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Abstract. Location-based AR games have experienced a tremendous rise. With Ingress (2013) and later Pokémon GO (2016), the two games have established a new genre on the one hand and set new bench-marks in popularity on the other. The specific characteristics, like multiplayer mode, integration of authentic places, and ubiquitous accessibility, make it likely that these games may have a potential as learning tools, i.e., being used in a game-based learning setting. In education for engineering disciplines, such as Environmental Engineering, authentic on-site experiences can be provided using location-based games. The study presented herein analyzes the application of a serious location-based AR game in the course Urban Water Management of the Master's programme Environmental Engineering. Methodologically, the application was evaluated with the help of questionnaires (N=7, 9, 17, pre- and posttest, perceptions and preferences of the students). Despite the advanced level of education, there was a high acceptance of the game-based learning setting. The study supports the hypothesis that location-based AR games can be well-suited learning tools in higher education.

Keywords: Augmented Reality, Serious Game, Location-based, Higher Education, Environmental Engineering

1 Introduction

In recent years, the popularity of location-based Augmented Reality (AR) games is increasing. For example, 2013 Ingress [1] has generated a hype that was surpassed by 2016 Pokémon GO [2] with an even larger player base. From a didactic perspective, location-based AR apps, which encompass Ingress and Pokémon GO, have a number of characteristics that make their use as learning tools very appealing: they lead learners

to real objects on location and supplement these objects with information to be learned. One of the principles supported is the contiguity principle: learning effects are reinforced by the temporal and/or spatial combination of object and information [3]. Location-based mobile apps may be also suitable as social interaction triggers for the joint development of learning content in groups or for making decisions and achieving goals as a team.

2 Study

The main objective of this small-scale study was to investigate to what extent the usage of a location-based AR game could increase the engagement, as well as the learning outcome related to the technical topic (i.e. the core objective of the course). The 18 participants of the study are enrolled in a course on management of urban water, which is a part of the master programme Environmental Engineering at Bauhaus-University Weimar offered as distance education with some on-site workshops. As a part of the first on-site workshop in Weimar, the students experienced a customized scenario using a location-based AR game, allowing the students to explore both touristic Points of Interests (POIs), as well as information related to water management. The theoretical foundations of the scenario are described in [4]. PlayVisit [5], the location-based game works on the principle of a scavenger hunt: it leads the students to the next POI by continuously indicating the current distance. Specific, customized information can be displayed for each of the POIs, and questions can be integrated in the location-based experience to allow checking the students' knowledge, to establish a competition and to capture students' interest. The scenario contained a total of 16 POIs, 6 of which were exclusively of a touristic nature. The differentiation between technical and touristic POIs was based on the subject of the related question. For example, the Kirms Krakow House, a touristic location, served as a setting for a question on the role of water in epidemics and therefore was considered a technical POI. Each POI was associated with one multiple choice question that had to be answered. Each questions was preceded by an introductory text, and the answer was followed by an explanatory text. Table 1 shows an example sequence of these texts.

The participants were divided into groups, using three different paths (set in the personalization of the game play) to avoid a joint tour in a single large group. Each group consisted of three participants, each of whom was asked to perform one of three tasks: 1) operating the mobile app, 2) coordination and documentation of the city tour, and 3) ensuring road safety for the group. Two outcomes were requested to encourage students to participate in the activity: The achieved score in PlayVisit and the handwritten completion of a protocol form in which, for each POI visited, the name of the POI, its key information from the students' point of view, as well as further remarks regarding the POI had to be entered. The tour was expected to last 70 min, and all groups had to return within 90 min. At the end there was a combined debriefing and feedback session of 15 minutes, where the winning group determined by the highest point score in PlayVisit, was rewarded with a box of sweets. A pre-test and a post-test in the days before and

after the event, a feedback questionnaire, as well as a feedback round within the debriefing were used as measuring instruments. Pre- (N=17) and posttest (N=7) as well as the questionnaire (N=9) were provided online via Moodle. The voluntary response resulting from the field study explains the large variation in the number of participants. Pre- and posttest both consisted of 5 questions, which were randomly selected from a pool of 29 questions and were similar to the questions to be answered via PlayVisit. The feedback questionnaire consisted of 16 questions, out of which three questions each asked several items on a 5-point Likert scale.

Table 1 Information provided at the first POI, the Urban Water Management Laboratory of the university (Correct answers underlined)

Introductory text	The characteristics of water are described using physical, chemical and microbiological parameters. The concentration of organic material is of great importance for the quality of water. In order to measure the concentration of organic material in the water, there are different sum parameters such as BOD5 and COD.
Question	Which of these two sum parameters (BOD_5 and COD) has always a larger value than the other? (BOD_5 and COD)
Explanatory text	Right! The COD indicates how much oxygen is needed to oxidize the organic ingredients to CO_2 and H_2O. The BSB_5 indicates how much oxygen was consumed by the microorganisms in 5 days to biodegrade the wastewater substances. However, since only a part of the organic wastewater constituents is biodegradable, the following always applies: COD > BOD_5

Table 2 Sample questions (Correct answers underlined)

Technical	Which groundwater aquifer is most probable in Muschelkalk? (porous aquifer, karst aquifer)
	How can fine-grained up to colloidal particles be turned into a filterable material? (precipitation, sedimentation, flocculation)
	Who is the eponym of the formula for calculating the flow velocity of a watercourse? (Reynold, Manning-Strickler, Pettenkofer)
Touristic	To whom does the Poet's Room in the City Palace pay tribute? (Wieland, Herder, Schiller, Goethe)
	What was the ox-eye (Ochsenauge, a small pond with fresh water supply) used for in the past? (washing laundry, drinking water supply, tanning)
	Which building is on the western side of the market square? (City Hall, Cranach House, Goethe's residence)

3 Results

This section describes only a selection of the results. In the feedback session, the participants expressed themselves positively about the game play activity and stated to have learned during the activity. This impression is confirmed by the items referring to

the question of how the city tour was perceived: "was fun" (4.1), "a good mixture between technical and touristic POIs" (3.8), and "the technical POIs were interesting". (3.4). The items "was boring" (1.1), "the questions were too difficult" (2.0), and "was work" (2.4) found the least approval. The item "I prefer a city tour with a human guide" was rated neutral with 2.4. The game was seen as a good support, and the overall conclusion was that also the students found that they learned a lot by taking the tour (both scored 3.3). Interestingly, only 2 out of 9 participants were regular users of commercial location-based AR games, such as Ingress or Pokémon GO. In addition to the closed questions for which we used a 5-point Likert scale, it was also possible for the participants to add their own comments. The overall comments were positive, showed a general acceptance and indicated that the usage led to engagement with the topic. However, some participants had too little time and it was an issue in keeping the spatial orientation without looking at the mobile device continuously. Furthermore, a critical issue was that for some groups the game did not work correctly at the beginning.

4 Discussion and Conclusions

This small study showed that even if only a minority of the participants regularly play location-based AR games, the integration of this element in a learning context was perceived as motivating and interesting. The mix of different types of point of interests may have contributed to this success and also the fact that the participants did not know their surroundings well before. The results related to the learning aspects are in line with a similar experiment carried out with a group of engineering students in January 2018, but the fun score is higher in this study. The main reasons for this are most likely the usage of AR and also that the game is now much more stable and less energy consuming. However, work still to be done includes more extensive studies with more participants, dealing with unfavorable conditions such as rain and cold, and an exact effect analysis.

5 References

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