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Conceptualizing and Developing an AR-enriched Workshop for Teaching School Children in a Botanical Garden

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Abstract. In this paper, the concept and development of a workshop for a program at a botanical garden for secondary school classes is described. The topic of the interdisciplinary program focuses on how plants change the world, combining a historical perspective with biology, politics, economics, and education for sustainable development. To deliver a novel learning experience and support learners' understanding, the workshop will leverage augmented reality (AR) for visualizing 3D material and linking physical and virtual objects. The workshop consists of (1) an input phase, enriched with AR-based visualizations, (2) an exploration phase in which students collect virtual material like photorealistic 3D models of the plants, and (3) a design phase in which they will develop AR-supported material themselves. 3D models of the corresponding plants will be produced with the help of photogrammetry beforehand. In further steps in the project, this program will be implemented in the botanical garden and evaluated with experts and the target group.

Keywords: Augmented Reality, Botanical Garden, Photorealism, Instructional Design.

1 Introduction

In this paper, we describe a project that is currently taking place as an interdisciplinary collaboration between the department of digital education and the botanical garden at the University of Potsdam. The aim of the project is to develop a workshop for the Green Classroom, a program for school classes to visit workshops in the botanical garden. In the novel workshop, advantages of augmented reality (AR) materials and methods will be used to improve information presentation and learner motivation in input and project phases. Theoretical and empirical insights from research on AR-based learning will be transferred into educational practice and evaluated in the field. This paper describes first steps in conceptualizing and developing the learning material and AR integration.

Botanical gardens have been identified as an important informal learning environment, including elements to improve knowledge, education and awareness about plants and plant conservation strategies [1]. Frequent interactions with physical plants have been proposed to improve sustainability education [2]. In previous research, botanical garden field trips have been shown to influence students' environmental perception, including different emotional reactions to, a more correct behavioral approach, and a different perception of the main theme of a story about a butterfly who leaves its cocoon [3]. In recent years, more technology-enhanced educational experiences have been embedded in botanical gardens, including AR and VR technologies. A systematic review from 2023 shows that out of 22 studies of AR and VR in informal learning settings like museums, science centers and zoos, two studies took place in a botanical garden, one with AR and one with VR [4]. In the study focusing on AR-based material, an eco-discovery AR-based learning system is implemented and compared to traditional paper handouts with a commentator [5]. The results show that learning outcomes, positive emotions, engagement, and feelings of competency are increased when using AR instead of the traditional setting. Usage of an AR application in a botanical garden has led to positive evaluations by a variety of visitors [6]. AR thus seems to have the potential to increase learning, engagement and affective responses when used in a botanical garden experience.

2 Conceptualization and Implementation of the Workshop

The program "Green Classroom" at the botanical garden in Potsdam brings secondary school students into contact with plants in different workshops. Currently, a new workshop on the topic "How plants change the world" is being developed. The basic content of this workshop deals with the global historical influences of plants (e.g., tea, coffee, cotton) and has an interdisciplinary focus, including anchors in biology, history, politics, and economics as well as education for sustainable development (ESD). Different plants will be introduced to the students, including a description of the plants, images, information on their usage, historical events and political decisions in connection to the plants, and their influences on the environment. The workshop will integrate digital content and methods with learning in the physical reality of the botanical garden. For this, the cross-reality properties of AR as part of a portable mobile application will be leveraged.

In AR, virtual and physical elements can be combined. AR can support learning, for example, through the unique characteristics of contextuality, interactivity, and spatiality [7]. One special feature of AR is its ability to link virtual and physical elements in learning environments. This can be particularly useful in natural environments in which unaltered physical objects (e.g., flowers, trees, stones) are part of the experience. Botanical gardens enable the encounter with plants and the pursuit of learning objectives in a natural environment. Digital and virtual elements should not replace the physical elements, but they can be used to enrich the experience. AR can be used to present learning content and tasks in a corresponding physical location and to present interactive, virtual 3D objects integrated into corresponding learning situations. In the program, AR will be used on the one hand as a medium for conveying information in a realistic 3D format, in addition to usual text and images.

2.1 Learning Objectives and Workshop Structure

The workshop provides an interesting current, interdisciplinary topic with ESD reference and the use of novel technologies aimed at grades 9 to 12 (ca. 14 – 18 years). Students from these grades were chosen, because relevant basic knowledge and a reflective approach to content and technology can be expected from them. The curriculum for secondary education in the region where the Botanical Garden Potsdam is located, includes many potential connections to the topics in the workshop, so that teachers can prepare their class before going to the workshop.

The overarching goal of the workshop is to inform students about the historical influence of certain plants on the world and their role in forming the world as it is today. The plants are commonly known and potentially every student has come into contact with most of them in one way or another. Showing today's influence of these plants and how those are partly connected to political or environmental issues can improve the students' awareness of the relevance and value of different plants, implying the necessity to not destroy biodiversity.

There will be three parts to the workshop: input, exploration, and design phase.

a) *Input phase*: As a starting point, the students are asked to name plants that have (had) an influence on their life. Collecting the different responses on a board, an instructor helps to cluster the responses by category, illustrating different areas in which plants can impact their lives. Based on an example plant (e.g., tea), the instructor then demonstrates the historical impact that plants have (had) on the world in general. Relevant historical events and political decisions are described and materials including pictures are used for illustration in a tablet-based app. In this app, the instructor can also access photorealistic AR 3D models of the plants, and students can get acquainted with the type of materials they will use in the exploration and design phases. At the end of the phase, students are split into groups and each group receives the name of a plant with a particular relevance to world history for which they will be the experts.

b) *Exploration phase*: In the small groups established in the previous phase, the students explore the botanical garden using a tablet-based AR application to obtain additional information on their respective plant. Each group receives one tablet with an application that is specifically designed for this workshop. In the application, they can find information on the different plants. Their first task is to find their assigned plant in the botanical garden. When getting to the plant, the tablet can be used to scan an AR marker which activates an interface with basic information about the plant, which first includes information in simple text and picture format. To access more information about the plant, the students need to correctly answer multiple-choice questions about the previous material. This way, they are not overloaded with information and they need to engage with the material in order access more information. The information can be displayed as a text, a picture, or an AR-based 3D model. When accessing new digital material, the students can collect this material to prepare for the design phase.

c) *Design phase*: After accessing all material about their plant in the application, the students develop a presentation including different forms of material about this plant. They can use the digital materials that they collected in the exploration phase and are encouraged to implement AR materials with the tablet-based AR application. They then present their material to each other. Each group is thus the expert group for one of the plants, taking responsibility for informing the other students about this plant. In a presentation of what they learned, they can used the tablets to make short video clips, show pictures or show 3D models of the plants.

2.2 Implementation and Instructional Design

The AR implementations in the workshop include the creation of photorealistic 3D models (PR3DMs) through photogrammetry. The open source software AliceVision Meshroom [8] is used to construct virtual models from photos. The models will be presented in AR through a self-developed mobile application, using the Vuforia plugin [9] in Unity 3D [10], with cubical multi targets. Students can turn the cube to view the model from all sides. Fig. 1 shows a typical situation in which a learner accesses the AR material. In the instructional design of the workshop, different theories and frameworks were used, which will be described and explained in the following.

Fig. 1. A learner using a tablet-based AR application to view a virtual 3D model belonging to the corresponding plant.

Photorealism. PR3DMs can be created by using photogrammetry. With this approach, 3D models of plants from the botanical garden will be developed in the current project. In an analysis of the educational value of PR3DMs, Nebel and colleagues describe that the high fidelity and realism can improve perception and transfer of information, alter cognitive processes, and increase affective and motivational responses [11]. However, the authors also describe that, based on Cognitive Load Theory [12], high realism might cause an increase in cognitive load due to the seductive details effect. While this should be considered when implementing the workshop, the main role of the virtual plants is to connect physical world and virtual objects. The appearance of the plants will not be in focus for the learning objectives. For the current project, we want high fidelity and realism to illustrate the connection between physical and virtual elements. Supporting the mental connection between the virtual and the physical plants is one of the potentials of the contextuality of AR [7], which we will describe more in the next paragraph. The main advantage of implementing AR with PR3DMs is that the object can be shown in 3D and is more realistic through its marker-anchored placement as part of the physical world.

Augmented Reality. While a lot of different content can be created for AR, the AR-based elements in this workshop will mainly involve PR3DMs of the relevant plants. Three unique characteristics of AR include contextuality, interactivity and spatiality [7]. In this workshop contextuality, involving the integrated perception of virtual and physical elements, is leveraged through the co-located perception in the botanical garden. The PR3DMs include realistic, spatial representations, thus leveraging the characteristic of spatiality. Interactivity, including the connection of physical interaction with virtual interaction, is leveraged by using a physical anchor as an AR marker to turn the 3D model of the plant. This should invoke a sense of ownership, as they can hold the content in their hands. Spatiality will be implemented in the 3D representation of the PR3DMs. While the spatial structure of the plants is not necessarily relevant to understand the material, it might help with the sense of ownership and with the realism of the representation, as the physical plant is also spatial. All in all, the AR materials are thus mainly implemented to support the connection between physical and virtual materials. To not lose the connection to physical reality when using the mobile application, the camera stream will be visible in the background the whole time when looking at texts and pictures, and when viewing a 3D model, a cube-shaped AR marker will be used to access this information. When the students hold the virtual plant models in their hands, as seemingly a part of the physical, real world, they might feel an increased connection to their history.

Active learning. In the described workshop, another focus will be on active and interactive learning. During the exploration phase, learners collect materials on relevant plants in the botanical garden, which they unlock after working through learning materials about a plant and answering questions about it. With this quiz-based approach, learners must engage with the content before they can collect material for the design phase. They can access new information step-by-step, following the Segmenting Principle based on the Cognitive Theory of Multimedia Learning [13]. Through the self-regulated exploration with a mobile device, they can adapt the pace of accessing new information to their own needs. In the design phase, the learners will then design their own presentation materials, following a learners-as-designers approach. This approach has also been shown to be motivating and conducive to learning when creating AR materials [14]. Mayer and Fiorella [15] describe different activities to induce generative learning and thus deeper cognitive information processing. In the design task in the workshop, students will use the activity of teaching by conveying material to others, which should support the construction of their own understanding by organizing and elaborating on the material.

Motivational design. Next to cognitive processes, the instructional design of the workshop considers motivational factors. Based on the ARCS model by Keller [16], the four variables attention, relevance, confidence and satisfaction were chosen as motivational concepts for the workshop design. Attention will already be captured in the input phase, which is enriched with a PR3DM and should stimulate the students' curiosity through the instructors' presentation and the multimedia materials. The relevance of the content will also be clarified in the input phase, starting with a brainstorming of the personal influences and continuing informing about the historical and political relevance plants can have. Furthermore, through the location- and marker-based connection of the virtual elements with the physical plants, the relevance of the content for the real world will be clear. Confidence will be supported through the active learning tasks, including the students' creation of their own material to inform their peers. Satisfaction is targeted through the social interaction with peers by increasing feelings of social connectedness, and the students' material creation by increasing feelings of agency and competence. Addressing these factors, we aim at increasing students' motivation to engage with the material on a deeper level.

3 Future steps in the project

3.1 Evaluation of the Workshop

In future steps, the workshop developed in this project will be evaluated iteratively. Based on the proposed concept, experts from the content areas and the field of educational technology will be involved in the evaluation of the program. For this, experts from different areas and different stakeholders (e.g., instructional XR designers, garden pedagogics, secondary school teachers) will be asked to evaluate the first version of the workshop and the application which will be supported by descriptions of the workshop and application prototypes. Once the material and technology development for the individual parts of the workshop have been completed, field evaluations will be carried out with volunteers from the target group. A focus of the evaluation will be on technology acceptance as classified by the UTAUT model [17]; cognitive load as mentioned above, measured through a cognitive load questionnaire [18]; motivation as described above, including the constructs attention, relevance, confidence and satisfaction, measured through the IMMS questionnaire [19]; augmented reality immersion [20]; augmented reality experience [21], including the perceived connection between physical and virtual elements, and learning outcome as the increase of knowledge from before the experience to afterwards. After the workshop design has been completed, it will be tested with school classes within the Green Classroom program. The interaction will be tracked, short surveys will be applied, and the results will be used for further improvements before the workshop is fully integrated into the program.

3.2 Further Implementations and Limitations

Beyond the workshop itself, it will be reviewed if the materials created by the students in the workshops can be reused afterwards, e.g., to be exhibited in the botanical garden for the general public. This is possible, if the students create a video that explains something about one of the plants in focus. These materials could be added to a public virtual path through the garden, which the general public could access through their mobile devices. This could be implemented in future projects, e.g., through a world map with historically relevant plants and places that can be scanned with an AR app, or through a digitally overlaid path for visitors for this topic. However, privacy needs to be considered when the videos include images or audio recordings of the students.

The idea of this workshop can furthermore be easily transferred to other botanical gardens which have the same plants and similar programs for schools. When implementing the project in another botanical garden, limitations of the AR technology need to be considered. In this project, tablets were bought, and an application is designed specifically for this workshop. This material may not be available for all botanical gardens or secondary schools. The application might need to be adapted to the specific garden. When implementing the applications, technical difficulties may arise if there is an issue with the software or the hardware. This needs to be considered when using the application, and alternatives should be planned beforehand.

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