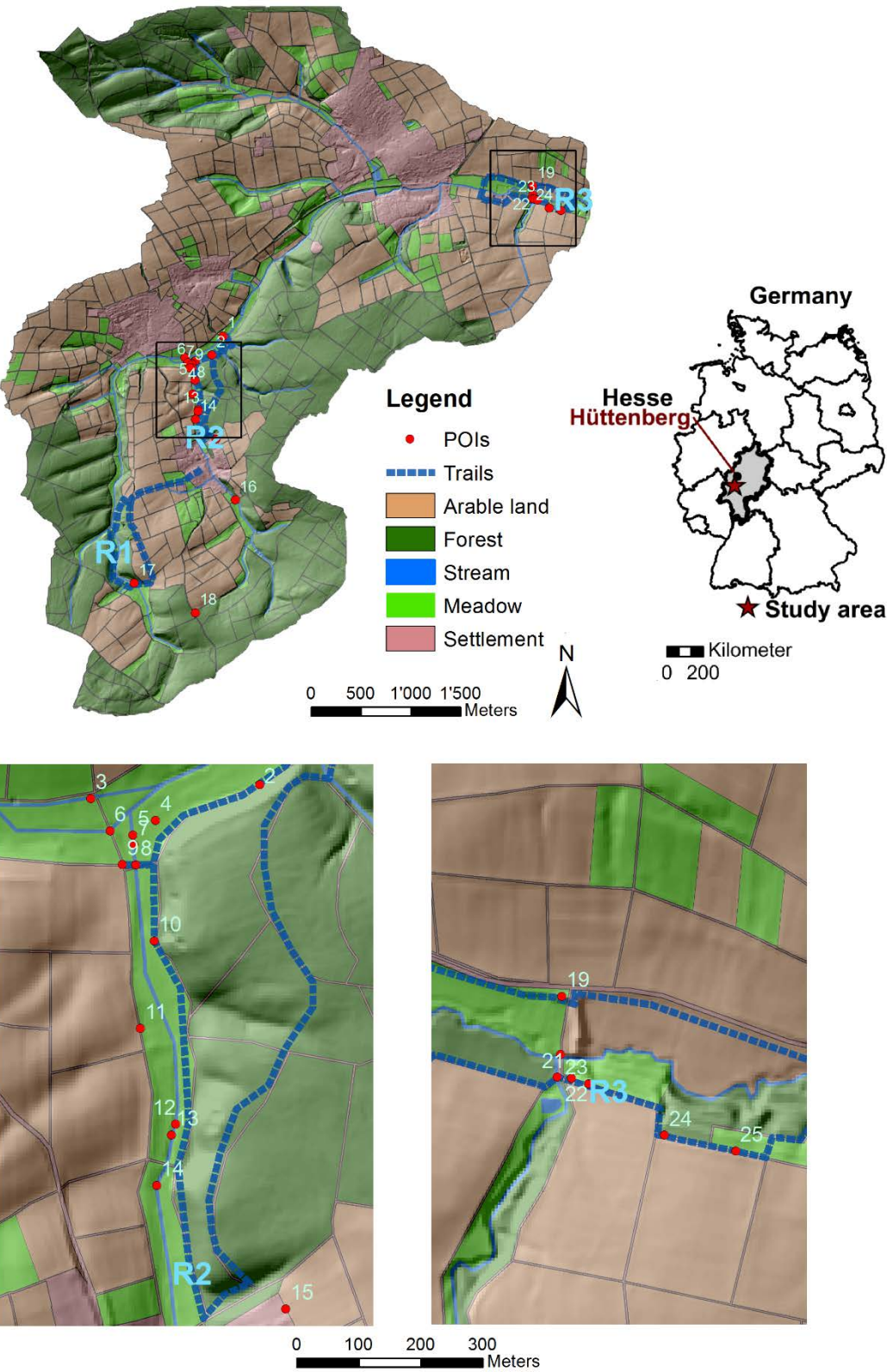
449 Table 1. Themes, titles and media of the points of interests (POI) of the AR-tour in  
 450 Studienlandschaft Schwingbachtal.

Number on the map	Type of POI	Topic	Title	Type of content available	Recognition tool (target used for visual tracking or coordinates)
1	Rich information	Hydrology	And so flows the Schwingbach	Audio comment+ link	Image on the board
2	Rich information	Hydrology	Water balance in the woods	Video comment + link	Image on the board
3	Static information	General	Elements of an agricultural landscape	Link to Geocache	Image on the board
4	Static information	Hydrology	Measuring groundwater depth	Comment + image	Coordinate
5	Live data	Hydrology	The climate station	Link to the live data	QR-code
6	Rich information	Hydrology	Every single drop counts	Discharge calculator + link	Image on the board
7	Static information	Hydrology	The lower RBC-flume	Comment	Coordinate
8	Rich information	Hydrology	The stream rustle	Video comment + link	QR-code
9	Rich information	Ecology	Arable land: let it live!	Memory-game	Image on the board

10	Static information	Ecology	Insects homeland	Links	Recognition of the insect hotel
11	Rich information	Soil	The various soil profiles	2 videos comment + link	Image on the board
12	Rich information	Hydrology	Nutrient inputs in water bodies	Video comment + link	Image of nettle on a wooden post
13	Static information	Hydrology	Combined sewage overflow	Figure + comment	Coordinate
14	Static information	Hydrology	The Upper RBC-flume	Figure + comment	Coordinate
15	Static information	Hydrology	Tipping buckets to measure rain	Image (scheme) + comment	Recognition of the tipping bucket-photo
16	Rich information	Hydrology	Collecting rain to estimate N-deposition under oak	Video	Coordinate
17	Static information	Hydrology	How does a V-notch work?	Comment + figure	Coordinate
18	Static information	Hydrology	Collecting rain to estimate N-deposition under spruce	Comment + figure	Coordinate
19	Static information	General	Water and intensive land use	Comment	Image on the board

20	Live data	Hydrology	The climate station at Vollnkirchener Bach	Link to the live data	QR-code
21	Live data	Hydrology	How does the wind blow in Schwingbach?	Live data + comment + link	Image on the board
22	Rich information	Hydrology	A hole in the soil is more than what you think	Audio + link	Photo on the board
23	Rich information	Soil	Loess, yellowish sediment from the ice age	2 videos	Image on the board
24	Rich information	Ecology	Orchads: let it live!	Audio + links	Image on the board
25	Static information	Soil	Soil erosion, the creepy loss of invaluable resource	Link list	Image on the board

452 Figure 1. Map of Studienlandschaft Schwingbachtal showing land use, digital elevation  
453 model, points of interest (POIs) along educational trails.



455 Figure 2. A few snapshot of the Schwingbachtal App: (a) how the AR navigation looks like,  
 456 the blue label indicating a point of interest (POI), (b) the preview of the POI, (c) one of the  
 457 super-imposed video: the lecturer explains the water cycles in the forest.

a)



b)



c)



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# Studienlandschaft Schwingbachtal: an out-door full-scale learning tool newly equipped with augmented reality

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## Abstract

This paper addresses education and communication in hydrology and geosciences. Many approaches can be used, such as the well-known seminars, modelling exercises and practical field work but out-door learning in our discipline is a must, and this paper focuses on the recent development of a new out-door learning tool at the landscape scale. To facilitate improved teaching and hands-on experience, we designed the Studienlandschaft Schwingbachtal. Equipped with field instrumentation, education trails, and geocache, we now implemented an augmented reality App, adding virtual teaching objects on the real landscape. The App development is detailed, to serve as methodology for people wishing to implement such an education tool for geosciences, in particular hydrology. The resulting online application, that is run in the ready-made augmented reality browser Wikitude, is described as an example. As it was proven in other communication field, we expect that such an App is useful for communication and education purposes, making learning pleasant, and offering personalized options. The benefits of the tool should be verified next semester.

## Keywords

Hydrology, education and communication, augmented reality, education trail, geo-cache



## 1. Introduction

### *Studienlandschaft Schwingbachtal: an out-door full scale learning tool*

Learning by doing is an old concept. At the university, education includes practical work, commonly when the topic allows it, and field excursions, more seldom due to travel financial and organisational constraints. Water sciences, and environmental sciences in general, are topics for which learning in the field is necessary (Nash et al., 1990): observing landscapes already tells a lot about the water cycle. Field learning also allows better understanding of measurement devices. Keeping this in mind, we decided to create an interdisciplinary landscape-based teaching facility that includes many different learning methods (Wagener et al., 2007). A further aim was to involve science-based projects in the landscape to facilitate a discussion between undergraduate and graduate students on the one hand, but also allow science to go public (Nash et al., 1990; Seibert et al., 2013).

In 2008, we established the study site Studienlandschaft Schwingbachtal. The goal was to create an education tool for the students of environmental sciences of the Justus Liebig University of Giessen, Germany. The chosen site needed to be in reasonable distance to the University and easily accessible with large group of students. It should be a headwater catchment, which size allows touring in a limited time (half day). Human impact such as settlement and agriculture should be present to raise awareness about their impact on the environment, as partly targeted by the majors in environmental sciences. The Schwingbach catchment, located 20 minutes' drive away in the south-west of Giessen met the above-mentioned criteria. A potential outlet stood as evidence with the existence of a retention basin, which offered facilities for further instrumentation (secured bridge above a regular straight stream section).

The Schwingbach catchment encompasses the Schwingbach and several small tributaries, of which the Vollnkirchener Bach is the largest one. A retention basin defines the outlet of the overall study catchment (Fig.1). It covers a total area of about 23.5 km<sup>2</sup> (Fig.1). The Schwingbach catchment is covered by forest (36.9 %), arable land (39 %), and grassland (10.5 %). The Vollnkirchener Bach flows through the small village of Vollnkirchen, while the upper headwater of the Schwingbach is free of settlements. Humans have modified stream networks with drainages to dry up arable land, a combined sewage overflow, and partially channelized stream reaches. Soils are diverse: Cambisols (mostly in the forested area), Gleysols (along the streams) and agricultural Stagnosol, making the catchment a good case

study, and reflecting a complex geology. The climate is temperate. Further information particularly about the hydrology of the catchment are described in Lauer et al. (2013) and Orłowski et al. (2014).

[Figure 1. Map of Studienlandschaft Schwingbachtal showing land use, digital elevation model, points of interest (POIs) along educational trails.]

The Studienlandschaft Schwingbachtal project includes various educational approaches from the start, all considering the principle of learning by doing. (i) Excursions with large groups of students, subdivided in smaller groups, are organised as part of lectures: many monitoring techniques, orally described with supporting pictures during the seminars are turned into gestures. For instance, students measure discharge using the salt dilution method, the speed of the water, by flumes (RBC, Eijkelkamp, NL). (ii) Three educational trails (Fig. 1), consisting of informative boards on hydrology, ecology and soils are installed in the catchment. Both students and locals can read them autonomously (though some locals commented that some boards were too technical). Thus, these trails are also a communication tool, informing locals of the University's involvement in the catchment. (iii) Since summer 2014, the trail hosts a geocache (<http://www.geocaching.com>, “ Studienlandschaft Schwingbachtal”), introducing game and challenge to motivate the strollers to go around the trail. Indeed, geocache principle is to reach a final point, through various stages, where hints about geographical coordinates are given. In this case, finding the hints requires the participant to read the boards. (iv) To deal with the collected data, assure coherence, and no loss of data a database with an online interface was created (Institute for Landscape ecology and resource management, 2012). The web frontend of the database is designed to assist students, researchers and technical assistants from planning the maintenance tasks, to quality assurance and data analysis, over the data collection in the field. Users can upload manually collected data, like groundwater level with electric contact gauges, discharge using the salt dilution method, as well as lab results, using spreadsheet templates. Data collected from automatic data loggers can be imported directly into the database and calibrated with the manual measurements from the same site; invalid values due to instrument failures are masked by the database manager. Users can export the time series, stored in a structured database, using filters for sites, instruments and dates. However, time series can also be plotted and transformed with the web interface. Specific data sets, like online available meteorological data, can be viewed by the public. (v) The Studienlandschaft Schwingbachtal also hosts many diploma works, from

Bachelor to Doctorate. Since 2008, over 30 theses were conducted in the study area, requiring students and PhD candidates to install measuring stations according to their research questions. As a result, the study site database counts over a hundred sampling points e.g. for discharge, groundwater level, surface- and ground-water chemistry, trace gas emissions, meteorology, etc. While several dynamic parameters are regularly measured (e.g. discharge, groundwater table depth, instream nitrate concentrations), others parameters are only measured once to improve the spatial coverage of information (e.g. infiltration, saturated conductivity). Student jobs and internships are the backbone of routine measures. This is also a mean for the students to explore their interest in academic studies (helping them to orientate towards their best interest).

All these ways of learning are well-known and nowadays commonly used. Students' feedbacks to such approaches of hydrology are positive. But, as technology is continuously developing and part of our daily life (i.e. smart phone and the set of sensors they contain) and, as students presently entering the universities are part of the so called y-generation (Keith Macky et al., 2008), defined as "technologically sophisticated", new approaches need to be implemented. One of the most promising is augmented reality.

#### *Augmented Reality: the new learning equipment*

Augmented reality (AR) can be defined as any system that fulfil the three following requirements: It "combines real and virtual [world], is interactive in real time and is registered in three dimensions" as stated by Azuma (1997). Milgram and Colquhoun (1999) refine this definition assigning AR in a *reality-virtuality continuum*. AR is thus part of the domain of mixed reality, in which the real environment is the baseline and some virtual objects are complementing it. From the start, AR has been used for training in military context or in medicine. Thanks to the spreading of smart phones, AR has appeared in museums over the last decades as Apps to enhance visitors learning experience (for instance, Mannion, 2012). Indoor AR benefits from the infrastructures (e.g. access to Wireless Local Area Network (WLAN), constant light conditions). By contrast, outdoor AR remain challenging to (i) determine the user's position and orientation with sufficient accuracy to align properly virtual objects with real world; (ii) overcome constant changing environment (e.g. variation in light, moving objects, seasonal vegetation changes) and (iii) benefit from constant available network.

Since Azuma's review (1999), outdoor AR improved (for instance: Langlotz et al., 2011; Veas et al., 2012) and some native AR-Apps are nowadays available on the market, such as enhanced trail road in natural parks or touristic city guided tours (Guttentag, 2010; Jung et al., 2015). Native Apps are those developed for use on a particular platform or device, using smartphones specific hardware and software. They often use multiple tracking as to overcome the above-mentioned issues, i.e. they combine Global Positioning Systems, reckoning trackers (rate gyroscopes), passive optical trackers (video sensors, line-of-sight), electronic compass, and tilt sensors (inclinometer).

The present paper focuses on the development of an AR-App built on existing software, for the Studienlandschaft Schwingbachtal. First, the concept and technical aspects of the development will be described, as a methodology to develop such a tool, then, the resulting application will be depicted. To finish, expectations of the use of such AR tool for teaching hydrology will be discussed.

## **2. Development of the Schwingbachtal App**

### **2.1. Conceptual design of the Schwingbachtal AR-App**

"Mobile learning" means learning with mobile media (e.g. smartphone, phablet, tablet) (Kingston et al., 2012), i.e. learning whatever the situation and whenever. Thus, mobile learning is not a substitute to a more classic form of learning, but an extension. The benefit is to allow spontaneous learning, when a stimulus provokes an urge for learning, in particular learning something small, in a short time. The Schwingbachtal application lays in a restriction of mobile learning as it is meant to be site-dependent. However, the content should be accessible without a predefined order, warranting as much flexibility and spontaneity as the user wishes. The technical aspect of the use of AR should not be a barrier to the learners and thus should be intuitive.

The target audience needs to be defined as it conditions the level of prior knowledge and the scientific concepts to explain. In the case of the Schwingbachtal App, the audience is meant to be the same as for the educational trail and for the outside teaching lectures, i.e. undergraduate students. However, there might be other interested visitors (public audience, local people, school classes) who wander on the trail and are wishing to learn more. Thus, the new App should take into account that the educational trail was reported to be not so accessible for the locals, i.e. content should be made more accessible..

The points of interest – POIs, where to provide knowledge – also needs to be defined. We decided that the App will mostly be a technological update of the existing written static information of the educational trail. It should keep the interdisciplinary theme “Soil, Ecology and Water”, adding video and audio contents, as well as interactive contents to enter the domain of active learning: (i) real-time picture recognition (AR component) to guide visitors around the trail (visual tracking); (ii) see “inside” devices (in a tipping bucket for instance); (iii) games such as memory cards for plant recognition complementing ecology panels; (iv) flow calculation after reading the water level on the scale of the RBC flume complementing the discharge measures panel), (see results for a complete description of the App content).

## **2.2. Technical design**

### *Choosing the AR-browser and App structure*

Every AR App needs to provide a common set of features, (i) to detect the reality to be augmented, like reading the absolute position in space using the GPS and gyro sensors or interpreting the actual camera picture etc., and (ii) to display content that augments the reality. While specialized technical knowledge is needed to provide the infrastructure, domain knowledge is needed to provide the content. So-called AR-browsers are native Apps which provide location and recognition techniques to show content, as web browsers have the ability to open and display web sites. Publishing content for an AR-browser, which is what we have done, is very similar to creating web sites. Then, the end-user only needs to download the AR-browser from a store (eg PlayStore, AppStore) and install it on the smartphone. At the time of development of the Schwingbachtal App three different AR-browsers were available on the market: Layar, Junaio and Wikitude. To our understanding, the Wikitude browser (GmbH, Salzburg, Austria), most used worldwide, offers advanced image and location recognition, full assistance for site-specific service and image recognition. In addition, a wide range of content types including super-imposed videos is available. Within this browser, sites –called “worlds” or AR-Apps by Wikitude - are stored, including our Schwingbachtal App. When the world is loaded in the browser, the user browses the augmentation of the reality, not by entering web site names and using search engines, but by moving through the real space and real objects. Since the content is loaded live from a web server, a constant mobile internet connection needs to be available in the area of interest. For rich content, like video and audio services, a 3G connection, or better, is needed. We checked the 3G- and 4G-reception in the

Schwingbach. Given the four mobile network providers in Germany, it was observed that the study site is in general well-covered with 3G- and 4G-reception, apart local exceptions.

### *Location-dependent tracking*

The augmented reality browser offers location-based services. Depending on the current position of the user, points of interest (POI) are displayed on the basis of predefined geo-coordinates. All information of a POI (coordinates, descriptive text, title, images, links) are stored on a server. POI locations are marked at their geographical coordinates (latitude and longitude). Clicking on a POI makes information of the POI appears on the right-hand side of the image together with a link. This way, before getting the scientific content, the user can decide to access this information or walk to the next POI. The implementation used in this work originates from a template provided by Wikitude (2014).

To assist the user in orientating, a radar – small compass showing the location of the POI –, a map view, and a help button are added. The radar adjusts the visible POI according to the user's location and his/her distance to it. The radar and range-restriction are implemented using a Wikitude template (2015). The map view, from Google Maps, shows the POI (in JavaScript, stored in an Hypertext Markup Language (HTML) page). It also marks the current user location (using a HTML script). The help button is integrated over a continuously displayed i-Button at the bottom of the App. Linking the help button to the help page browser is done via integration in the index-HTML.

### *Visual tracking, or image recognition*

In addition to the location-based tracking, the AR-browser offers image recognition. Tracking visual objects are required, i.e. recognizing images. These can include for instance images displayed on the boards or Quick Response (QR) codes (Denso Wave Incorporated, Kariya, Japan). For image recognition in Wikitude, a tracking file (.wtc) is needed. The images to be recognized are uploaded to the server of Wikitude as .wtc-files in a “target collection”. The tracker code aims at examining continuously the camera image from the smartphone and compares it with the images stored in the target collection specified in the program code (in our case the Studienlandschaft Schwingbachtal target collection, JavaScript code).

### *Image overlay*

Once the image is recognized, i.e. visual tracking performed, a linked virtual object can be displayed on the screen, augmenting reality. This act of adding an image to the real world is called image overlay. This is done in Wikitude (2015) by the target manager tool. Each image

of the “target collection” are linked with the content to overlay, either image, audio or video files, for image-, audio-, video-overlay, respectively. When the image is recognized, the linked content is allocated in a virtual place holder. Both the camera image and the place holder are then combined into a Trackable2DObject, which results in what is displayed on the smartphone screen. In the Schwingbachtal App, a quiz on self-propagating plants in agricultural fields, a discharge calculator and the access to subpages are realized using the image overlay.

#### *Video overlay*

Video overlay works similar to image overlay and is started when the triggering visual object is recognized and stop as soon as the object leaves the camera picture. Videos for the Schwingbachtal App have 960 x 256 pixels resolution (in H.264 / MPEG-4 AVC compression standard) and a frame rate of 15 frames per second. Therefore, the size of a two-minute video file is about 2-3 MB. This reduced size speeds up the transmission and optimizes the smartphone data volume used. For an educational App, like here, a lecturer popping out of an installed information board, is a nice effect. To realize this, the background of the lecturer needs to be transparent. Few video formats support transparency natively, the only format supported by the Wikitude AR-browser (H.264) is not an exception. However, it is possible to split the video into two screens: the original video and a moving transparency mask. These two screens are merged together by the browser to show only the lecturer and not the background. The mask video can be extracted using any professional video cutting software with a chroma-keying. To this end, the lecturer is recorded in front of a green wall, and the software detects the green background and can transfer it into the mask screen.

#### *Audio overlay*

Audio-only overlays are not supported by the browser. However, a complete transparent video without any visual content is effectively stored as video codec, making this a valid alternative approach where audible information is needed. In fact, the resulting file size is, due to the modern audio compression in modern video codecs, usually smaller than an MP3 file of the same audio quality.

#### *HTML overlay*

HTML overlay works similar as image overlay. The HTML information is given in a JavaScript code, together with previously created images and link buttons. These elements are

combined into a Trackable2DObject by the tracker code. In the Schwingbachthal App, current climate data of the weather station, transferred by the University server, are called by the HTML overlay.

### **3. Results and discussion**

#### **3.1. The trail whose reality is augmented by virtual objects**

The user is now able to connect from his smartphone to the AR-browser. The App forwards the user's request and location information to the Wikitude server. In turn, the Wikitude server then forwards the request to the university IT-infrastructure where the content of the App is stored. Then, the Institute server sends the data back to the Wikitude server, which forwards it to the user: the POI appears on its mobile with a proper style sheet.

Twenty-five POIs compose the Schwingbachthal App (Table 1), among which three types are identified: static information POI (providing HTML links), live data POI (continuously providing data that were just measured) and rich information POI (including video and audio content, as well as games). The trail is now composed of the landscape elements and information boards (reality), complemented with the virtual objects from the AR App. Two sets of videos were shot and cropped for the AR (video comments) and 25 web pages written (textual comments and links). The POI are presented in Table 1 and snapshots of the App in Fig.2. A video is available as online supplement. Points can be reached in any order as they bring independent information.

[Figure 2. A few snapshot of the Schwingbachthal App: (a) how the AR navigation looks like, the blue label indicating a point of interest (POI), (b) the preview of the POI, (c) one of the super-imposed video: the lecturer explains the water cycles in the forest.

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Different navigation options are available for the App user. First, one can use the map representation. The overview map shows the location of all 25 POIs. The map can be zoomed in and out, and also used for navigation when the current position is marked. Second, when using the AR-browser-view, the POIs are marked by blue labels on the viewed landscape. These labels are defined by their latitude and longitude and are downloaded once, at the start of the App. The navigation is supported by a radar view, small compass on the left upper corner of the screen, which indicates the limit of sight and the POIs with small dots. The



number of POIs in view sight and the coverage, can be adjusted by a “range” button, the user can decide how far the displayed POIs are. At any time, the navigation mode can be changed.

We would like to emphasize that explaining complex concepts within the limits of small smartphone display was challenging, in particular due to the screen size. For future similar project, we recommend to focus on the use of larger screens such as tablets or phablets. However, one needs to be aware of the trade-off between comfort of the user and size of the App, i.e. download speed. Offering a fluid entrainment is a topical concern for AR App (Tönnis, 2010). Indeed, the propagation delay between the tracking system, the conversion of the data, and the rendering explain the un-smoothness. This could be improved either by reducing the data size of the content (for instance of the video) or by creating an offline App. Our current solution is optimised for smartphones to facilitate download, using a quality of the visuals not suitable for bigger screens. At the moment, a good in-situ connection is necessary: it is currently not possible to pre-download the content and recall the already-downloaded content on the field. This latter option would also be questionable, as it is not expected that a user wish to read from all the POIs, and thus pre-downloading everything would just be memory consuming.

During tests, mistakes in localisation of POIs occurred. This is certainly due to shadowing of the signal and the rather low quality sensors that compose our smartphones (Langlotz et al., 2011). Location and visual tracking are still research topics (Veas et al., 2012). In our case, thanks to the preview (map-view), the user can understand if there is a location tracking mistake, and then, look for the right location changing navigation mode. This location tracking mistakes being expected, we decided to offer many POIs linked to image recognition. However, for a performant visual tracking, images should show prerequisites (i.e. showing high-contrast, large structured areas and angular elements (“Wikitude,” 2015)), which was not always the case, as the trail was pre-existing. Light effect and mirror effect of the Plexiglas are also reasons for incorrect image tracking (Tönnis, 2010).

A last point to be discussed is the fact that, as such, the Schwingbachthal App is energy consuming. All sensors need to be continuously activated for the tracking (location and image) and for the data download. Incorporating in the App scripts for activation/deactivation of the sensors would optimize the energy used, and warranty longer exploration.

### 3.2. Is the Schwingbachtal App educationally relevant?

As preliminary evaluation of the Schwingbachtal AR learning tool, a group of 12 students (B.Sc. and M.Sc. with major on environmental and resources management, biology, nutrition and medicine, aged 20-30 years old, using their own Smartphones (all with Android operation system)) said they experienced “joy of discovery” and “surprise”, particularly facing the super-imposed videos. They felt involved in the trail. The AR fascinates the user, and this fascination for the technical aspects is transferred in fascination for the content. As it has been shown by others, the learner is motivated and wishes to explore and learn more (Radu et al., 2010; Tönnis, 2010). This positive emotional state also makes the experience memorable, helping memory encoding and learning of the content (Fredrickson, 1998). However, when AR will be a common experience, research will observe whether this emotional benefit is sustainable in the long-term.

Other expected benefits from learning with the Schwingbachtal App can be suggested, based on literature work. A proper evaluation of the learning tool to verify our expectations still need to be performed. First, it is an intermodal tool, using imaged, audio and textual contents. Intermodal learning helps to keep learning for longer time and is more efficient (Barron, 2003; Bitter and Corral, 2014). Second, it is a kind of active learning, thus, it develops self-training skills, and it was observed during the preliminary test that the autonomous search for POIs raises the curiosity of the user. Third, we think that the Schwingbachtal App displays intuitive navigation and object manipulations, thus, presenting low learning costs and limiting cognitive loads. Cognitive loads happen when activities require working memory and thus reduce learning potential (Radu et al., 2010).

The AR tour is a supplementary tool that add to the existing others. It is developed following the concepts of “micro-teaching” module (Brall and Hees, 2007), aiming at keeping the users stimulated and actively thinking . The Schwingbachtal App addresses mostly students who have to learn, but is expected to meet the curiosity of strollers eager to learn. Adapting the contents to the target public significantly reduces displeasure to use the App (Herber, 2012). To check if the App is adapted to our scholar target, a thorough evaluation of the App will be carried on in the summer semester of 2016: is the App an effective complementary learning tool? In addition, the App brings the understanding that processes happens on the field, at any moment the user is standing there, as well as before (for instance by providing instant

measures but also whole time series). It therefore enhances the local and temporal aspect of the processes that can be hard to otherwise explain (Herber, 2012).

Of course, a limiting point to the use of the Schwingbachtal App is the necessity to own a smartphone – but as it is optional resource, we do not consider it as discriminating. Another limit worth-mentioning is the workload for keeping contents up to date. The future use and success of the App rely on a good communication/advertising on the tool from the University-site, but also in local media, a task which remains to be done.

As a whole, we consider the App as a clever way to use a smartphone for teaching purposes. As stated by Teacher et al. (2013), “the phone in our pocket deserves better application as a collector and handler of data, while its inbuilt links to the internet reveal the potential for real-time information flow between collectors, databases, interpreters, and users of information. These technologies provide an unusual opportunity to link science with society [...]”. We are likewise thinking how to use smartphones not only as a “top-down” link between science and society, but also as a bottom-up link, where any users could actively participate e.g. as data collector and provider, in other words, how to implement the use of smartphone in Schwingbachtal in a citizen science project.

#### **4. Conclusions**

The Studienlandschaft Schwingbachtal is an out-door full-scale study site since 2008. It deals with hydrology in an interdisciplinary approach and enhances active learning by various means (field monitoring, education trails and geocache). In order to adapt to the change in students habits and to suit better as a communication tool for the locals, it is newly equipped with augmented reality which adds virtual objects on the real landscape. The development of the augmented reality learning tool was discussed in details, as guidelines for future similar projects, and expectation concerning the benefits for learning are suggested, awaiting full evaluation during the summer semester 2016.

#### **Supplementary Material**

The source code of Schwingbachtal App can be downloaded from the following server: [fb09-pasig.umwelt.uni-giessen.de/sbappdescription]. The Augmented Reality browser Wikitude can be downloaded via the app-store (in accordance to the smartphone operating system). A video showing the use of the Schwingbachtal App is available as an online supplement.

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442 Table 1. Themes, titles and media of the points of interests (POI) of the AR-tour in  
 443 Studienlandschaft Schwingbachtal.

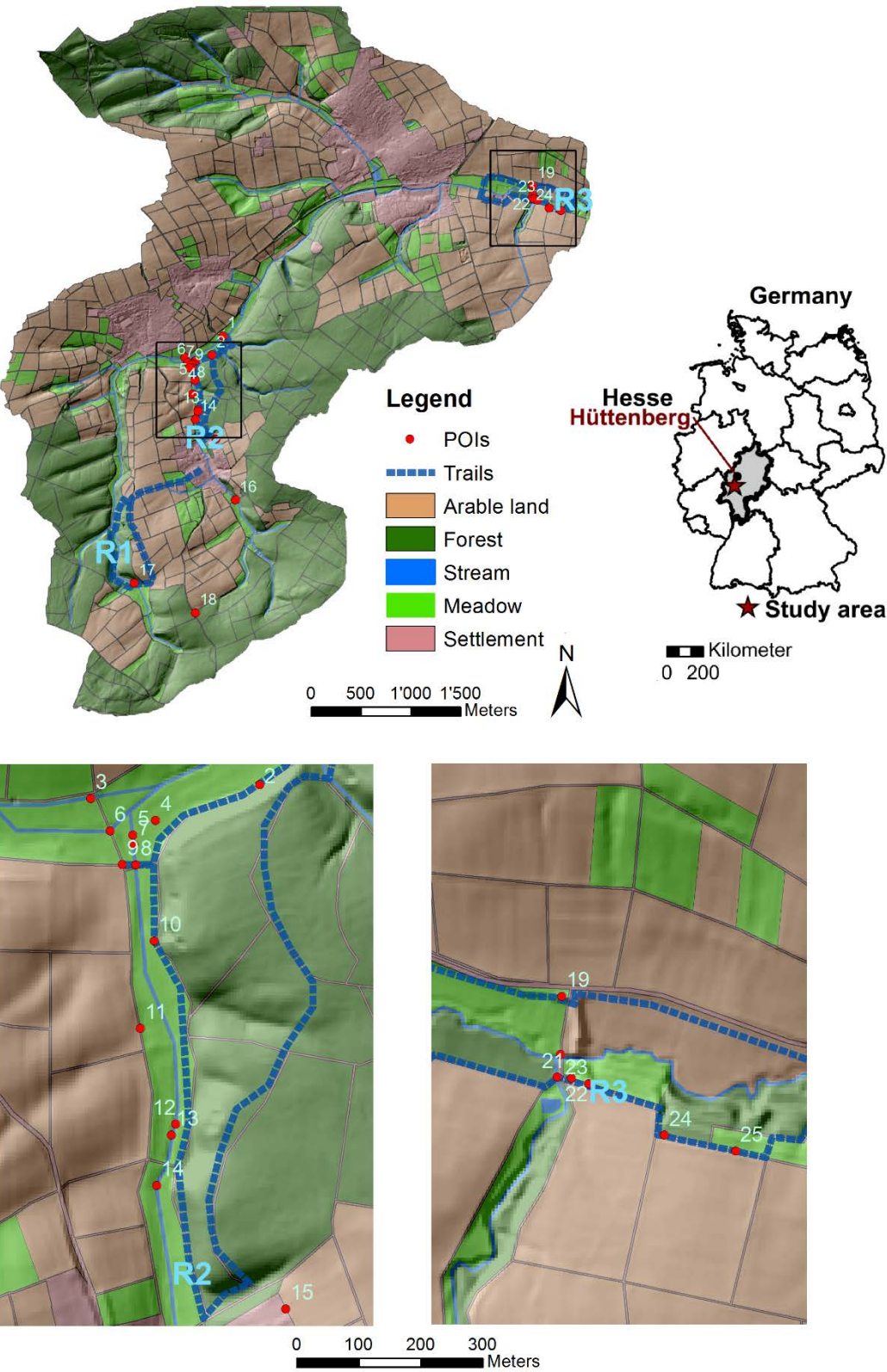
Number on the map	Type of POI	Topic	Title	Type of content available	Recognition tool (target used for visual tracking or coordinates)
1	Rich information	Hydrology	And so flows the Schwingbach	Audio comment+ link	Image on the board
2	Rich information	Hydrology	Water balance in the woods	Video comment + link	Image on the board
3	Static information	General	Elements of an agricultural landscape	Link to Geocache	Image on the board
4	Static information	Hydrology	Measuring groundwater depth	Comment + image	Coordinate
5	Live data	Hydrology	The climate station	Link to the live data	QR-code
6	Rich information	Hydrology	Every single drop counts	Discharge calculator + link	Image on the board
7	Static information	Hydrology	The lower RBC-flume	Comment	Coordinate
8	Rich information	Hydrology	The stream rustle	Video comment + link	QR-code
9	Rich information	Ecology	Arable land: let it live!	Memory-game	Image on the board

10	Static information	Ecology	Insects homeland	Links	Recognition of the insect hotel
11	Rich information	Soil	The various soil profiles	2 videos comment + link	Image on the board
12	Rich information	Hydrology	Nutrient inputs in water bodies	Video comment + link	Image of nettle on a wooden post
13	Static information	Hydrology	Combined sewage overflow	Figure + comment	Coordinate
14	Static information	Hydrology	The Upper RBC-flume	Figure + comment	Coordinate
15	Static information	Hydrology	Tipping buckets to measure rain	Image (scheme) + comment	Recognition of the tipping bucket-photo
16	Rich information	Hydrology	Collecting rain to estimate N-deposition under oak	Video	Coordinate
17	Static information	Hydrology	How does a V-notch work?	Comment + figure	Coordinate
18	Static information	Hydrology	Collecting rain to estimate N-deposition under spruce	Comment + figure	Coordinate
19	Static information	General	Water and intensive land use	Comment	Image on the board

20	Live data	Hydrology	The climate station at Vollnkirchener Bach	Link to the live data	QR-code
21	Live data	Hydrology	How does the wind blow in Schwingbach?	Live data + comment + link	Image on the board
22	Rich information	Hydrology	A hole in the soil is more than what you think	Audio + link	Photo on the board
23	Rich information	Soil	Loess, yellowish sediment from the ice age	2 videos	Image on the board
24	Rich information	Ecology	Orchads: let it live!	Audio + links	Image on the board
25	Static information	Soil	Soil erosion, the creepy loss of invaluable resource	Link list	Image on the board



445 Figure 1. Map of Studienlandschaft Schwingbachtal showing land use, digital elevation  
446 model, points of interest (POIs) along educational trails.



448 Figure 2. A few snapshot of the Schwingbachtal App: (a) how the AR navigation looks like,  
 449 the blue label indicating a point of interest (POI), (b) the preview of the POI, (c) one of the  
 450 super-imposed video: the lecturer explains the water cycles in the forest.

a)



b)



c)



451