# 360-DEGREE VIRTUAL TOUR FOR EDUCATIONAL PURPOSES. AN EXPLORATION ON THE DESIGN CONSIDERATIONS AND DECISIONS

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## ABSTRACT

Field trips are often used in higher education as a practical learning tool. They are not always accessible for all students due to limited financial and organisational resources. A 360-degree virtual tour could be an alternative for field trips. However, there are limited to no design principles for the development of a virtual tour. This paper describes the exploration of the design considerations and decisions for developing a virtual tour and the possible impact on the learning outcomes. A virtual tour has been developed via a design-based approach involving preliminary research, development and prototyping phase, and evaluation phase. The exploration resulted into three main design clusters that require decision making; camera, system and storytelling. The impact of the decisions on the learning outcome need to be further researched via design experiments. Ultimately, design principles need to be formulated to make proper design requirements for a straightforward decision process.

## KEYWORDS

360-degree, virtual tour, field trip, design elements, design decisions, design considerations, engineering education. Standards 6,7,8

## INTRODUCTION

Field trips can be an effective working method to help students make deeper level connections to the subject than books and lectures alone (Wright, 2000). Wright’s study revealed that field trips benefit students in understanding abstract concepts, instructors become more enthusiastic about the course, students use their experiences for future research and the students are able to test theories and compare different sources of data. The accessibility of field trips for a large amount of students may be challenging due to limited organisational and financial resources (Krepel & DuVall, 1981), (Disinger, 1984), (Fisher, 2001).

An effective substitute for current field trips could be a virtual tour. Virtual environments can “stimulate learning and comprehension, because it provides tight coupling between symbolic and experiential information” (Bowman, Hodges, Allison, & Wineman, 1999). A virtual tour can be re-used, altered to specific needs, seen in student’s own pace, accessible at any time and place and therewith provides a flexible learning experience (D. Zhang, Zhou, Briggs, & Nunamaker, 2006).

Current virtual tours for educational purposes can be expensive and may not be close to a real-world environment. They are often build using 3D scanners or computer reconstructions of existing buildings and environments or make use of a website providing separate photos, 2D movies, and text of the environment (Lukesh, 1994)**,**(Jones & Christal, 2002)**,**(Jan, Roque, Leuski, Morie, & Traum, 2009)(Costa & Melotti, 2012).

360-degree spherical video and photo technology is a possibility to develop cheaper and more realistic virtual tours. These images can be placed in a sequence with an interactive walkthrough that simulates the process of a real-life and realistic environment. Additional audio and textual information can be integrated to create a guided tour.

The current design guidelines for virtual tours do not focus on the technological development of the tour itself but mainly on the curriculum design, instructors role or assessment method (Grant, Heirich, Martin, & Eck, 1981),(Krepel & DuVall, 1981),(Orion & Hofstein, 1994)(Lacina, 2004), (Procter, 2012). However, the technological development is important for the technology acceptance otherwise learning may not take place (X. Zhang, Jiang, Ordóñez de Pablos, Lytras, & Sun, 2017)(Davis, Bagozzi, & Warshaw, 1989). There are no design principles for the development of a virtual tour that enhances learning. It is necessary to perform an exploration of the technological design considerations and decisions.

### *Case: waste water treatment plant*

A field trip to a waste water treatment plant is organised for a bachelor course ‘Introduction to Water Treatment’ of the Faculty of Civil Engineering and Geosciences at the Delft University of Technology. The learning objectives are; to recognise the process units, describe their function and make design calculations on the wastewater treatment plant.

Only 20 of the 120 students of the course can join the field trip. During the lectures and online videos the students only see photos or schematic visualisations of wastewater treatment plants. However, these do not provide a proper spatial or complete overview of the site. During the field trip it is intended that students get a better view of the installation size, how sludge looks like in different stadia of the process, how much/fast water flows through the plant, what peripheral equipment looks like and which control parameters are used.

## DESIGN METHOD

A design based approach has been chosen to develop the virtual tour for the wastewater treatment plant to explore the design decisions and considerations for educational purposes. The structure of the design method is divided into three phases; preliminary research, development and prototyping phase and the evaluation phase with each several design and research techniques (van den Akker, Bannan, Kelly, Plomp, & Nieveen, 2013).

- *Preliminary research:*

1) Observations of a wastewater treatment plant field trip to gain information about the group interaction (Kothari, Kumar, & Uusitalo, 2014).
2) Site visit of a wastewater treatment plant to analyse the context for potential media recordings.
3) Expert interviews to enhance the understanding of 360-degree recordings and online-education.

- *Development and prototyping phase:*
  1) Designing concepts and iterative co-creation sessions with AV technicians, students and teachers (Abras, Maloney-Krichmar, & Preece, 2004).
  2) Literature research of other case studies with online-education and field trips for the design of virtual tour.
  3) Prototyping of the concepts in a virtual environment for evaluation (Hall, 2001).

- *Evaluation phase:*
  1) Self-evaluation to discover obvious errors within one prototype
  2) Small group test and semi structured interview to evaluate the usability of one prototype.

### *Design constrains*

Scalability of the virtual tour is important as it has to be implemented during a course serving around 120 students. Furthermore, flexibility is important as it was requested to use the tour for additional purposes apart from the course. The organisational scope wished for an emphasis in exploring the technological challenges in Virtual Reality (VR) and VR headsets. The virtual tour had to be recorded at a wastewater treatment plant in Amersfoort in the Netherlands because most essential process steps are visual and easy accessible. Essentially, no actual key-requirements and functional specifications were predetermined since it is an explorative design research. Specifying key-requirements limits the exploratory study particularly in the design phase.

## FINDINGS

### *Preliminary research*

A wastewater treatment plant field trip observation has been conducted during the course Introduction to Water Treatment at a plant in Den Hoorn in the Netherlands. The plant in Amersfoort has been visited to examine the environment. Three online education experts have been interviewed via a semi-structured interview

O*bservations*

The wastewater treatment plant field trip in Den Hoorn started with an introduction presentation about the plant at the main building. During the presentation and the subsequent tour, several questions were asked but no notes were taken by the participants. At the wastewater treatment plant site the participants were looking over and underneath objects and railings. However, the view was sometimes blocked by the bystanders or the tour guide. The order of tour did not match the actual process of the wastewater treatment plant and several steps were skipped due to limited time and safety issues.

*Site visit*

At the site visit of the wastewater treatment plant in Amersfoort it was possible to observe all individual steps of wastewater treatment plant process as the on-site technician could open all rooms and hatches. During each process step, the camera positions were listed on a map and a hand-held 360-degree camera was used to take several preliminary photos of the environment. After reviewing the photos the significant recording locations were selected in collaboration with the teacher of the course.

*Expert interviews*

The three semi-structured interviews were focussed on the development of (VR) e-learning methods. It revealed that the quality of current technology for 360-degree recording and (VR) playback systems is still underdeveloped. It is difficult to incorporate 360-degree media and learning analytic software to the current educational platforms of Universities. Developing new e-learning software including learning analytics requires extensive ethical procedures that deals with privacy issues. Understanding the 360-degree technology, the development of 360-degree recordings and enhancing student engagement had more priority for the interviewees rather than focussing on the ultimate learning effectiveness.

### *Development and prototyping phase*

*Design concepts*

Three basic concepts have been developed as a start and can be read in table 1. The concepts increase in developmental difficulty and the level of additional information about wastewater treatment.

Table 1. Design concepts of the virtual tour

| | |
|---|---|
| Design concept 1 | 360-degree photo tour of multiple static recordings for desktop<br>Tour can be used in the lectures and computer via student platform<br>All photos can be accessed via click/walk-through |
| Design concept 2 | 360-degree video tour of multiple static recordings<br>360-degree audio of all the different steps via a voice over<br>Tour can be seen via desktop or a VR headset<br>The audio explains the text and asks several (rhetoric) questions about the situations that can be seen in the video |
| Design concept 3 | 360-degree video tour of multiple static recordings<br>360-degree audio of all the different steps via a voice over<br>Tour can be seen via desktop or a headset<br>The audio explains the text and asks several (rhetoric) questions about the situations that can be seen in the video<br>Additional insert videos of detailed important elements of the environment<br>The additional videos can be seen separately on the students platform within the different modules |

The first two design concepts have been developed into workable prototypes. The third design concept is still under construction. The development of the design concepts resulted into a structured collection of design elements. Their cohesion have been developed into a design framework setup (figure 1.). It consists of three main clusters; camera, system and storytelling that require design consideration and decisions.

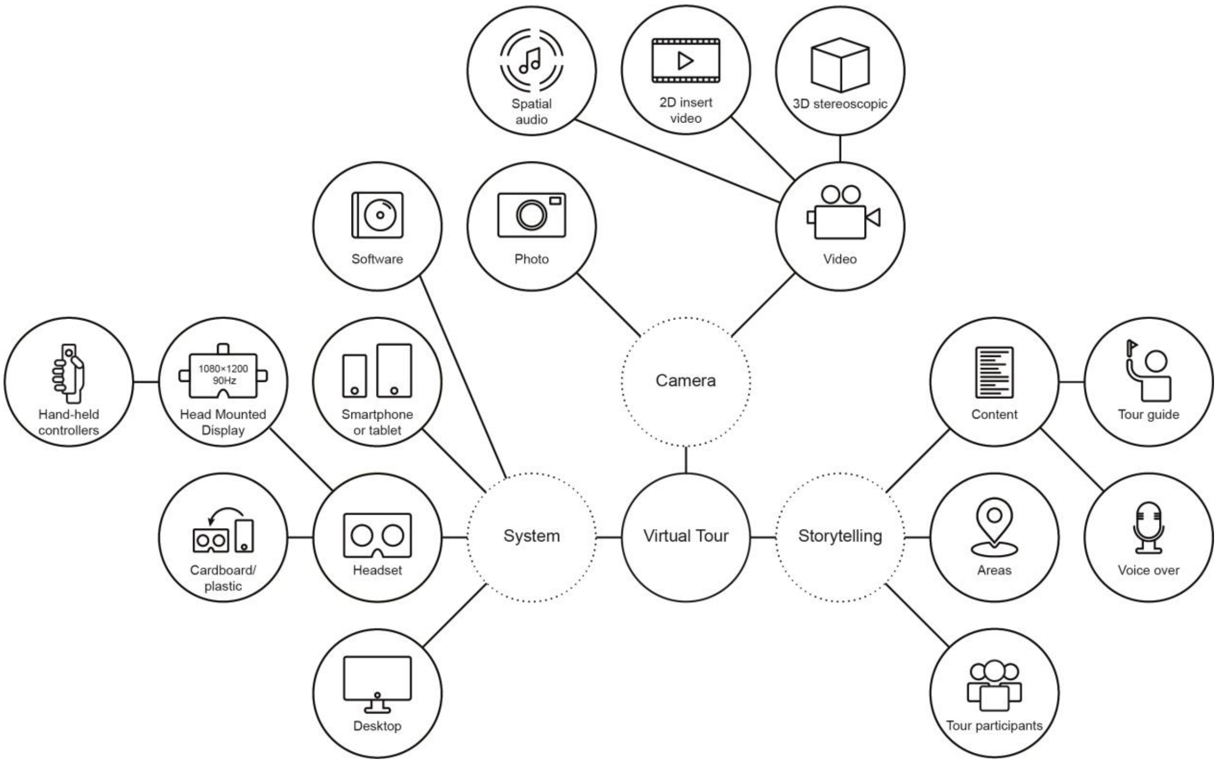


Figure 1. Design frame work setup of the design elements and their consideration and decisions possibilities

*Literature research*

The design considerations and decision process and the design elements is described in detail in the following section. Additional literature research explores the considerations on basis of educational learning and the impact on immersion, presence, engagement and cognitive load in general. Ultimately, a short overview of the design considerations and decisions for the wastewater treatment plant case is described.

*Camera*

A decision has to be made using photo or videos of the environment. The camera quality has to be taken into consideration and costs may determine the most feasible choice.

Videos in itself do not affect learning but it is the way the video is used. Video may increase motivation and engagement with the subject as it grab students' attention (Maniar, Bennett, Hand, & Allan, 2008). Videos are closer to reality as it portrays change over time but the presented content may be harder to perceive and may result in cognitive overload (Tversky, Morrison, & Betrancourt, 2002).

Higher video and photo resolution increases the amount of relevant as well as irrelevant detail and may overload the working memory and cognitive load (Brame, 2015). The quality of the cameras evolve rapidly. There are multiple 360 photo and video cameras on the market e.g. Panono, Ricoh Theta V, Insta360 pro, GoPro Omni mounts and Nokia Ozo ranging from 450 – 50.000 euro. Renting the camera is an option however, high-end cameras may require experienced operators provided by the rental company.

It is possible to see a 3D effect within a VR headset instead of 2D images. This 3D stereoscopic effect can be recorded by high-end cameras such as the Nokia Ozo. The 3D effect can enhance the sensation of depth (Fonseca & Kraus, 2016) and provides more depth cues about the relative size and position of objects in space (Hubona, Wheeler, Shirah, & Brandt, 1994). However, 3D-stereoscopic recordings do not influence an extra sense of presence for the 360-degree videos (Bessa, Melo, Narciso, Barbosa, & Vasconcelos-Raposo, 2016).

*System*

An interactive virtual tour can be built with the recorded videos and photos using commercially available software. The virtual tour can be seen via several playback devices e.g. desktop, hand-held display or VR headset. Similar to the camera, the devices differ in quality and costs may determine the most feasible choice.

Placing the 360-degree recordings in a sequence and creating walk-through can be built in a software application. Additional audio and 2D insert video hotspots can be incorporated to increase in amount of interaction which may increase the engagement. There are several software programmes to develop virtual tours e.g. Panotour Pro, Pano2VR, Autopano Pro or Unity. The software has to be compatible with the playback device. The usability and the amount of functions of the software programs differ.

Viewing a virtual tour with a VR headset can enhance an immersive experience and the perception of being presence in the real-world environment. It can have a positive effect on learning in comparison to a regular computer screen experience (Gutiérrez et al., 2007). The head movements and 360-degree spatial audio enhances the preservation of real-world sensory fidelity of a system (Slater, 2003). Compared to a desktop environment, VR headsets can improve the search task performance (Pausch, Proffitt, & Williams, 1997).

High-end headsets such as a head mounted displays have an integrated screen with high resolution and can have interactive hand-held controllers. Examples are the Oculus Rift or HTC Vive. Head mounted displays are expensive and may require additional computers, sensors, separate rooms and could result in logistic issues. The current head mounted displays are not easily accessible for large group of students. Furthermore, there are several side effects of exposure to VR environments such as headaches, dizziness or drowsiness. These are caused by i.a. display and characteristics such as contrast, resolution, refresh rate and time delay (Riva, Lewis, & Griffin, 1997).

A cheaper alternative for HMDs are cardboard or plastic headsets without integrated screens such as Google Cardboard or Google daydream. The student needs to place their own smartphone with an integrated gyroscope into the case to see the virtual tour. The quality of the virtual tour depends mainly on the quality of the smartphones. Using Google Cardboards may experience head discomfort wearing spectacles or after wearing the cardboard too long.

*Storytelling*

Next to a visual representation it is better to add audio to the presented material (Mayer & Moreno, 1998). Background sounds and a narrated story can simulate the actual field trip.

Audio can direct viewer's attention in the video (Brown, Sheikh, Evans, & Watson, 2016) but irrelevant sounds needs to be limited (Moreno & Mayer, 2000). The audio only needs to contain relevant information and meet the learning objective. Maintaining student engagement may be possible to segment the videos in the different process steps with a maximum length of 6 minutes (Guo, Kim, & Rubin, 2014).

It is possible to incorporate a real tour guide in the 360-degree videos that narrates via a pre-determined script. The tour guide can speak fairly fast, with high enthusiasm and via a personal and conversational style to become more engaging (Guo et al., 2014) (Mayer, 2008). The points of interest during the tour can be exaggerated by natural interaction such as looking or pointing. Gazing towards a point of reference makes it easier for students to follow the content (Sharma, Jermann, & Dillenbourg, 2015). Additional tour participants can be incorporated as well and may increase a sensation of presence. However, adding a tour guide or additional tour participants can cause blocking the points of interest.

360-degree recordings do not have the same degrees of freedom simulating head movements compared to a real field trip and it is not possible to look over railings or objects. Incorporating additional 2D insert videos of specific subjects can offer the specific information required for the learning objectives.

Spatial audio can increase the sense of presence (Västfjäll, 2003). Some 360-degree cameras can record spatial audio with their internal microphones. Recording a voice over in 360-degree audio is possible as well. Listening to the virtual tour using a headphone can cut off distracting environmental sounds and the spatial audio can increase the sense of presence and immersion (Tse et al., 2017).

*Case: prototyping design decisions*

In the following section the design decisions for the wastewater treatment plant case are described.

*Camera decision*

The Delft University of Technology and its media department (NewMedia Centre) invested in the software and cameras for the development of future virtual tours. Three 360-degree cameras were bought; Panono, Ricoh Theta S and the Insta360. The Panono is a high-resolution photo camera and is very easy in use. Teachers and students can easily take photos themselves on location. The Ricoh Theta S is a small video camera but did not meet the expected quality. It has been used as a low-threshold camera to capture the environment to explore the areas during preliminary sight visits. The Insta360 video camera was around 4000 euro, still 10 times cheaper compared to the Nokia Ozo. It was assumed that the quality of the Insta360 would be accepted by the students.

*System decision*

An internal AV systems engineer developed the tour with Autopano Pro. It has extensive functions but was easier in use compared to Unity. The software provides a hyperlink to access the virtual tour online and it runs on a server of the University.

Based on the design constraint; serving 120 students, a decision has been made to develop the tour for a Google Cardboard headset. There was no space, budget or a large amount of high-end HMDs available to support 120 students. Still, to give some idea about the spatial dimensions and enhancing the sense of presence, Google Cardboards were distributed.

*Storytelling decision*

The virtual tour has been recorded without a physical tour guide or additional tour participants. The on-site technician could tell a considerable amount of information of the wastewater treatment plant, but it was complicated to control specific information to meet the learning objective for the students. Testing with additional tour participants did not fit the planning as weather conditions were crucial and winter was coming.

A voice-over script was developed in collaboration with students, the teacher and the on-site wastewater treatment plant technician. There was a maximum amount of 200 words per process step. There were in total 21 process steps divided into two lines (water and sludge line) that resulted in a virtual tour of approximately 25 minutes. The voice over has been recorded stereo as it was too hard to embed the 360-degree spatial audio within the software and meeting the deadline and budget. Environmental sounds have been recorded and embedded in 360-degree audio.

***Evaluation phase***

Only concept 2 has been evaluated via a self-evaluation and small group test as it is a CDIO project in progress, the two other design concepts will be evaluated in a later stage.

*Self-evaluation*

Design concept 2 has been evaluated by the internal team to discover obvious errors such as order of the process steps, stitching errors, voice-over and colour corrections. Stitching errors were only corrected at the points of interest for the learning objectives.

*Small group test*

Design concept 2 has been evaluated via a usability test with 11 students divided over three days. The participants received a written instruction to assemble the provided VR headset and to access the virtual tour. They were instructed to only experience the tour for 20 minutes without any support of the researcher. The following list is a summary of the main findings:

- Overall the virtual tour design was “cool”, fun to use, useful, and easy to learn. However, interacting with the tour was not straightforward and required improvement.
- The written instructions were not clear as visual aids were missing. This resulted in difficulties to assemble the VR headset and access the virtual tour. Some participant needed support from the researcher to not exceed the time frame. It could also depend on the novelty of the system as only two of the 11 participants have used a VR headset before with assistance of an external party.
- The participants did not pay attention to voice-over tour guide as they were exploring the environment at first after entering the scene or looking for the access points to enter the next scene.

- It also occurred that participants non-intentionally looked at access points and entered next scenes, but the virtual tour was not programmed to be able to go back.
- Most participants would like to experience the virtual tour in a safe context where they do not knock over any obstacles once they move around in the virtual environment.
- Several participants felt lonely during the virtual tour and they ideally wanted to interact with other students to discuss their experiences. The other participants did not necessarily felt lonely, but they thought it would be nice to discuss their experiences.
- Some participants experienced nausea and one participant suggested that a standing position would lead to less nauseating feeling. This is most likely the result of the system quality.

## CONCLUSION AND RECOMMENDATIONS

Developing a virtual tour is a complex process as many design decisions have positive as well as negative consequences. If the technology is not accepted by students learning may not be achieved. The cameras, headsets and software develop rapidly and become more accessible for students and Universities. Improved technology will resolve many health issues in the future.

The list of design elements and their considerations and decisions is not finite. The virtual tour design concepts are very specific to the wastewater treatment plant case and new design elements may emerge from other concepts and designs. When developing a virtual tour it is recommended to initiate an interdisciplinary design team with experts from different fields; education, AV technology, user-interaction, content experts and students.

Scalability, flexibility, quality, budget and planning were important design constrains for the development of the virtual tour. Once scalability is an important factor, the desktop solution for the virtual tour is currently the best option to serve a large amount of students as the low-end headsets cannot offer the optimal quality for students. When the technology improves, the tour can be altered for high-end immersive systems. If flexibility is less important, it is recommended to incorporate an actual tour guide within the scenes. This can increase engagement and makes the students feel less lonely once experiencing the tour in an immersive setting. The virtual tour can be an overwhelming experience and taking control on the interactions is important for the technological quality and acceptance. These interactions need to be intuitive and simple to make the novel experience user-friendly. If Universities lack 360-degree video and software experience for the development of a virtual tour, outsourcing is recommended when budget is available.

The different design considerations and decisions and their impact on student learning need to be further examined. First findings will be examined via an experiment during the course. More extensive research is necessary to evaluate the impact of the virtual tour on engagement, immersion, sense of presence and cognitive load. This could enhance the decision process and the development of design principles for a virtual tour.

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