H. Söbke, J. Baalsrud Hauge, M. Wolf, & F. Wehking (eds.):
Proceedings of DELbA 2020
Workshop on Designing and Facilitating Educational Location-based Applications
co-located with the
Fifteenth European Conference on Technology Enhanced Learning (EC-TEL 2020)
Heidelberg, Germany, Online, September 15, 2020

Location-based Apps in Environmental Engineering Higher Education

A Case Study in Technical Infrastructure Planning

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Abstract. For education of environmental engineers, on-site experience of planning scenarios is considered to be beneficial. In recent years, location-based apps – i.e. mobile apps that provide information and allow interactions specific to the current location – have emerged as learning tools. The study investigates a site inspection scenario using a location-based app for students of a bachelor study program in environmental engineering. The gamified, digital scavenger hunt app is applied during a lecture in a group setting. The site inspection is complemented by a briefing and a debriefing phase and requires the preparation of a protocol during the site inspection. Methodologically, the field study uses a feedback questionnaire (N=16), observations, protocols and guided interviews with students (N=3) to determine motivation, attitudes and learning-related findings. The results indicate high motivation of the students and their positive attitudes towards the site inspection. All in all, the approach presented is to be seen as promising for conveying on-site experiences in technical infrastructure planning and related technical domains as it may easily be integrated into lectures due to low efforts required.

Keywords: augmented reality, location-based app, higher education, field trip, site inspection, educational location-based app

1 Introduction

Location-based apps are installed on mobile devices and exploit the current position of the mobile device to present location-based information, often through exploitation of augmented reality (AR) technologies. In general, location-based apps feature characteristics predestining them as learning tools: Location-based apps support problem-based learning by enriching real objects with additional information. Further, Location-based apps meet the contiguity principle by presenting information and the object close together [1]. Additionally, location-based apps enable learning in groups using real objects [2] and self-directed learning [3] by allowing learners to choose the time and subject of the learning activity [4]. Accordingly, Zydney and Warner have identified in their literature review the following main didactical foundations for mobile apps constituting a superset of location-based apps: situated learning, inquiry-based learning, sociocultural theory scaffolding, community of practice and seamless learning [5]. However, although location-based apps were included in the literature review, no case study of a location-based apps within higher education could be identified by Zydney and Warner [5]. Accordingly, case studies describing location-based apps for educational purposes in higher education are rare.

Against this background, the case study following is embedded in the context of higher education. The article is organized as follows. In the next section the theoretical background is presented, section 3 describes the rationale and the goals of the study, while the scenario design is outlined in section 4 describes the scenario design. The methodology employed is designed in section 5. Further, in section 6, the findings of the study are presented. Section 7 comprises the conclusions and in the final section 8 limitations and their implications for research and practice are outlined.

2 Theoretical background

In the theoretical background of the study, the term *educational location-based apps* (ELA) is used to summarize apps that are used on mobile devices and display location-based information for educational purposes, possibly using AR technologies and game mechanics. The following characterization of ELAs is given along four categories: location-based content, didactics, AR and app genre.

Location-based content. Location-based content refers to locations and objects in the real world. Although ELAs function for objects having variable positions (for example, plants in a botanical garden [6]), ELAs are in particular advantageous for disciplines with absolute location references, such as environmental engineering, civil engineering or architecture. Also, urban planning is a discipline mostly using absolute location references, as ELAs might support the creation of consensus among different stakeholder groups [7]. For the content provision itself, authoring tools allowing the content to be created without programming skills are beneficial. Authoring tools have been available for a considerable time: For instance, ARIS [8] is an example of an open source authoring tool for creating educational applications, such as narratives or serious games. PlayVisit [9] represents authoring tools supporting digital scavenger hunts. Further authoring tools are part of an overview of development platforms for mobile AR games compiled in [10].

Didactics. Supporting the goal of learning requires designing ELAs and didactic scenarios to be based on learning principles. Georgiou and Kyza report high motivation being a predictor of high immersion while using an ELA, and immersion in turn being positively correlated with learning outcomes [11]. In a further study, Kyza and Georgiou show real-world materiality significant impacting the design of didactic scenarios for ELAs, e.g., some locations are susceptible to distractions detrimental to learning. In their review of educational AR applications [12], Wen and Looi also survey the theoretical foundations of AR-based learning scenarios [13]. Among their findings is the Cognitive Theory of Multimedia Learning [14], and the concept of situated cognition, which implies learning being bound to concrete contexts [15]. Furthermore, frameworks exist for designing ELAs and designing didactic scenarios for the application of ELAs, such as the *PGDF Framework* [16]. Additionally, design guidelines for generating motivation and avoiding disturbance factors are provided [17]. Zimmermann and Land suggest guidance on overarching objectives for the design of ELAs including objectives, such as promotion of domain-related communication, strengthening of domain-related observations of the respective location, and broadening of perspective by introducing new location-related knowledge [18]. Suárez et al. describe a framework for inquiry-based learning regarding mobile apps to be considered for designing location-based apps with the goal of fostering agency among learners [19].

Augmented Reality. Forming a definition, the presentation of location-based information on a mobile device itself may be considered as AR, even if typical AR technologies, such as video-see-through are not employed. For example, Ingress [20] is considered an AR game, although Ingress does not support video-see-through AR. AR as an inherent trait of ELAs is considered contributing to improving learning outcomes regarding a variety of aspects. For example, Khan et al. present a study highlighting an ELA increasing motivation [21], an effect that is observable for AR-based applications in general, as meta studies show, e.g., [22, 23]. Further benefits of AR in learning – mentioned by the meta studies – include positive attitudes of students, creation of opportunities for interactions and visualization of nonvisible concepts. White and Feiner demonstrate an example of contextual additional information when visualizing local pollutant concentrations in the air [24].

App genre. ELAs may be categorized into different genres. For example, Wikitude [25] is a browser displaying additional information for the immediate environment. Walker et al. introduce the popular AR game Pokémon GO as ELA [4]. Hence, Pombo et al. present a geocaching game-like ELA [26]. As strengths, these ELAs show characteristics of games such as immediate feedback and interactions among learners. Also gamification, i.e. the application of game elements such as points and badges [27], is often applied for increasing motivation of learners. The app PlayVisit used in this study is an example of a gamification-featured app.

3 Rationale and research goals

In this article the use of a scavenger hunt app for performing site inspections as learning activities in the course *Urban Water Management* of the bachelor study program *Environmental Engineering* at Bauhaus-Universität Weimar, Weimar, Germany is examined. In a pre-study [28], students were guided to urban water management-relevant locations and touristic locations in the city of Weimar at the beginning of the semester. The study results were encouraging: Creating the content did not require much effort. Further, the engagement of the students, who accepted the site inspection as an appreciated change of their daily learning routine, was consistently high. The blending of technical points of interest (POIs), such as stormwater outlets, with tourist POIs, such as the municipal theatre, was also positively received. The setting of the pre-study focused on a playful introduction of the students to each other and to introduce the students to the city and to visit the most important technical POIs. In contrast, this study's goal is the concrete transfer of knowledge, as it was accomplished in the original learning scenario as lecturer-guided site inspection, which showed some shortcomings, such as lack of students' attention and poor acoustic understandability of the lecturer's explanations. Thus, using a design-based research approach based on the experiences of the pre-study, modifications in the study design comprise the technical topic – this learning scenario is about planning of water infrastructure –, the declaration as a formal learning scenario, a smaller area to be visited and the evaluation of learning outcomes. The main research question of this qualitative study is determining if the learning scenario might substitute a lecturer-guided site inspection of the same area – also given the demanding target group of students in higher education.

4 Learning scenario

This section describes the learning scenario studied. First, the base learning scenario including a lecturer-led site inspection is presented. Thereafter, the learning scenario under investigation is outlined.

4.1 Original learning scenario

Urban water management addresses the design and operation of water-related technical infrastructure, aiming at – amongst others – wastewater drainage, water supply or stormwater management. Within the bachelor's study program in *Environmental Engineering*, the course in *Urban Water Management* is compulsory for all students in the fifth semester. Infrastructure-related urban land use planning is the subject of one double lecture in the course. The lecture contains a site inspection of a nearby housing estate of about 40 single-family houses, which has been built on a former barracks site of the Russian army in East Germany at the turn of the millennium. An ensemble structure ambitiously designed in terms of urban land use planning contrasts with the sometimes flawed details of the implementation [29]. All in all, both the innovative planning and the planning mistakes are well suited to provide students with hands-on knowledge about urban land use planning.

The schedule of the learning scenario (Fig. 1) is divided into 4 phases:

- **Briefing**: The lecturer presents the principles and challenges of urban land use planning including planning of technical infrastructure in form of a lecture.

- **Site inspection**: The previously imparted knowledge is deepened by a site inspection guided by the lecturer, which also addresses planning mistakes such as insufficient curve radii, e.g. for waste collection vehicles, but in particular includes infrastructure facilitating water supply and wastewater drainage, such as fire water tanks and sewers.
- **Planning**: Following the site inspection, the hypothetical planning of the wastewater drainage infrastructure of the housing estate area is carried out in small groups using paper-based maps of the housing estate area, i.e. the layout and size of sewers must be planned. The planning is hypothetical, since a wastewater drainage infrastructure system already exists for the housing estate, but sewer design rules changed since then. And, there is always the chance to discuss improvements. Furthermore, the students may practice to what extent they were able to capture the local conditions during the site inspection.
- **Debriefing:** The planning suggestions of all groups are presented and commented on by the lecturer in the class room. Special attention is paid to the fact that the basics of wastewater drainage, for example the use of gravity to save pumping energy, have been considered.

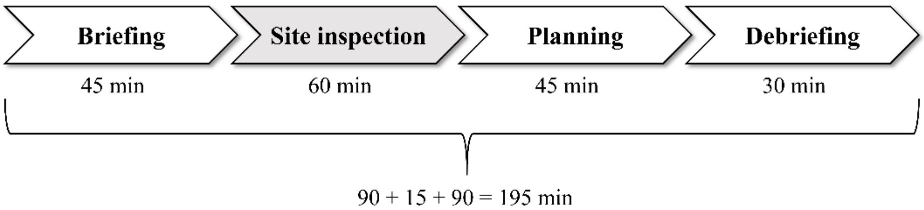

Fig. 1. Time schedule of the didactic scenario

The basic learning scenario already stood out from common learning activities due to the practical approach of site inspection and planning. For the lecturer-led site inspection, the lecturer observed that not all students could be reached equally. Commonly, there was a group of students who gathered around the lecturer and listened. Other smaller groups followed at a distance sometimes discussing the observations among themselves. Further students, however, simply followed the site inspection apparently not being very involved. Thus, an app-guided tour in groups is intended to increase the participation of all students.

4.2 App, learning content and didactic design of the site inspection

The app PlayVisit [9] – used in this study – is browser-based and thereby generally independent of the mobile device's operating system. The app is based on so-called *virtual tours*, which consist of several points of interest (POIs) [30]. A gamification layer is integrated into the app, for example by means of points for questions correctly answered or by means of virtual objects rewarding the visit of specific POIs. Virtual tours and POIs are to be administered via a web-based authoring tool. Virtual tours define a sequence of POIs included (Fig. 2). In addition, virtual tour attributes, such as the maximum time allowed, are defined.

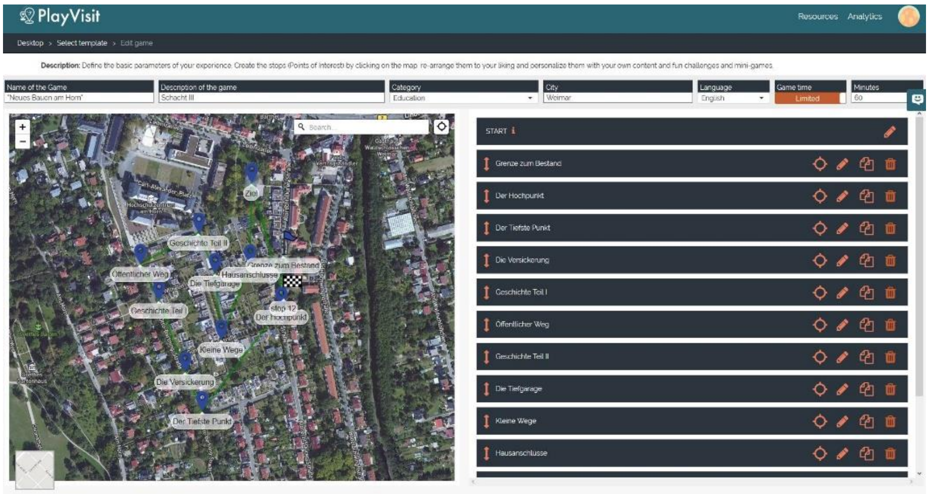

Fig. 2. Screenshot of PlayVisit's authoring tool

If the mobile device falls below a so-called trigger distance within the site inspection, the POI is considered to be reached and information regarding the POI is displayed. After the user has acknowledged this information, a multiple choice question appears. Having selected an answer, a general feedback text appears showing the number of points achieved.

The virtual tour has been defined by a research assistant who had participated in the site inspection the year before and has been refined according to feedback of the lecturer. Ten POIs were included in the virtual tour. As a rule of thumb, 50% was added to the time used by the research assistant familiar with the virtual tour to obtain the maximum time allowed (60 minutes). In addition, two POIs exhibiting historical locations were included in the virtual tour.

The didactic design includes the task of manual keeping a paper-based protocol, documenting information about each POI, such as name, key information and remarks. The protocol is intended to encourage students' reflection on the POIs. Furthermore, the site inspection is to be done group-wise using one mobile device jointly. On the one hand, groups may increase engagement, on the other hand, communication within the groups may create discourses fostering learning. Groups of three students include three roles: the *app operator* is in charge of the mobile device, the *knowledge manager* records the protocol and the *environment observer* compares information provided by the app with the environment and takes care of traffic safety. The groups are sent out of the class room and are instructed to meet again in the class room before the maximum time allowed has elapsed. Preventing all groups from carrying out the site inspection together forming one large group and thereby reducing the engagement of many students, different routes connecting the POIs have been created.

5 Methodology

The main objective of this explorative pilot study is evaluating to what extent an app-guided site inspection can replace the lecture-guided site inspection conducted so far. Methodologically, various approaches of data collection are followed. A questionnaire completed after the site inspection is used for collecting quantitative data, regarding students' motivation, attitude and learning outcomes. Qualitatively, the learning scenario is observed by two experts, guided interviews are conducted with three students and the protocols recorded by students are evaluated. Further, a paper-based protocol form is filled out by each group during the site inspection. By answering multiple-choice questions via the app, the level of knowledge is also measured through the number of points achieved during the site inspection. A total of 16 (7 male, 9 female, average age 22.9 years) students participated in the study and performed the site inspection in a total of 6 groups.

6 Data analysis and findings

6.1 Site inspection duration and protocol

All groups returned to the class room within the maximum time allowed, on average, the groups came back after 49 minutes (41 - 58 minutes) and thus had more than 10 minutes left. For each POI, the students were expected to record information about names, key information and remarks. In total, 84% of the information was recorded at least using keywords. However, there was a tendency of declining commitment: While 89% of the information was given for the first 5 POIs, only 80% was given for the last 5 POIs. The multiple choice questions to be solved during the site inspection were answered to 80 % correctly by the groups.

In three of the groups there were little or no changes in roles, in the other three groups the roles were distributed relatively evenly, so that each student could take each role once. Factors for the decision whether a role change was carried out were on the one hand the desire to experience different roles and on the other hand the need of students not giving their own mobile device to others.

6.2 Questionnaire

Students' perception. First, students were asked to agree to various statements on a 7-point Likert scale. The pre-study had collected the same data (Fig. 3). The highest agreement (6.4) was reached for statement "*a - The site inspection was fun*". Accordingly, statement "*h - The site inspection was boring*" (1.7) and statement "*g - The site inspection felt like work*" (2.1) were rejected. Statement *b* attributed the site inspection as informative (5.8), just as statement *c* confirmed the app being appropriate for the site inspection (5.5). Similarly high was the agreement with statement "*d - The site inspection was a pleasant mixture of professional and entertainment POIs*" (5.4) and with the statement "*e - The professional POIs were interesting*". The high variance of agreement with the statement "*f - I prefer site inspections guided by lecturers*" suggests different learner profiles among students: some students prefer guided site inspections, while other students may work well with an app-guided site inspection. The rejection of the statement "*i - The tasks of the site inspection were demanding*" (1.4) is analyzed further in the following section about motivation.

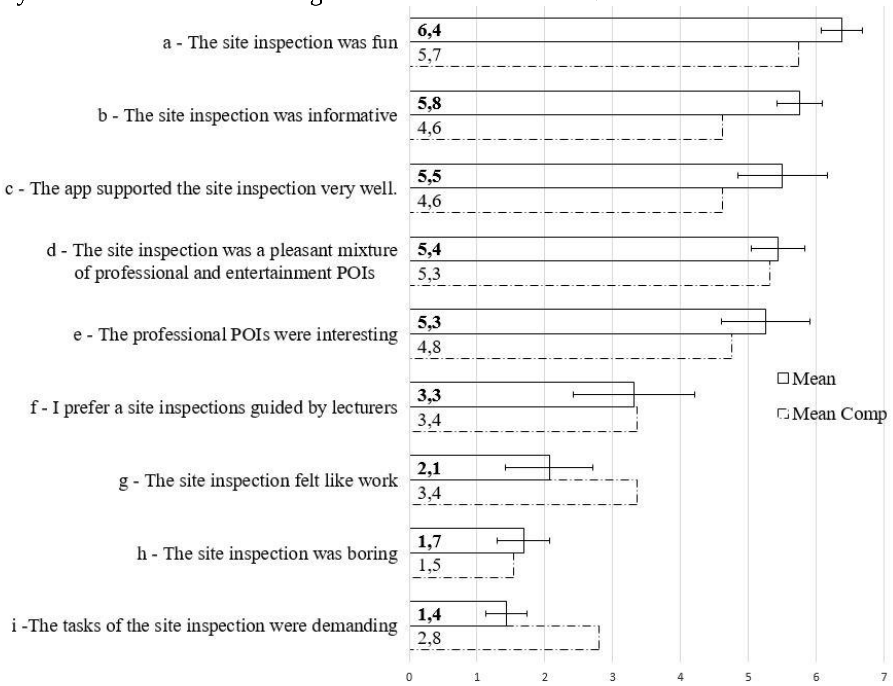

Fig. 3. Agreement on statements on a 7-point Likert scale (N=16, *Mean Comp* from pre-study [28])

Motivation. Motivation has been measured using the *Questionnaire on Current Motivation in Learning Situations (QCM)* [31]. The evaluation (Fig. 4) of the subscales reveals accentuated values. Having a value of 1.7 (using a 7-point Likert), the subscale *Anxiety* can be regarded as low. Despite the concrete learning situation, the students felt little timidity about not being able to master the challenges. Accordingly, the value of the subscale *Probability of Success* (6.0) as well as the value of the subscale *Interest* (5.8) can be considered excellent. Although the course is a compulsory in the *Environmental Engineering* study program, all students showed great interest in the concrete learning activity. The only mediocre score for the subscale *Challenge* (3.7) confirmed the students' statements made in the previous section and may indicate the task difficulty being too low. In summary, the values measured for all subscales can be considered as very conducive to learning.

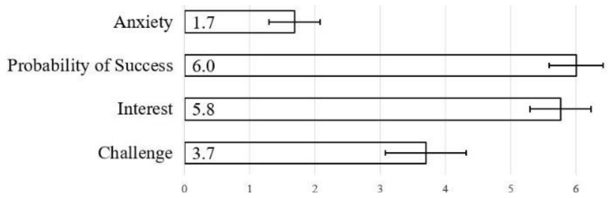

Fig. 4. Values of QCM [31] subscales (7-point Likert scale)

Learning. Furthermore, in a question allowing multiple selections, students are asked to what extent the site inspection contributed to learning outcomes (Table 1). No one denied that the app and the learning scenario may be helpful in conveying new knowledge (*D*). The decent level of prior knowledge is expressed in Statement "*A – No, I already knew most of it*" having an approval of 25 %. The historical stations (*B*) received greater approval (56 %) than the technical stations (C, 44 %). The comparatively low approval of the groups as a place of professional discourse (*E*, 8 %) needs to be investigated more closely.

Table 1. Learning-related aspects (N = 16, rel. frequency of approval)

Answer	Freq.
A - No, I already knew most of it.	25 %
B - Yes, the historical/tourist stations were particularly important.	56 %
C - Yes, especially the professional stations have provided me with new knowledge.	44 %
D - No, this was not possible with the app and in the group.	0 %
E - Yes, especially in the group there were insightful discussions.	8 %

Post-test. The questionnaire contained five multiple choice questions based on the questions being answered during the site inspection using the app. 99 % of the answers to these questions were correct in the post-test. This excellent result may have several reasons: First, the prior knowledge is to be regarded as quite good. The prior knowledge was imparted in the lectures of the course and trained using mandatory, course-accompanying multiple-choice tests [28]. Further, the learning experiences of the site inspection may also be fruitful. An ex-post ad-hoc study querying eight persons from the authors' social network being experts in other fields, two of whom had a doctorate, four had a bachelor's degree and two had completed vocational training, revealed only 45 % correct answers to the questions asked. With 33 % as the lower limit for random answers to the questions (each question had 3 answer options), the questions are not to be seen as being solvable by common sense alone. Relevant to further investigations may be also the increase in knowledge achieved: while 80 % of the questions were answered correctly in groups during the site inspection, 99 % were answered correctly by students individually.

6.3 Qualitative feedback

Qualitative feedback comprises interviews with three selected participants, comments from the questionnaire and observations. The results have been clustered into the following categories:

Technology. Although network coverage in the housing estate inspected was reasonable, about one third of the groups mentioned problems with GPS positioning, such as a delayed or inaccurate GPS signal or non-activated GPS tracking services on the mobile device. In one case, the virtual tour had to be activated again by entering the starting link. It was also noted that the screens of mobile phones – for example, an iPhone SE was used – were too small, especially if all members of the group were to look at the screen. Small screens require the group to be physically close together capturing the information well, which is done only reluctantly by some of the students.

App. The browser-based app itself was also the subject of comments. For example, the app's property of showing the distance to the next POI but not the direction to the next POI, was addressed and a direction-based navigation was requested. Furthermore, rotation of the map should be enabled. Also, the functionality to skip POIs that could not be found, was missed.

Attitude. The atmosphere in the groups was described as open-minded and tense. The activity was partly described as a fun game. The need to actively participate was highlighted as an advantage compared to guided tours. Competition between the groups was not very prominent; instead, communication took place between the groups. According to the measurement that the groups returned to the class room on average 10 minutes ahead of time, it was also stated not having time stress - although the observation showed that the groups walked purposefully not losing time from POI to POI. However, technical shortcomings - as described above - were mentioned as stress promoting.

Domain. It was explicitly recommended that virtual field trips might be offered for further study courses, such as architecture.

Didactics. A remark that not new knowledge was acquired, but existing knowledge was consolidated, seems interesting. The fun of experimenting using the app was complimented. However, the buildings or objects of POIs could not be always easily identified. Further, the paper-based protocol to be written was not considered a media break. Instead, the protocol was considered a common characteristic of scavenger hunts. Nevertheless, a further tablet was suggested for recording the protocol. The protocol led to pausing and reflection and was confirmed as a control instrument, although it was perceived in parts as annoying.

Further findings include that the planning results of the phase following were evaluated positively without exception by lecturers and observers, i.e. the site inspection provided a profound foundation. Remarkable is also the repeated positive mention of the app-guided site inspection in the official evaluation of the university (three of the seven free text assessments).

7 Conclusions

Mobile location-based apps offer a range of features that enable their successful use as learning tools. However, experiences using mobile location-based apps in higher education are rare. Thus, subject of the explorative study presented was an app-guided site inspection in a formal learning scenario of environmental engineering higher education. It could be shown that the app-guided site inspection was well received by the students and led to high motivation among the students. Thus, the app-guided site inspection can be considered a promising learning activity and a viable alternative to lecturer-led site inspections even in higher education, not at least because of the low technical and organizational efforts required.

8 Limitations and future research

Overall, the results of the study can be described as very promising. Due to low preparation efforts, integration of app-guided site inspections might become common. The feasibility of a Bring-Your-Own-Device-approach was confirmed. However, a few limitations and challenges have to be mentioned. First of all, it should be noted that an app-guided site inspection is bound to specific disciplines. Also noteworthy is the vulnerability to weather conditions. Further work is still needed on the technical problems, such as delayed positioning, which have caused irritation among students. A prerequisite for the application is sufficient mobile network coverage. One option to counteract technical problems is using the institute's own tablets, for which standardized conditions may be ensured and which would provide larger screens being more appropriate for group work. However, the costs for provision and maintenance of tablets would have to be borne again. Another cost factor is the licensing costs for the app not being applicable in this study because the app is currently free for small user groups. The legal framework of insurances for students during the learning activity still needs to be clarified.

Although the small number of participants led to no representative results, the positive impression of the pre-study was confirmed. The learning effectiveness of the described scenario was not examined, there were only indications of a good knowledge level of the participants.

Further studies will also have to clarify in how far the excellent values for motivation have to be attributed to the novelty effect. Additionally, in further studies it will be particularly important to validate the learning effectiveness and to investigate the influences of different characteristics of the learning scenario, for example the keeping of protocols, the screen size of the mobile devices or the entanglement of professional and entertainment POIs. The influence of learning prerequisites, such as prior knowledge of students, on learning outcomes further needs to be investigated.

9 Acknowledgements

The authors would like to acknowledge the financial support of the German Federal Ministry of Education and Research (BMBF) through grant FKZ 16DHB2131. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the institution mentioned above.

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