Supporting Learner-Content Interaction on Autodidactic Field Trips through Mobile Learning Applications

Full Paper

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Abstract

The increasing number of university students in Europe leads to an increasing student-to-lecturer ratio which finally results in a lower quality of studying experience. Thus, lecturers have to find new possibilities to adapt to the changing circumstances. This is particularly important in disciplines of natural sciences, as they integrate field trips in their curriculum, which require small groups of students. To be able to offer field trips in the future, one possible solution is to combine them with mobile learning application to enable autodidactic field trips. As prior research already showed that mobile learning applications can support autodidactic activities in education, the aim of this study is to design and develop a mobile learning application to support field trips. The existing research about designing such applications is limited, especially regarding needed requirements. With the aim of deducing meta-requirements and design principles for such applications, we apply the design science approach.

Keywords

Mobile Learning, Field Trips, Mobile Applications, Mobile Learning Applications, Design Science Research

Introduction

> *“Usually our field trips are performed in small groups of about 20 students. At the moment, we face the problem of having a huge amount of first-year students […] and we cannot offer field trips with so many people. […] one consideration is to offer autodidactic field trips.” (Expert 2)*

The increasing number of university students in Europe leads to an increasing student-to-lecturer ratio (EACEA 2012) which leads to an decreased level of interaction within educational courses. As the level of interaction among lecturers and learners, learners and learners as well as leaners and content is an important aspect of high quality teaching, the studying experience for students is also decreasing (Moore 1993). This is a challenge, especially in the disciplines of natural sciences: The curriculum in these disciplines often includes field trips as an important part of the academic education, which require relatively small groups of students (Nabors et al. 2009). However, to be able to offer field trips even for increasing amounts of students, new concepts for such field trips must be created. As confirmed by Expert 2, one of our interview participants in this study, one possibility is to combine field trips with new learning concepts, like mobile learning, to create autodidactic field trips, which can be conducted by students on their own. The resulting combination of classroom teaching and the use of new technologies – so called blended learning – gives the chance to improve the learning experience by supporting learner-content interaction (Dunlap et al. 2007; Sancho et al. 2006).

Prior research in other disciplines already confirmed that mobile applications can be successfully used in large scale blended learning scenarios to increase the interaction within university courses (Lehmann and Söllner 2014; Wang et al. 2009). The existing research about designing such applications in similar field trip setting is limited and focuses on special use cases only. It further lacks of a generalization of the results to provide reusable requirements. In this paper, we want to determine such requirements which are not only valid in our scenario but can also be transferred to other use cases in the future. Therefore, we apply the design science research process model as described by Peffers et al. (2006) to design and develop such mobile learning applications. Thus, we answer the following research questions:

> **RQ1:** Which requirements are needed for supporting autodidactic field trips using mobile learning applications in the disciplines of natural sciences?

Afterwards, we show a prototype to validate the realized requirements with a first exemplary use case. So we ask:

> **RQ2:** Can an implementation of the deduced requirements successfully support autodidactic field trips?

To answer the research questions above, the remainder of this paper is structured as follows: First we present related work in the area of mobile learning concepts within field trips. Afterwards, we describe our research methodology. Following this methodology, we deduce requirements from a focus-group interview. Based on this we derive design principles, describe the implementation of our prototype, and show results of a first validation that were gathered using a field experiment. Finally, we discuss our findings and highlight future research directions in the conclusion.

Related Research

Mobile learning applications are a subset of mobile applications and are as such running on mobile devices (Stormer et al. 2005). They are targeted at learners to support their current learning process. As these applications usually provide learning content or assignments by their own, they can be used for learning even without the involvement of lecturers (Leung and Chan 2003). Furthermore, such applications can benefit from being executed on a mobile device, e.g. to improve the learning experience by using information from sensors like GPS for linking learning content with real world objects (Wang 2004).

Prior research in the area of mobile learning already addresses the issue of supporting field trips with the help of mobile learning applications. In many cases, these research papers focus on demonstrating prototypes which can be used for supporting special tasks on field trips: Kohen-Vacs et al. (2012) demonstrate the Treasure-HIT application which can be used to create a GPS based game experience. Another example is the application QuesTInSitu, which provides the possibility to conduct formative assignments in situated learning activities (Santos et al. 2014). Based on the current GPS location, knowledge questions can be answered by the learner. A mobile application for supporting the task of retrieving learning content by taking photos of butterflies was demonstrated by Chen et al. (2004). There also exist mobile learning applications which combine support for several tasks, e.g. through the RAFT application (Kravcik et al. 2003). Using this application, learners on a field trip are able to collaborate in real time with other learners, who stay in the class room. Furthermore, learners in the field are able to collect and store photos with annotations. Finally the applications Mobilogue and Lemonade try to provide a full cycle support for conducting field trips by supporting content presentation and tasks like data collection (Giemza et al. 2011; Giemza and Hoppe 2013).

These prior research projects focus on developing and demonstrating working prototypes. Often, they concentrate on providing utilities for special tasks like real-time communication (Kravcik et al. 2003) or chose different settings like providing game experiences (Santos et al. 2014). In contrast, we want to determine how autodidactic field trips which are part of the curriculum of study programs in natural sciences can be supported. Thereby, we primarily concentrate on increasing the students' engagement with the learning content in order to support learner-content interaction. As this setting was not part of prior research yet and related research contributions lack in the formulation of general results like meta-requirements or design principles, the existing results cannot easily transferred for this setting. Thus, we need to deduce them without relying on previous research.

Research Design

To answer the research questions, we choose the design science research paradigm (Hevner et al. 2004) in order to develop a mobile learning application for supporting field trips. The research design is based on the design science research process model (Peffers et al. 2006), which was already used for designing mobile learning applications (Lehmann and Söllner 2014). Figure 1 displays the adapted model for this paper. Thereby, we choose a problem centered research approach: We start our research with problem identification and motivation, which we already did in the introduction of this paper. We also stated the objectives of a solution in the introduction and formulated research questions.

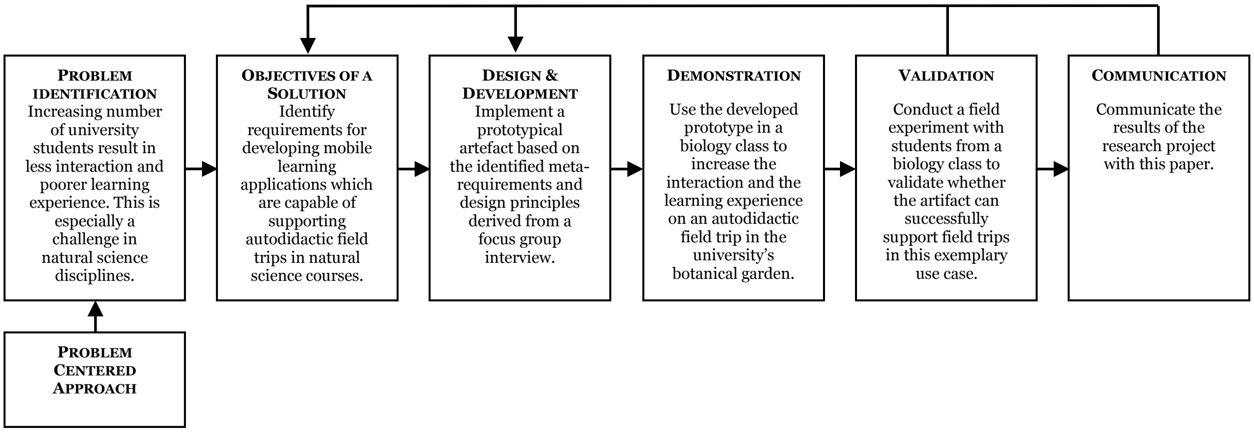


Figure 1. Research design of this paper adapted from Peffers et al. (2006)

In the following section, we will deduce meta-requirements and design principles from the results of a focus group interview (Greenbaum 1998). Afterwards, in the design and development phase, we will describe the implementation of a prototype based on the deduced design principles. As required by the demonstration phase, we use the prototype to support an autodidactic field trip of a biology course in the university's botanical garden. We will present the results of a field experiment for validating the implemented design principles in one example use case (Venable et al. 2012). Therefore, we derived hypotheses from the technology acceptance model by Davis et al. (1989), which has already been used for validating mobile learning applications (e.g. Huang et al. 2007; Park et al. 2012). For testing these hypotheses we created a questionnaire with quantitative items. During the field experiment, all students of one biology class were asked to express their opinion about their technology acceptance including the usefulness of the prototype using this questionnaire. For communicating the results according to the design science research model, we conclude this paper by outlining the contributions of our work for theory and practice.

Requirements

Meta-Requirements from a Focus Group Interview

We conducted a focus group interview to derive the meta-requirements (Greenbaum 1998). To ensure that we are able to identify all relevant aspects of autodidactic field trips in natural sciences, we selected one experienced lecturer from each field of study, which typically uses field trips at most (Green et al. 2006; Mintzes and Leonard 2006): biology (Exp1), earth science (Exp2) and (forest) ecology (Exp3). Furthermore, one didactical advisor joined the interview to cover pedagogical aspects of e-learning and mobile learning systems. Using this selection of interviewees, we incorporated practical expertise from the most relevant disciplines for field trips and combine them with pedagogical expertise.

The interview was conducted as a semi-structured interview in April 2014 (Myers 2013). Thereby, we wanted to discuss the most important aspects, but leave the interviewees enough room for expressing own ideas. We ended the interview with an open discussion about further aspects and did not stop as long as new aspects came up. Thus, we wanted to make sure to consider all relevant factors of autodidactic field trips. For further analysis, the interview was recorded on tape and transcribed. Relevant paragraphs were translated into English for citation in this paper. As a result of the interview, we identified six meta-requirements which are explained in the following:

As students conduct autodidactic field trips without a lecturer, the presentation of learning content must be provided by the application. The interviewees proposed to allow different content types for presenting the learning content to the students. Especially multimedia content can help to visualize the learning content in an appropriate way:

> *"We have small videos to summarize [...] and to show the most important aspects. [...] we have pictures, that show the details and most important characteristics." (Exp1)*
>
> *"Exactly, something like this is important. [...] e.g. to provide the possibility to show maps [as images] or to play audio or videos in the field" (Exp2)*

Therefore, a mobile learning app for supporting field trips must be able to show different types of multimedia learning content (**MR1**).

On field trips, usually several different places are visited. At each place the lecturer presents the learning content which is linked to this location:

> *"On a field trip, we talk about the topic directly at the location of the object [e.g. plant]" (Exp2)*

Accordingly, linking the content with objects of the real world is the basis of field trips in natural sciences courses. In doing so, it is possible to engage the learners with the content:

> *"So, I am standing right in front of a plant and think: 'Oh, that is interesting. What is this about?' Then I get an interesting quiz question, maybe a small video, which causes me to reflect [...] plus a text which helps me to understand it" (Exp1)*

In practice, varying location detection methods are needed, as the use cases of field trips differ, e.g. biology courses often take place in a botanical garden, where locating a single plant with very high accuracy (inaccuracy <10cm) is needed. In other cases, like geology courses, high accuracy is not important, but the lecturer is not able to visit the location in advance to mark the exact position (e.g. via QR-Code):

> *"The detection of the current location is often done using a barcode, but I do not always have the possibility to pin up the barcodes in advance. But I would appreciate the opportunity to [locate the learner] on the basis of geographic coordinates." (Exp2)*

This expresses the need to provide multiple types of localization services to support all different kinds of use cases (**MR2**).

Besides presenting content which is linked to a location, the interviewees mentioned:

> *"[...] questioning and answering is important. You can learn a lot from it." (Exp3)*
>
> *"[...] if you get a quiz question, then there is ambition to solve the questions correctly [...] and thereby we strengthen the motivation and the incentive to go on with the next location." (Exp1)*

Thus, content specific assignments consisting of knowledge questions are important to involve learners and can be used by the students to verify whether they have understood the content correctly. Furthermore, assignments can help to increase the learners' motivation. Consequently, an application must provide functionalities to support such content specific assignments by asking knowledge question to test the learners' state-of-knowledge (**MR3**).

Based on these assignments, the application needs to be able to show adapted content (**MR4**). This is especially relevant, because the students may face problems solving them and there is no lecturer or mentor available on autodidactic field trips:

> *"As a lecturer you can equalize it [differences in the state of knowledge]. This element is missing in* autodidactical *scenarios." (Exp3)*

> *"But you can do it for example in assessments [...] you can provide additional in-depth information if they does not know it [the answer]" (Exp1)*

After talking about the learning experience, learning context and content, we focused on organizational issues:

Two experts mentioned that it is important to be able to use the mobile learning application without the need of a constant internet connection (**MR5**):

> *"You need – of course – the possibility to download this [the learning content] in advance. Or you need to cache the data." (Exp2)*
>
> *"Yes, it is rather an exception, that students have internet access [on a field trip]" (Exp3)*

This requirement is important in outdoor learning environments, because these courses often take place outside of cities where no (free of charge) internet access (e.g. wifi) is available.

In addition to the meta-requirements which focus on supporting students on field trips, the participants also mentioned, that it would be useful for lecturers to enable at least some kind of interactivity between lecturers and students. Therefore, the interviewees proposed to provide feedback from the students automatically:

> *"[...] if you look for example at a specific location of the field trip, that can be interesting of course. Then I can find out whether it is totally hard, or really interesting. How long did they need to complete it? Are they able to complete it? Such things are of course interesting." (Exp4)*
>
> *"[...] as a lecturer I can check, whether I have to adjust the question. [...] I can see how many people skipped the test [...]" (Exp2)*

Thus, an application needs to collect usage statistics to be able to determine the learners state of knowledge. This must be provided to the lecturer for further analysis and to adjust the remaining in-class course (**MR6**).

Table 1 depicts all meta-requirements which we could derive from the expertise of the participating interviewees.

Label	**Meta-Requirement**
MR1	Functionalities to present different multimedia content types.
MR2	Functionalities to support different possibilities to determine the learners' location.
MR3	Functionalities to provide content specific assignments.
MR4	Functionalities to show adapted content based on the level of knowledge of the learners.
MR5	Functionalities to provide offline usage.
MR6	Functionalities to send feedback to lecturers.

Table 1. Meta-Requirements derived from a focus group interview

Design Principles

In the following, we derive design principles for implementing a mobile learning application. The design principles are grounded in the previously identified meta-requirements (Gregor and Hevner 2013). They act as a basis for our prototypical implementation (see next section). We assign the design principles in two groups, as one half of the design principles focuses on how to support the actual learner-content interaction whereas the others describe utilities which are needed for conducting the autodidactic field trips: Content specific design principles (I) define functionalities needed for presenting the learning content and increasing the students engagement with it. Operational design principles (II) define functional aspects (including technical functionalities) which are needed to support the actual use of the application.

We focus on **content specific design principles** first. As learning without content is not possible, the mobile learning application must provide appropriate ways to present it. Usually mobile devices are limited in the available screen size, so it is not an option to present large amounts of textual content to the learner. Thus, other types of learning content must be supported as well, to be able to communicate the content: Textual content, images, audio files and video files are needed to present the learning content (**DP1** based on MR1). To further increase the interactivity and the students' engagement, content specific assignments should be integrated. As the field trips should be conducted by learners on their own, an automatic evaluation of the assignments is needed. Furthermore an instant feedback system should be included, so that students can receive the results which describe their current knowledge immediately. As there are only limited possibilities to execute an automated evaluation of textual answers, the application should focus on assignments types that allow this automated handling, like e.g. single- or multiple-choice questions. It should further provide an automated evaluation and feedback functionality (**DP2** based on MR3). In addition to that, evaluation results can be used for visualization and simple forms of gamification. By aggregating all assignment results of a learner, the mobile learning application should provide the functionality to visualize the learning progress and the state of knowledge. By presenting this information, learners can be motivated to work with the provided content to improve their skills and to compare their results with other learners (**DP3** based on MR3). Furthermore, this collected information should be used to adapt the learning content to the learners' field knowledge. Thus, the application should show additional learning content, if the learner is not able to solve an assignment correctly (**DP4** based on MR4).

Table 2 summarizes the content specific design principles.

Label	**Content specific design principles**
DP1	Provide functionalities to present text, images, audio files, and video files to the learner for visualizing the location based learning content.
DP2	Provide functionalities for content specific assignments which allow an automated evaluation (e.g. single- or multiple-choice questions) and for returning instant feedback to the learners whether they have passed the assignments question.
DP3	Provide functionalities to visualize the learning progress by aggregating assignments result to motivate the learner.
DP4	Provide functionalities to adapt the learning content to the learners' state-of-knowledge by showing further explanations if the learner failed to solve assignments correctly.

Table 2. Summary of content specific design principles

In addition to content specific principles, **operational design principles** can be derived. Besides supporting the presentation of content, the application needs to assist the learner to find the relevant locations that should be visited. Therefore functionalities to guide the learner to the locations of the field trip must be provided. When the learner arrives at a location, the application needs to detect this in order to present the needed information (e.g. learning content and assignments) (**DP5** based on MR2). There exist several technologies for locating a learner using mobile devices. As mentioned in the focus group interview by Exp2, it depends on the circumstances of a field trip, which technology can be used: If the learning content needs to be linked very precisely (e.g. a single flower) or the location is inside a building, using QR-Codes is an option. Instead, as GPS has a precision of several meters, it can be used in many cases if it is sufficient to know the approximate location (e.g. for identifying a large rock). GPS further has the advantage that no labeling (e.g. placing a QR-Code) is needed in advance. To deal with the different needs, an application must provide at least GPS localization and QR-Code scanning as position technologies (**DP6** based on MR2). In many cases field trips take place at sites where no constant internet connection can be guaranteed. So the application needs to download and save all required content in advance of the field trip to provide full offline usage (**DP7** based on MR5). This includes, that all functionalities (e.g. automated evaluation of assignments or localization services) must be executed locally on the mobile devices. Finally, the application should collect statistics about the usage of the application and the learners' scoring within the assignments (**DP8** based on MR6). By providing this information to the lecturer, additional student-lecturer interactivity can be reached. As the application needs to be able to operate without an internet connection, the statistics must be stored locally as long as no internet connectivity is available. Afterwards the data must be sent to the lecturer over the internet.

The operational design principles are summarized in Table 3.

Label	Operational design principles
DP5	Provide functionalities to guide the learners from one location of the field trip to another and link the locations with relevant learning content.
DP6	Provide functionalities to locate the learners using technologies for high accuracy positioning (i. e. QR-codes for accuracy of <10cm) and GPS for less accurate positioning.
DP7	Provide functionalities to download and store all data in advance of a field trip to be able to conduct a field trip without the need of an internet connection.
DP8	Provide functionalities to collect usage statistics, e.g. how often a field trip was used in the past or what were the learners' assignments results, and provide these statistics to the lecturer as soon as internet connectivity is available.

Table 3. Summary of operational design principles

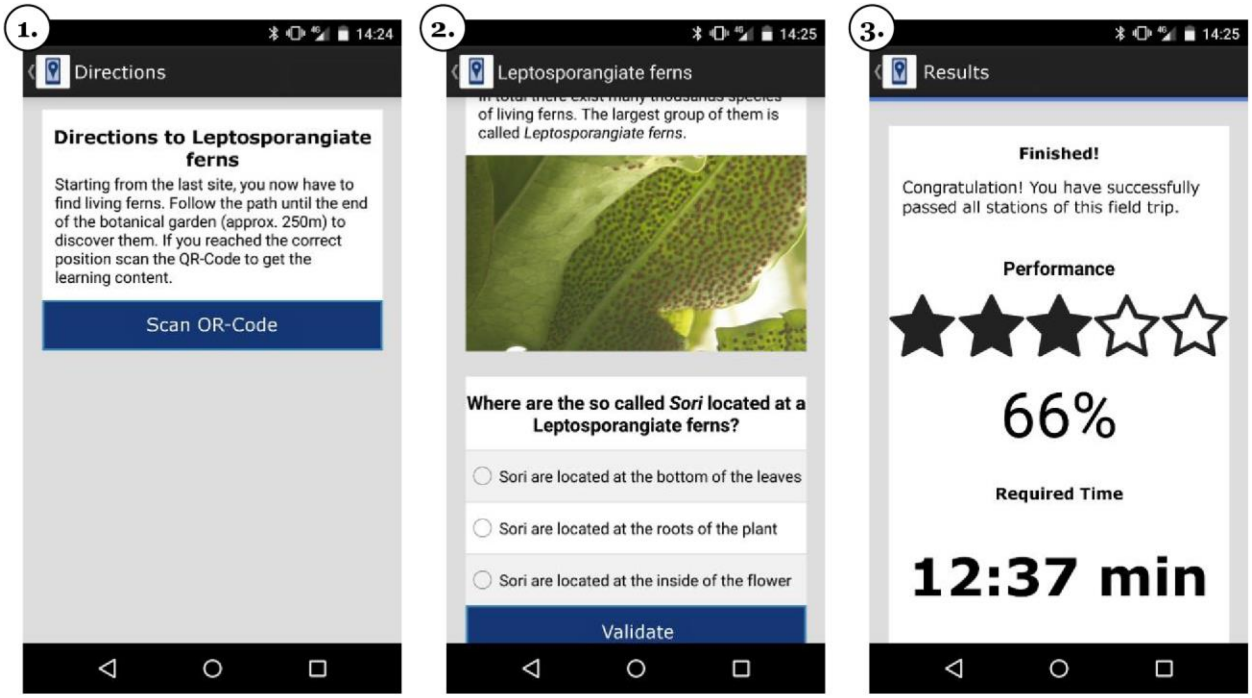
Prototype Development

We developed a prototype to demonstrate a solution, based on the identified design principles. It was implemented as a native application designed for the Android operation system using the Java language. The native development approach was chosen, because some of the requirements need access to the Java application programming interfaces (APIs) (Masi et al. 2013): Access to the camera for scanning QR-Codes or obtaining the location of the Android device with high accuracy is not possible using JavaScript-APIs as needed if the application was developed using web technologies (Charland and Leroux 2011). As a trade-off between providing a modern user interface and supporting a wide range of Android devices, we chose to support all Android versions since 4.0.x.

The user interface is designed according to the Android Design Principles and focuses on providing the needed functionalities. By doing this, an appropriate user experience without the need of training the learners how to use the application can be created. The user interface is separated from data and program logic using the model-view-controller-pattern (Gamma et al. 1994). After installing the application on an Android device, no learning content is stored on the mobile device. Therefore the application implemented functionalities to download and store a field trip including all of its content (including multimedia files and assignment questions and answers) from a remote server using a JSON based RESTful interface (**DP7**). Thus, the application acts as a container and can be used for multiple field trips.

Figure 2 depicts an overview of the mobile learning application based on an example field trip. After starting the application, the learner is given an overview of all locally available field trips (i.e. field trips that were already downloaded by the user). The user can conduct one of these field trips or can download a new field trip by scanning a QR-Code or by inserting an identification code. When the user starts a field trip the application guides the learner to the first location (Figure 2.1; **DP5**). Therefore a description how to find the first place is shown. The description can be enriched by multimedia content (e.g. images of a map or videos, **DP1**). After reaching the first location, the user either scans the location's QR-Code or the location is detected automatically via GPS (**DP6**) and the application shows the learning content of the first location (Figure 2.2, **DP1**). Afterwards, the learner has the possibility to work with the provided content (e.g. read text, watch videos, look at images or listen to audio files). To finish dealing with the first location, the learner has to pass the assignment (**DP2**). It is shown below the content as a single- or multiple-choice question. After answering the question, it is automatically evaluated and instant feedback is provided (**DP3**). Furthermore if the learner failed to answer the question correctly, additional explanations of the topic are shown to help the learner to solve the assignment in a second try (**DP4**).

After passing the assignment, the application guides the user to the next location and the workflow is repeated.



Directions to Leptosporangiate ferns

Starting from the last site, you now have to find living ferns. Follow the path until the end of the botanical garden (approx. 250m) to discover them. If you reached the correct position scan the QR-Code to get the learning content.

of living ferns. The largest group of them is called *Leptosporangiate ferns*.

Where are the so called *Sori* located at a Leptosporangiate ferns?

○ Sori are located at the bottom of the leaves
○ Sori are located at the roots of the plant
○ Sori are located at the inside of the flower

Finished!

Congratulation! You have successfully passed all stations of this field trip.

Performance

★★★☆☆

66%

Required Time

12:37 min

Figure 2. Screenshots of the developed prototype (translated into English)

After all places of the field trip have been passed, the learner sees a summary of the field trip: Aggregated results of the assignment as well as the time required for conducting the trip are visualized (Figure 2.3, **DP3**). As soon as an internet connection is available on the mobile device, these aggregated and anonymized data, as well as the result of each assignment, will be send to a remote server using a JSON based RESTful API. The lecturer who supervises the field trip is then able to access the anonymized usage statistics (**DP8**).

Validation

In order to verify that our implemented artefact which is based on the deduced design principles is able to support field trips successfully, we conducted a field experiment. Thereby, we answer research question RQ2, by analyzing whether the developed prototype can support field trips. Thus, we wanted to validate our results with a first exemplary use case. As the setting for our experiment, we chose an obligatory course in the Bachelor of Science study program in biology in the summer term 2014. As the lecturer and all students of the course agreed to participate in our experiment, we assume no bias.

In preparation of the validation, we cooperated with the lecturer to create an autodidactic field trip. Even though the lecturer did not need our technical expertise, we accompanied the whole process from creating learning content until using the prototype in the course. The lecturer supplied learning content for 13 places, which was especially designed to fit the students' state-of-knowledge. It consisted of textual content, images, audio and video files, which we integrated in the prototypical artefact. As we could not rely on every participating student owning a suitable Android device, we prepared mobile devices with the application preinstalled.

For determining the students' opinion whether we reached our goal to support autodidactic field trips, we created a quantitative questionnaire: As mobile learning applications were not used for supporting field trips at the university before, the participants did not have any experience with such solutions as part of their curriculum. Consequently, we decided to focus on the technology acceptance for this first validation.

The technology acceptance model by Davis et al. (1989) has often been used for similar validations of (mobile) applications. Furthermore prior research in the mobile learning discipline has already verified, that this model can be used successfully for explaining the technology acceptance in this discipline (e.g. Huang et al. 2007; Park et al. 2012). The model explains the actual use of a system based on four main variables: perceived ease of use (PEU), perceived usefulness (PU), attitude towards using the system (A) and the behavioral intention to use the system (BI). With the aim of analyzing whether these variables are positively perceived by the participants, we formulate our hypotheses as follows:

H1 (PEU): The students positively perceive the ease of use of the application.

H2 (PU): The students perceive the usefulness of the application.

H3 (A): The students have a positive attitude towards using the application.

H4 (BI)**:** The students' behavioral intention to use the application on field trips is positive.

We also considered formulating additional hypotheses, which describe correlations between the variables of the model. But verifying correlations between variables would require usually large sample sizes, which go beyond the scope of our first exemplary validation. Additionally, monitoring the learning performance of participants in comparison to students who attend traditional field trips would bring further evidence whether the developed prototype improves the learning process. To be able to verify that the application provides a real improvement of the performance, the usage of the application has to be monitored over several semesters. Therefore, we could not address it in this first validation.

As listed in Table 4, we created 23 items to analyze the hypotheses. All items were measured using a five-point Likert scale, with one being labeled with "I disagree" and five with "I agree". An overview of the questionnaire is listed in the appendix in Table 6.

Hypothesis	**Number of items**	**Neutral value**	**Items**
H1 (PEU)	5	15	Handling; Presentation; Scanning QR-Codes; Downloading learning content; Usage perspicuity
H2 (PU)	12	36	Linking content to location; Understanding content; Simplicity; Motivation to learn (3 questions for each item)
H3 (A)	3	9	Attitude towards mobile applications, Attitude towards location based learning, Attitude towards learning practical content
H4 (BI)	3	9	Intention (2 questions), Recommendation

Table 4. Composition of the questionnaire

At the date of the field experiment in July 2014, eleven students attended the course. After either installing the application on their own mobile devices or picking one of our Android devices with the application preinstalled, all students conducted the autodidactic field trip. After approximately 70 minutes, everybody finished the field trip and was asked to complete our questionnaire.

With only one questionnaire being invalid, we had 10 questionnaires out of 11 (response rate of 90.9%) for our analysis. However, the sample size is rather small for a statistical analysis. So, we could not completely generate highly significant results for all hypotheses. But some statistical test could be applied successfully: Therefore, we grouped the items as described above in Table 4 before analyzing them. The mean value of all four resulting datasets, are greater than the neutral value. For further analysis, we used IBM SPSS Statistics. We applied Kolmogorov-Smirnov tests to our data to check if all four datasets are normally distributed. As shown in Table 5, all tests return significance values larger than 0.05. Consequently, we can assume that the data is normally distributed. With this given prerequisite, we further analyzed the data using t-tests: Hypotheses H1 to H3 can be verified with significance values lower than 0.01. H4 can be verified with a significance value lower than 0.1.

Hypothesis	P (Kolmogorov-Smirnov-Test)	Number of questions (Neutral value)	Mean value	t-value	p (t-test)
H1 (PEU)	0,526	5 (15)	23,1	11,468	0,000***
H2 (PU)	0,956	12 (36)	44,1	3,613	0,007***
H3 (A)	0,996	3 (9)	12,5	7,000	0,000***
H4 (BI)	0,930	3 (9)	10,6	1,922	0,087*

Table 5. Results of our statistical analysis (* p < 1%; * p < 10%)**

To sum up the results of this first validation, we can conclude, that at least in this special use case our implemented instantiation of the design principles were well accepted by the participating students. They verified that supporting field trips using mobile learning application can be useful and can bring benefit to biology courses. This can be seen, as 90% of the students would recommend courses which use this application to their fellow students.

Conclusion

The goal of this paper was to determine how autodidactic field trips in the discipline of natural sciences can be supported using mobile learning applications. After reviewing existing literature, we derived six meta-requirements from a focus group interview. Based on this, we deduced eight design principles which can be used as a basis for developing further applications. Afterwards we described our solution for implementing a prototype based on the identified design principles. For demonstration and validation of our prototype with a first example, we performed a field experiment with learners from our target audience – students of natural sciences. As a result of our experiment, we can conclude that our prototype including the deduced design principles can – at least in our use case – successfully support learners on autodidactic field trips.

However, our study faces some limitations that should be addressed in further research. We deduced meta-requirements from practice, but our focus group interview took place without the participation of actual learners. Only later in the demonstration and validation phase, learners were integrated in the research process. As the number of participants in our evaluation was rather small and limited to a single use case, we could not analyze correlations between single design principles and technology acceptance. To do so, the number of participants should be increased and extended to students from other study programs than biology. Furthermore, other use cases should be tested as well and the long-term learning performance of students should be monitored by conduction a long-term study. For using the developed prototype in practice, it should be considered to port the application to other mobile platform than Android as well.

Nevertheless this research paper contributes to both, research and practice: First, by deducing meta-requirements and design principles, we proposed a conceptual design for supporting field trips using mobile learning applications. Second, we demonstrate an actual implementation and show the validity of the research using one sample use case. To sum up, this paper shows how mobile learning applications can be used to support field trips.

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Appendix

Label	**Item**
Handling	The mobile application was easy to use.
Presentation	The presentation of the learning content was clear and comprehensible.
Scanning QR-Codes	Scanning QR-Codes using the mobile application was easy.
Downloading learning content	Downloading the field trip data (learning content) was easy.
Usage perspicuity	The next steps in the mobile application were always obvious to me.
Linking content to location	The mobile application supported me to create a linkage between the learning content and related real world objects (plants) better than: - self-study learning without using the mobile application - traditional field trips. - classroom teaching.
Understanding content	It was easier to understand the presented learning content in the mobile application than: - self-study learning without using the mobile application. - traditional field trips. - classroom teaching.
Simplicity	Learning was easier for me using the mobile application than: - self-study learning without using the mobile application. - traditional field trips. - classroom teaching.
Motivation to learn	Using the mobile application increased my motivation to learn in comparison to: - self-study learning without using the mobile application. - traditional field trips. - classroom teaching.
Attitude towards mobile applications	The use of smartphones and tablets is helpful for teaching learning content.
Attitude towards location based learning	Using the mobile application for learning location based content provides additional value.
Attitude towards learning practical content	Using the mobile application for learning practical content provides additional value.
Intention	I would rather participate in lectures which use the mobile application than - traditional field trips. - courses in the classroom.
Recommendation	I would recommend courses which use the mobile application to my fellow students.

Table 6. Items of the questionnaire (translated into English)