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More than experience? - On the unique opportunities of virtual reality to afford a holistic experiential learning cycle

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ABSTRACT

Virtual reality has been proposed as a promising technology for higher education since the combination of immersive and interactive features enables experiential learning. However, previous studies did not distinguish between the different learning modes of the four-stage experiential learning cycle (i.e., concrete experience, reflective observation, abstract conceptualization, and active experimentation). With our study, we contribute a deeper understanding of how the unique opportunities of virtual reality can afford each of the four experiential learning modes. We conducted three design thinking workshops with interdisciplinary teams of students and lecturers. These workshops resulted in three low-fidelity virtual reality prototypes which were evaluated and refined in three student focus groups. Based on these results, we identify design elements for virtual reality applications that afford an holistic experiential learning process in higher education. We discuss the implications of our results for the selection, design, and use of educational virtual reality applications.

1. Introduction

Virtual reality (VR) generates a simulated environment through head-mounted displays (HMDs) and creates an immersive and interactive experience for users. While the entertainment and gaming industry still accounts for the largest market share, VR technology is increasingly seen as a promising opportunity to innovate online teaching and learning in higher education (Wohlgenannt, Simons, & Stieglitz, 2020). The global VR market is projected to reach a market size of 120.5 billion US dollars until 2026 and the adoption of VR is expected to witness fast growth in the education industry (Fortune Business Insights, 2019). According to previous research, the opportunity to create learning experiences that would otherwise not be possible in the real life classroom represents the most important motivation to use VR in education (Freina & Ott, 2015). A recent study supports the notion that experiential learning through VR is indeed possible and also effective in terms of learning outcomes (Kwon, 2019). Many other studies highlighted the potential of VR technology to afford experiential learning (Aiello, D'Elia, Di Tore, & Sibilio, 2012; Gouveia, Lopes, & De Carvalho, 2011; Jarmon, Traphagan, Mayrath, & Trivedi, 2009; Le, Pedro, & Park, 2015; San Chee, 2001; Su & Cheng, 2019).

However, we found that most of these emphasize the learning mode of concrete experience, although experiential learning does not only consist of *experience* as the name suggests. According to experiential learning theory, students cycle through the four different learning modes of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). Furthermore, most of these studies focused on virtual worlds (e.g., Second Life) and therefore did not consider the technological advancements in the meantime. Thus, the open question remains whether VR only affords the learning mode of concrete experience or whether the technology also provides unique opportunities to afford the remaining three learning modes. In addition, a systematic literature review of VR studies in higher education revealed that most design-oriented studies lack a foundation in learning theory (Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). As a result, the majority of educational VR applications are designed with a specific *learning outcome* in mind but do not aim at supporting a specific *learning process* such as experiential learning. Some recent studies started to address this research gap by grounding the design of educational VR applications in learning theories such as

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constructivism (Kim et al., 2020), the peer assessment learning approach (Chang, Hsu, & Jong, 2020), or inquiry-based learning (Jong, Tsai, Xie, & Kwan-Kit Wong, 2020; Petersen, Klingenberg, Mayer, & Makransky, 2020). We aim to contribute to this line of research and identify VR design elements that can be implemented to afford a holistic experiential learning process. Hence, we ask the following research question:

RQ: How can educational VR applications be designed to afford the four experiential learning modes (i.e., concrete experience, reflective observation, abstract conceptualization, active experimentation)?

To answer this question, we followed a user-centered design approach and conducted three design thinking workshops with interdisciplinary teams of lecturers and students. Afterward, we evaluated and refined the designed VR prototypes in three focus groups with students. The results of the workshops and focus groups were analyzed through an experiential learning and affordance lens. With our study, we contribute a deeper understanding of how the unique opportunities of VR technology afford a holistic experiential learning cycle.

The remainder of this article is structured as follows: In Section 2, we provide the theoretical background of our study and summarize previous work about VR in higher education, experiential learning, and affordance theory in the field of education science. Then, we describe how we conducted and analyzed the design thinking workshops and focus groups in Section 3. In Section 4, we present detailed results from the workshops followed by detailed insights from the focus groups in Section 5. We then derive design principles from our findings and discuss these in light of previous research in Section 6. In Section 7, we conclude with a summary of our key results, the limitations of our study, and avenues for future research.

2. Theoretical background

2.1. Virtual reality in higher education

Biocca & Delaney (1995, p. 63) define VR as *"the sum of the hardware and software systems that seek to perfect an all-inclusive, sensory illusion of being present in another environment"*. Previous research suggested that VR enables users to experience a higher degree of immersion, interactivity, and presence than other information systems (Walsh & Pawlowski, 2002). There are systematic studies that provide an overview of VR use for education and training (e.g., Chavez & Bayona, 2018; Feng, González, Amor, Lovreglio, & Cabrera-Guerrero, 2018; Radianti et al., 2020; Suh & Prophet, 2018; Wang, Wu, Wang, Chi, & Wang, 2018; Wohlgenannt, Fromm, Stieglitz, Radianti, & Majchrzak, 2019). In general, they concur that VR is a promising approach to support higher education. However, only recently scholars began to discuss VR design elements for higher education, supported by solid learning theories that assure effective learning outcomes. Wang et al. (2018) examined various works concerning the use of VR for training in construction engineering. The authors concluded that VR is suitable for a flipped classroom and ubiquitous learning activities. They underlined that educational VR kits need to consider emerging education paradigms. Chavez and Bayona (2018) emphasized the essential VR characteristics that determine positive learning effects such as interactive capability, immersion interfaces, animation routines, movement, and simulated virtual environments. Overall, the authors revealed seventeen positive effects of VR-supported learning, ranging from improved learning outcomes, increased learning motivation and learning interest to the possibility of enabling learning through "live experience". Suh and Prophet (2018) identified the theoretical foundations applied in educational VR studies. However, the authors did not focus on how these learning theories can be used as a basis for educational VR design and development. Feng et al. (2018) focused on VR applications for evacuation training and carried out an extensive analysis of the VR learning outcomes, covering both pedagogical and behavioral impacts. Suh and Prophet (2018) and Feng et al. (2018), however, neither provided suggestions on how learning theories can inform the design process, nor identified which learning theories would enhance the learning outcomes from the literature under study.

A literature review about the use of VR for the design of educational virtual environments also revealed that learning theories are often implied but seldom explicitly mentioned (Mikropoulos & Natsis, 2011). As a response, Fowler (2015) introduced the "design for learning" perspective and argued that an understanding of pedagogical underpinnings should inform the design of educational VR applications. More recently, Radianti et al. (2020) and Wohlgenannt et al. (2019) conducted an extensive survey of the literature in the area of immersive VR for higher education. Radianti et al. (2020) reviewed literature published between 2016 and 2019 and identified the applied learning theories as well as the application domains, design elements, and learning outcomes of VR applications for higher education. The authors identified fourteen VR design elements and mapped these to different learning outcomes. However, the study revealed that the majority of design-oriented immersive VR studies under review did not explicitly mention a learning theory as foundation for the development of educational VR applications. When broadening our scope beyond higher education, we found that scholars more frequently elaborated on how learning theories guided the design and evaluation of educational VR applications. For instance, Chang et al. (2020) introduced the peer assessment learning approach triggering better learning achievement, self-efficacy, and critical thinking. The study is based on a solid learning theory, which served as guidance for the design process of VR learning activities. Kim et al. (2020) used the constructivist learning approach as theoretical underpinning for the development of an immersive VR app for gardener apprentices. Jong et al. (2020) proposed a pedagogical framework (LIVIE) that provides guidance on how to leverage immersive VR apps for geography education based on the inquiry-based learning model. In a similar fashion, Petersen et al. (2020) developed and evaluated immersive VR field trips guided by inquiry-based learning theory. In both studies, the design and evaluation of the VR learning activities were grounded in solid learning theories. Following this stream of research, the experiential learning theory will guide our qualitative design-oriented study.

2.2. Experiential learning theory

Kolb (1984) defined the theory of experiential learning based on several fundamental models of experiential learning, including Lewin, Dewey, and Piaget, which basically refer to *learning from experience* or *learning by doing*. Learners immerse in a particular experience and reflect their experiences to develop new skills, attitudes, or ways of thinking (Lewis & Williams, 1994). Experiential learning is defined as *"the process whereby knowledge is created through the transformation of experience. Knowledge results from combination of grasping and transforming experience"* (Kolb, 1984, p. 41). The theory of experiential learning builds on *six propositions* (Kolb, 1984). First, learning is a process and not an outcome. The process shall be accompanied by feedback. Second, learning always includes relearning. Learners' beliefs of a particular topic are challenged and tested with new ideas and insights. Third, the learning process is driven by conflicts, differences, or disagreements. By resolving conflicts or discussing disagreements the individuals learn. Fourth, learning is adapting to the environment by feeling, thinking, perceiving, and behaving in a certain way. Fifth, learning results from assimilating new experiences to existing concepts and vice versa (i.e., synergetic transaction). Finally, the learners create new knowledge. Based on these six propositions and to acquire new skills, attitudes, or knowledge, learners need to confront *four modes of experiential learning*. The learning modes include two opposing modes of grasping experiences and two opposing modes of transforming experiences. Grasping experience includes *Concrete Experience* and *Abstract Conceptualization*, whereas transforming experiences refers to *Reflective Observation* and *Active Experimentation*. These learning modes occur in a four-stage cycle. First, learners have concrete experiences. They involve themselves in a new situation with an open mind and without any bias. Second, learners reflect on and observe these experiences from several perspectives. Third, the learners engage in abstract conceptualization. They are able to transform their observations in theory by creating concepts that are generalizations or principles that are logical. Fourth, learners make use of their developed theories to solve a given problem. These theories serve as guidance for learners to engage into action by testing what they learned in complex situations. After the learners actively experimented with their new learning, the process restarts.

The theory of experiential learning has been increasingly associated with digital technologies in general, but also with VR in specific. For instance, studies focused on the integration of experiential learning into online classes to elaborate skills and competences that are helpful for the connection of experience and communication technologies (Baasanjav, 2013) or investigated the role experience plays in e-learning from simple content sharing to direct experience and action learning (Carver, King, Hannum, & Fowler, 2007). With regard to VR studies, the theory of experiential learning is one of the most widely applied learning theories for VR-enabled learning (Li, Ip, & Ma, 2019). Bricken (1990), for instance, advocated the use of VR as a tool for experiential learning as it supports learners to apply knowledge and experience consequences. Bell and Fogler (1997), San Chee (2001), and Chen, Toh, and Ismail (2005) pointed out that VR accommodates the experiential learning theory, as it allows students to explore, experience, and examine their environments freely, even hazardous and inaccessible locations such as operating nuclear reactors or microscopic pores. San Chee (2001) grounded the development of an interactive, collaborative virtual learning environment on Kolb's experiential learning framework to obtain concrete learning experiences through active experimentation. Students can learn by making sense of observations as well as problem solving and coordinated joint activities in the virtual world. Studies from different research fields (e.g., education, medicine) advocated the potential of VR as this technology allows the inducement of interactivity (Sultan et al., 2019). VR provides a rich and engaging education context that supports experiential learning as students can experience learning by doing. This raises interest and motivation which effectively supports knowledge retention and skills acquisition (Sultan et al., 2019). Using VR in teaching encourages a more concrete experiential mode of learning from the students (Wang, Newton, & Lowe, 2015) and reflective observation in a safe and authentic environment (Li et al., 2019). Further, first small attempts have been made which focus on the design of VR learning scenarios or learning content, especially for children with autism spectrum disorder (Li et al., 2019).

Experiential learning theory received criticism from various researchers (e.g., Garner, 2000; Morris, 2019). Researchers raised questions concerning a lack of theoretical foundations, a lack of clarity, or conceptual weaknesses. For instance, some researchers argued that experiential learning theory lacks theoretical and empirical foundations including the instruments validity to measure learning style or the model's logic itself (Coffield, Moseley, Hall, & Ecclestone, 2004; Garner, 2000; Hawk & Shah, 2007). They questioned whether Kolb's work could reliably describe an individual's learning style. Further, De Ciantis and Kirton (1996) maintained that Kolb's learning styles in fact define a learning process rather than a style. Additionally, Morris (2019) was concerned about a lack of clarity regarding what "concrete experience" exactly constitutes and how educators can interpret the meaning of it. Despite the criticism, many researchers advocated and positively reported on Kolb's work (Garner, 2000), as this theory considers a holistic view of learning on the combination of experience, perception, cognition, and behavior (Kolb, 1984). Kolb's work is probably the *"most scholarly influential and cited model"* regarding learning theory (Morris, 2019) and has been successfully applied in multiple research fields (e.g., business, engineering, medicine) including the field of VR (Li et al., 2019). Thus, we consider this theory suitable as our theoretical foundation.

2.3. Affordance theory in education science

The notion of affordances has its origin in ecological psychology and was introduced by James J. Gibson who questioned existing assumptions about visual perception (Gibson, 1979). He challenged the traditional assumption that animals including humans first perceive physical properties of their environment and then deduce the interaction possibilities offered to them. Instead, he assumed that animals and humans directly perceive the action potential of their environment meaning *"what it offers [...], what it provides or furnishes, either for good or ill"* (Gibson, 1979, p. 197). In his view, the physical properties of surfaces, substances, objects, and other animals in the environment determine the offered affordances to a certain extent, however, affordances are also unique for each species or even for different members of the same species (Gibson, 1979).

The affordance concept has been adopted in the field of information systems, studying the design, use and impact of information technology (Dremel, Herterich, Wulf, & Vom Brocke, 2020; Lehrer, Wieneke, Vom Brocke, Jung, & Seidel, 2018; Seidel, Recker, & Vom Brocke, 2013) as well as in education science as a theoretical foundation for the selection and design of e-learning technologies (Antonenko, Dawson, & Sahay, 2017; Bower, 2008; Kirschner, Strijbos, Kreijns, & Beers, 2004). While traditional instructional design approaches assume a causal relationship between technology, instructional methods, and *learning outcomes*, the affordance concept allows designers to focus on promoting a certain kind of *learning behavior* (Strijbos, Martens, & Jochems, 2004). For example, Kirschner et al. (2004) suggested that e-learning environments should offer certain educational, social, and technological affordances to enable the emergence of collaborative learning processes. Furthermore, Bower (2008) developed an affordance-based methodology that allows educational designers to match the affordance requirements of learning tasks with the provided affordances of available e-learning technologies. In a similar fashion, Antonenko et al. (2017) proposed an affordance-based design process that emphasizes the alignment of user needs with the affordances of educational technologies.

Meanwhile, affordance studies in education science have investigated the educational affordances of various technologies such as social media (Manca, 2020), wikis (Fu, Chu, & Kang, 2013), mobile computing (Tang & Hew, 2017), wearables (Bower & Sturman, 2015), learning management systems (Rubin, Fernandes, & Avgerinou, 2013), and Web 2.0 (Augustsson, 2010). There also have been several studies that identified the educational affordances of VR, however, these focused on virtual worlds such as Second Life and Active Worlds (Dalgarno & Lee, 2010; Dickey, 2003, 2005; Gamage, Tretiakov, & Crump, 2011; Shin, 2017). In the meantime, VR technology has evolved and there are consumer-friendly standalone headsets on the market (e.g., Oculus Quest) that allow a higher degree of immersion and interactivity than the aforementioned desktop-based VR worlds. In previous studies, VR has often been described as promising to support experiential learning processes (Aiello et al., 2012; Gouveia et al., 2011; Jarmon et al., 2009; Le et al., 2015; San Chee, 2001; Su & Cheng, 2019). However, we still require a deeper understanding of VR technologies' unique educational affordances that enable the emergence of experiential learning processes.

3. Research design

3.1. Design thinking workshops

In the context of e-learning, workshops have been proposed as a research methodology that allows researchers to identify factors that are not obvious to either the participants or the researchers advancing the meaning negotiation between them (Ørngreen & Levinsen, 2017). Hence, we conducted workshops following the user-centered innovation approach of design thinking. This innovation approach has become increasingly established in practice for the development of products, services, and processes, as the resulting innovations are not only technologically feasible and viable for the business, but also focus on the users' needs and problems (Brown et al., 2008). The early integration of future users into the design process and the development of a deep understanding of their problems and needs is of great importance; not only in business. Successful design thinking is characterized by three essential elements: 1. design thinking mindset, 2. process, and 3. methods (Brenner, Uebernickel, & Abrell, 2016). The design thinking mindset forms the framework for the entire process and includes aspects such as user centricity, co-creativity, and interdisciplinarity (Carlgren, Elmquist, & Rauth, 2016).

In education science, researchers most often discussed pedagogical strategies to promote design thinking as a valuable 21st century skill enabling students to solve complex problems in their future work lives (e.g., de Figueiredo, 2020; Linton & Klinton, 2019; Razzouk & Shute, 2012; Scheer, Noweski, & Meinel, 2012). However, design thinking has also been proposed as a valid research method for design-oriented studies in the field of information systems (Devitt & Robbins, 2012; Dolak, Uebernickel, & Brenner, 2013). In this field, many design-oriented researchers follow the established design science research paradigm which aims at the development and evaluation of an *"IT artifact created to address an important organizational problem"* (Hevner, March, Park, & Ram, 2004). The design science research paradigm provides a research process model (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) and seven research guidelines (Hevner et al., 2004). Furthermore, design science research consists of three research cycles: The relevance cycle bridges the application domain with the design activities; the design cycle includes artifact building and evaluation activities; and the rigor cycle connects design activities with the existing knowledge base (Hevner, 2007). Dolak et al. (2013) found that design thinking fulfills the design science research guidelines but expressed concerns about a lack of rigor during the design evaluation process. While the design science research paradigm provides guidance on how to establish rigor in design-oriented research, the human-centered nature of design thinking can enrich the relevance cycle (Dolak et al., 2013; Hevner, 2007). As a result, they argue for the extension of design science research through design thinking and vice versa (Dolak et al., 2013). Another comparative study described design science and design thinking as complementary research paradigms which are both equally viable depending on the problem area (Devitt & Robbins, 2012). The authors describe design thinking as well suited for wicked, ill-defined problem areas which require stakeholder understanding, empathy, creativity, and co-creation to bring radical innovations to market or application context (Devitt & Robbins, 2012). Wicked problems are complex because various stakeholders have different views on what the actual problem is and how a solution could look like; at the same time the problem evolves dynamically and the solution of today might not be the solution of tomorrow (Rittel & Webber, 1973). Borko, Whitcomb, and Liston (2009) recognize teaching and learning with emerging technologies as a wicked problem: *"The rapid growth of digital technologies, coupled with the complexity of classroom life, increases both the potential transformative power and the difficulty of problems associated with incorporating innovative technologies in teaching."* Therefore, we deemed design thinking an appropriate research paradigm for our study. To address the concerns about a lack of rigor in design evaluation, we combined design thinking workshops with focus groups as an established method for design evaluation and refinement (Tremblay, Hevner, & Berndt, 2010). In recent literature, further examples of studies that applied design thinking in design-oriented research can be found (e.g., Fromm, Mirbabaie, & Stieglitz, 2019; Grobler & De Villiers, 2017; Przybilla, Klinker, Wiesche, & Krcmar, 2018). Various phase models exist for conducting design thinking workshops, with Fig. 1 illustrating the widespread design thinking process developed by Plattner, Meinel, and Weinberg (2009).

To move from a problem to a solution space, the design thinking process includes six interrelated steps: understand, observe, define, ideate, prototype, and test. The *understand step* involves creating a common understanding of the design challenge. The *observe step* involves empathizing with users and understanding their needs and problems in their everyday environment based on surveys, interviews or observations. The *define step* involves consolidating the collected information to one main design objective with the help of methods such as point-of-view-statements or developing personas. A persona represents the target person whose problems will be solved. The *ideate step* involves generating and selecting suitable solution ideas based on methods such as brainstorming. The *prototype step* includes making the solution ideas tangible and experienceable based on low fidelity prototypes, role plays, or storytelling. Finally, the *test step* involves evaluating the prototypes with the target group to receive feedback with the help of interviews and refine the prototype.

3.1.1. Participants

The goal of the workshops was to identify the learning challenges perceived by students, assess their needs, and to develop innovative VR solutions fostering experiential learning processes. Hence, we conducted three design thinking workshops with interdisciplinary teams of lecturers and students from various fields. The participants were recruited by personal request of the authors. Table 1 gives an overview of the workshop participants. We took care to recruit participants from different disciplines for the workshops. An interest in technology-supported learning was communicated as a requirement for participation, whereas prior knowledge or experience with VR technologies was not required. All three workshops were moderated by a professionally trained design thinking coach.

3.1.2. Workshop procedure

All participants had the opportunity to familiarize themselves with the VR technology (i.e., HTC Vive) prior to the workshop. They were

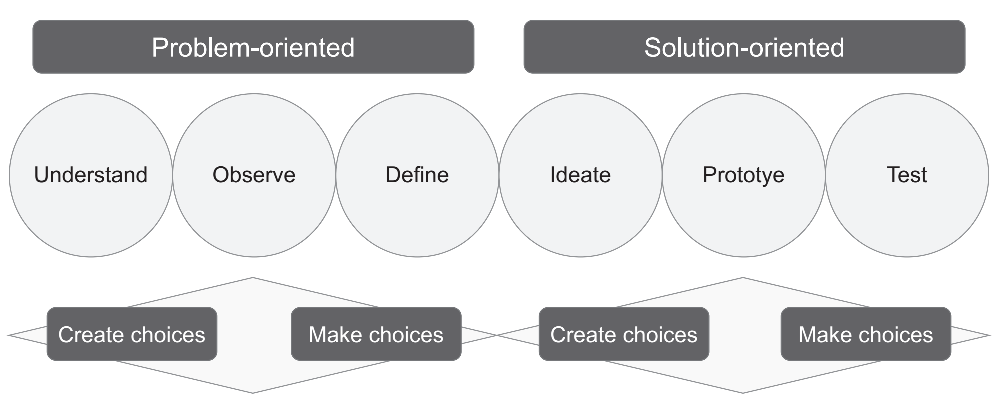

Fig. 1. Design thinking process. Adapted from Plattner et al. (2009).

Table 1
Design thinking workshop participants.

Workshop	Gender	Role	Department/study program
1	Female	Lecturer	Architecture
1	Female	Lecturer	Information systems
1	Female	Lecturer	Media science
1	Female	Lecturer	Architecture
1	Female	Lecturer	Information and communication technologies
1	Male	Lecturer	Business administration
1	Male	Lecturer	Information systems
1	Female	Student	Information systems
1	Male	Student	Business administration
1	Male	Student	Business administration
2	Female	Lecturer	E-learning
2	Female	Lecturer	Mathematics
2	Male	Lecturer	Information systems
2	Male	Lecturer	Mathematics
2	Male	Lecturer	Information systems
2	Female	Student	Media science
2	Female	Student	Media science
2	Male	Student	Media science
3	Female	Lecturer	Information systems
3	Female	Lecturer	Education science
3	Female	Lecturer	Information and communication technologies
3	Female	Lecturer	Media science
3	Male	Lecturer	Information systems
3	Male	Lecturer	Information systems
3	Male	Lecturer	Information systems
3	Female	Student	Information systems
3	Male	Student	Information systems

able to try out various VR applications (e.g., The Lab, Google Blocks). The design thinking coach explained all central elements (i.e., mindset, process, and methods) and afterward he presented the design challenge, which was developed in advance by the authors in collaboration with the design thinking coach (i.e., *How can VR technologies support an experiential learning process for students in higher education?*).

The workshop participants followed the six-step design thinking process of Plattner et al. (2009). In the *understand step*, the participants derived a common group understanding of the challenge by discussing the design question. In the *observe step*, the participants created an interview guide and interviewed students in their everyday settings around the university campus (e.g., library, cafeteria). The interviews concentrated on the students' current learning habits, tools used, perceived learning challenges, and their ideas about learning in the future. In the *define step*, the participants presented these insights to their team members and grouped all insights into meaningful clusters. One participant presented the results of an interview, while the other participants listened and used sticky notes to note the key findings on each person interviewed. These were then placed on a whiteboard and sorted into the predefined categories goals, activities/tasks, pain points, observations and artifacts/tools. Based on these categories the participants created a persona. The personas were fictitious students including name, age, study program, hobbies, interests, learning goals, habits, problems, and needs.

In the *ideate step*, the participants took part in a rapid brainstorming session. For example, the participants wrote down ideas for suitable hardware, specific software functionalities, and the interface design of a VR solution for the students' problems. The participants presented their ideas to each other and clustered their solution ideas. The participants then selected a "safe bet", "most meaningful" and "longshot" idea. A safe bet idea is a less original and at the same time technologically feasible idea, while a longshot idea is very original, but may only be technologically feasible in the future. The implementation of a most meaningful idea, on the other hand, would make the biggest difference for the target group. When selecting the most meaningful idea, participants were asked not to consider the technological feasibility of the idea in their evaluation. After the voting process, the participants selected their most meaningful idea for a prototype implementation. In the *prototype step*, the participants were able to choose their favorite method to make their selected solution idea tangible. The participants prepared a role play, a storyboard made of writable scene boards or a tangible prototype made of handicraft materials (e.g., cardboard and aluminum foil). At the end of the workshop, the participants presented their prototypes and it was discussed to what extent the presented idea was suitable to solve the identified problems of the students and could support an experiential learning process. Especially the student participants as part of the target group gave valuable feedback.

3.1.3. Documentation of workshop results

The design thinking coach informed the participants about the documentation of the results and obtained their oral consent. The participants were encouraged to write their thoughts down continuously and arrange them on their flip charts. The co-authors followed the groups as passive observers and took notes and photos of the flip charts to document the results of each process step (Darsø, 2001). The presentation and discussion of the prototypes were video recorded and transcribed following the rules of Kuckartz (2012). Afterward, one author created a description of the developed personas, point of view statements and prototypes based on the transcripts, photos, and notes. Upon request, at least one participant from each design thinking workshop agreed to review the descriptions. The descriptions were then supplemented with the comments of the participants. This ensured that the descriptions in the results section actually reflected the thoughts of the workshop participants.

3.2. Focus group discussions

After the design thinking workshops, we conducted three student focus group discussions. A focus group is defined as a moderated discussion among a group of people who discuss a topic under the direction of a facilitator whose role is to promote interaction and keep the discussion on the topic of interest (Stewart, Shamdasani, & Rook, 2007). The aim of the focus group discussions was twofold: 1. evaluation and 2. refinement of the developed prototypes. The focus group method has its origin in social research, however, Tremblay et al. (2010) proposed focus groups as a valid method for artifact evaluation and refinement in design research. Meanwhile, focus groups are commonly used in design research (e.g., Gibson & Arnott, 2007; Lins, Schneider, Szefer, Ibraheem, & Sunyaev, 2019; Niemöller, Metzger, & Thomas, 2017).

3.3. Participants

In each of the three workshops, the participants developed ideas for VR applications that were aimed at students of different study programs depending on the students they interviewed during the workshops. The prototype developed in the first workshop addressed the needs of business administration students, while the participants of the second workshop focused on the needs of media science students, and the participants of the third workshop developed a VR solution for students in the field of education science. In the composition of the focus groups, care was taken to select students from these respective study programs. In addition, we invited media science students to include some participants with VR experience in each group. Table 2 gives an overview of the focus group participants.

3.3.1. Focus group procedure

Before conducting the focus groups, we developed a facilitator guide to set the agenda for the focus group discussions. The facilitator guide was structured following the guidelines from Krueger (2014). The focus group discussion took place in a meeting room that was equipped with a large round table, a whiteboard, and recording equipment. During the focus groups, the facilitator guided the participants and encouraged everyone to participate in the discussion while being open, honest, and respectful to each other. To provide a basis for discussion, the facilitator

Table 2
Focus group participants.

Group	Age	Gender	Study program	VR experience
A	19	Female	BA media science	Participated in VR studies
A	18	Female	BA business administration	*None*
A	22	Female	BA Business administration	Watched VR Let's Play videos
A	20	Female	BA media science	Played VR games
B	19	Male	BA media science	Owns VR headset; Played VR games
B	22	Female	BA media science	Participated in VR studies
B	18	Female	BA media science	Played VR games; watched VR Let's Play videos
B	27	Male	MA media science	Participated in VR studies; visited a holo café; Owns mobile VR headset
B	28	Female	MA media science	Participated in VR studies
B	20	Female	BA media science	Participated in VR studies
C	25	Female	MA media science	Played a VR game once
C	26	Female	MA media science	Participated in VR studies; tried out VR at a trade fair
C	19	Male	BA education science	*None*
C	20	Female	BA education science	*None*
C	22	Female	BA education science	*None*
C	24	Female	BA media science	Participated in VR studies; developed a VR app in a university course
C	21	Female	BA media science	Participated in VR studies; developed a VR app in a university course

presented one persona and prototype developed in the workshops using the descriptions that were created based on the workshop documentation. Another author served as assistant to observe the discussion and take notes. The discussions were audio recorded with the consent of the participants and the recordings were transcribed according to the rules of Kuckartz (2012). On average, the focus group discussions lasted two hours. Table 3 outlines the structure and content of the focus group discussions as described in the facilitator guide.

3.3.2. Analysis of workshop and focus group results

In our analysis, we included the prototype descriptions resulting from the workshops and the transcripts from the focus group discussions. To analyze the text material, we conducted a qualitative content analysis applying the method of deductive category assignment (Mayring, 2014). In the following, we explain how we implemented each step of the deductive category formation. *Definition of research question and theoretical background:* We formulated a clear research question (see Section 1) and described our theoretical background of experiential learning and affordance theory (see Section 2). *Definition of the category system:* From our research question, we defined two main categories before the coding process (i.e., VR design elements, experiential learning affordances). Based on a recent systematic literature review about VR in higher education (Radianti et al., 2020), we defined fourteen sub categories of VR design elements (i.e., realistic surroundings, passive observation, moving around, basic interaction with objects, assembling objects, interaction with other users, role management, screen sharing, user-generated content, instructions, feedback, knowledge test, virtual rewards, and making meaningful choices). Informed by experiential learning theory and affordance theory, we defined four sub categories of experiential learning affordances (i.e., concrete experience affordance, reflective observation affordance, abstract conceptualization affordances, active experimentation affordance). *Definition of the coding guideline:* We created a table with the four columns category label, category definition, anchor example, and coding rule as a coding guideline (see Table 9 and Table 10 in the Appendix). Before the coding process, we

Table 3
Focus group procedure.

Structure	Content of the focus group discussion	Duration
Introductory stage	The facilitator greeted the participants, provided them with a nameplate and presented the purpose of the focus groups. The facilitator informed the participants about the focus group procedure and their rights as participants. The participants filled out a short questionnaire to collect sociodemographic data and signed the declaration of consent. The participants were asked to introduce themselves and tell the others about their study program, VR experience, and motivation to take part in the focus group.	25 mins
Transition stage	The facilitator presented one of the personas developed in the workshops and asked the participants how much they can identify with the persona and what differences they see between themselves and the persona. The participants discussed their learning habits, challenges and needs compared to the presented persona.	10 mins
In-depth investigation (part 1)	The facilitator presented one of the prototype developed in the workshops and asked the participants to discuss the usefulness of the prototype: What is your first impression of the prototype? How could the prototype help you to learn? How useful do you find the application? What do you like about the prototype? What do you not like about the prototype? What would keep you from using the prototype?	30 mins
In-depth investigation (part 2)	The facilitator asked the participants to discuss how they would extend or change the prototype to support an experiential learning process. While refining the prototype the participants should think about questions such as: What could the virtual environment look like? What could the technology enable you to do? What action potentials does your technology offer? How does the technology help you with your learning activities? How does the technology help you with your learning activities? The participants presented their refined prototype.	50 mins
Closure	The facilitator summarized the most important aspects of the discussion and asked the participants if they have any further questions or ideas.	5 mins

filled in the category labels and category definitions derived from previous research and our theoretical background. *Preliminary coding:* Three authors started to code the material independently from each other. When the authors found a text passage fulfilling a category definition, the category label was assigned to this text passage. During this trial run-through, the authors also added text passages as anchor examples and coding rules to the coding guideline. *Revision of the categories and coding guideline:* After the trial run-through was completed, the authors discussed their discrepancies until they reached agreement and revised the coding guideline. They decided to adjust the category labels of some VR design elements to distinguish more clearly between design elements and affordances as action potentials (1. moving around was changed to character movement and 2. making meaningful choices was changed to realistic scenario). Furthermore, the coders did not found an anchor example for every VR design element proposed by Radianti et al. (2020). It was therefore decided to remove these sub categories from the coding guideline. However, we also added a new design element labeled interaction with intelligent agents to the original framework of Radianti et al. (2020). In previous literature, an agent has been defined as *"a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives"* (Wooldridge, 2009). To be intelligent, an agent further has to be reactive, proactive and social (Wooldridge, 2009). We define the VR design element interaction with intelligent agents as follows: *Students can interact with intelligent agents that have a visual representation. The intelligent agents are able to process the speech and body language of the students, analyze how well they perform a certain skill and show a realistic reaction. For example, if a student practices presentation skills in front of an intelligent agent, the agent reacts with changing facial expressions based on the student's performance (*e.g. *bored* vs. *excited expression)*. Furthermore, we revised the coding rules of the experiential learning affordances, in particular, to distinguish more clearly between the reflective observation and abstract conceptualization categories. The final coding guideline can be found in the Appendix. *Final working through the material:* The three authors conducted a second round of coding with the revised coding guidelines and resolved their few remaining discrepancies through a discussion at the end. *Analysis:* We used the Code-Relations-Browser in MAXQDA to analyze which categories were assigned to text passages in close vicinity. This allowed us to create a systematic mapping of VR design elements that were associated with specific experiential learning affordances (see Table 8 in Section 6).

4. Workshop results

4.1. Personas and student needs

The workshops resulted in three personas that represent common characteristics of the interviewed students and served as a basis for the user-centered design process. For example, some students spent a lot of time at university to visit lectures and meet with learning groups (*Giselle*). Other students worked a few hours per week but still prioritized their studies and visited most lectures (*Marcel*). A few students were working part-time and wanted to complete their studies soon, so that they could start working full-time (*Pascal*). Furthermore, students differed in their preference for individual learning (*Pascal*) and group learning (*Marcel, Giselle*). For individual learners, it was difficult to stay focused because they were often distracted by their phones (*Pascal*). Many students with a preference for group learning needed time to reflect on learning content and wished for opportunities to discuss with other students (*Marcel, Giselle*). Furthermore, they often did not feel prepared for their future career and were bored with lectures that require them to memorize a lot of facts (*Marcel, Giselle*). Instead, they wished for practice-oriented content and opportunities to experience real-life situations (*Marcel, Giselle*). In summary, students demanded space for conversational learning, acting, and reflecting as it is suggested by experiential learning theory. Table 4 provides an overview about the developed personas.

4.2. VR prototypes and experiential learning affordances

Based on the personas, the workshop participants developed three prototypical ideas for VR applications that afford experiential learning. The prototypes were presented in the form of a roleplay and address the needs of the business administration student Pascal, the media science student Marcel, and the education science student Giselle. Tables 5, 6 and 7 (following on pages 7 to 8 along with an explanation) summarize each prototype's design elements and their experiential learning affordances.

VR Business Pitch (Table 5) enables Pascal to practice a business pitch in a safe environment in front of a virtual manager. When Pascal starts the application, he is welcomed by a virtual instructor. Pascal is teleported into a virtual meeting room and has the possibility to present slides he has prepared in advance. An intelligent agent dressed like a manager listens and provides live feedback through simulated facial expressions (e.g., bored or excited). Based on his performance, the virtual instructor provides Pascal with feedback on his performance and recommends a video from an integrated media library that helps him to improve individual weaknesses.

VR Tweet Emergency Team (Table 6) illustrates how a VR case study can supplement a theoretical lecture about social media analytics. Together with other students, Marcel experiences a realistic emergency scenario and must decide where emergency forces should be sent on the basis of tweets. The VR application allows to access additional information about tweets. The students are also able to perform a 3D network analysis, which allows to visualize the tweet authors' position in the network. Altogether, this information allows conclusions about the relevance of the content and the author's credibility which helps to decide whether emergency forces should be sent. The VR case study enables Marcel to gain a better understanding of social media analytics in a practice-oriented way. Working with other students on a realistic case prepares Marcel for a potential career. For him, learning in an immersive environment is also a welcome alternative to memorizing the contents of lecture slides.

VR Classroom Simulator (Table 7) allows Giselle to experience realistic teaching scenarios that enable her to prepare for difficult situations in the classroom. The application offers a large database of realistic scenarios created by recording 360° videos of thousands of real lessons. When starting the application, Giselle receives a scenario suggested by an intelligent agent and can observe the real course of a lesson from the teacher's point of view. Critical situations are recognized by the intelligent agent and Giselle is asked how she would react (e.g., if a student insulted another student). The intelligent agent provides multiple choice options, evaluates the answer and selects a suitable 360° video from the database to continue the scenario. Thus, Giselle influences the outcome of the scenario and becomes aware of the consequences of her decisions in the real classroom. After she completed a scenario, Giselle can enter a VR meeting room to reflect on her experience and discuss her performance with other students.

Table 4
Overview about personas.

	1st Persona Pascal	2nd Persona Marcel	3rd Persona Giselle
Age	21 years	23 years	24 years
Study program	Business administration	Media science	Education science
Job	Consultant (part-time)	Research assistant (six hours/week)	None
Location	Lives and works in the same city, commutes to university	Lives, studies, and works in the same city	Lives and studies abroad (international exchange student)
Learning habits	Summarizes contents of lecture slides, studies on the train	Enjoys learning in groups, likes to discuss content with other students	Enjoys learning in groups, likes to discuss content with other students
Learning challenges	Often distracted by his mobile phone, not much time for his studies because of his part-time job	Dislikes memorizing the content of lecture slides, quickly forgets facts after exams, feels unprepared for his future job	Cannot stay focused during lectures without interactive sessions, not enough breaks to reflect on learning content during lectures, feels unprepared for her future job
Student needs	Needs a solution to focus on his studies, needs a solution that allows him to study time-efficiently	Needs practice-oriented learning content, needs a collaborative solution	Needs a solution to focus on her studies, Needs practice-oriented learning content, Needs a collaborative solution, Needs breaks and short learning sessions

Table 5
VR business pitch: design elements and experiential learning affordances.

Learning mode	Design element	Experiential learning affordance
Concrete experience	Realistic surroundings (virtual meeting room) Interaction with intelligent agents (realistic facial expressions)	Pascal can experience how it feels like to pitch a business idea in front of a decision-maker; Pascal can experience how it feels like to receive unpleasant reactions during a pitch
Reflective observation	Feedback (report from virtual instructor) Interaction with intelligent agents (realistic facial expressions)	Pascal can observe the reactions of the intelligent agent and reflect how convincingly he presents
Abstract conceptualization	Instructions (video recommendations)	Pascal can analyze how he could transform the theoretical explanations from the videos in his presentation practice
Active experimentation	Immediate feedback (report from virtual instructor) Interaction with intelligent agents (realistic facial expressions)	Pascal can try different presentation techniques to change the facial expression from the intelligent agent

Table 6
VR tweet emergency team: design elements and experiential learning affordances.

Learning mode	Design element	Experiential learning affordance
Concrete experience	Realistic surroundings (virtual emergency room) Realistic scenario (different crisis scenarios) Interaction with other users (group decision-making)	Marcel can experience how it feels like to be part of an emergency management team that has to make difficult decisions under time pressure; Marcel can experience how the consequences of his decisions feel like
Reflective observation	Realistic scenario (different endings based on decision)	Marcel can observe how the scenario unfolds based on the team decision and reflect about their analysis approach and decision-making performance
Abstract conceptualization	–	–
Active experimentation	Realistic scenario (different crisis scenarios) Basic interaction with objects (interaction with tweets and social network)	Marcel can try different social media analysis techniques and see how this changes the outcome of the scenario

Table 7
VR classroom simulator: design elements and experiential learning affordances.

Learning mode	Design element	Experiential learning affordance
Concrete experience	Realistic surroundings (virtual classroom) Realistic scenario (different teaching situations) Interaction with intelligent agents (presents multiple choice options, continues scenario)	Giselle can experience how it feels like to react to difficult teaching situations Giselle can experience how the consequences of her decisions feel like
Reflective observation	Interaction with other users (discussion with other students)	Giselle can discuss her feelings during the experience with other students and reflect about her emotional response during the scenario
Abstract conceptualization	Interaction with other users (discussion with other students)	Giselle can discuss her reactions to difficult teaching situations with other students to develop theoretical ideas on how she could improve her teaching style
Active experimentation	Realistic scenario (different teaching situations) Interaction with intelligent agents (presents multiple choice options, continues scenario)	Giselle can try different multiple choice options to see how this changes the outcome of the scenario

5. Focus group results

5.1. VR business pitch

Overall, most participants of focus group A evaluated VR Business Pitch as useful because *"the application would allow to practice presentation skills before they have to be applied in a serious situation"* (A5).[1] A student emphasized that the application would be helpful because students are required to give presentations in class although *"presentation skills are something you do not get taught at university"* (A2). Another student imagined that it would be helpful for nervous students because *"you just feel more secure when you have done something like this business pitch before"* (A7). Two participants perceived that presentation situations occur rarely in the business administration program which is why they would not use the application often (A1, A3). One of these students explained that the application would provide more value if it could also be used to memorize learning content for the exams (A3). Two other students liked the idea of VR Business Pitch but imagined that the direct feedback via the virtual manager's facial expressions would overwhelm them (A1, A6). Related to this, one student explained that it would be stressful if *"the virtual manager looks mad, but I do not know what I did wrong"* (A6).

The participants of focus group A improved the prototype so that it addresses Pascal's needs better and suggested that the application should allow him to upload and present lecture slides. Instead of summarizing lecture contents in a written form, he could summarize the lecture slides during his presentation. An intelligent agent in the audience could be connected to the Internet and automatically fact-check his presentation. This way, the application would not only allow him to improve presentation skills for the special occasion of a business pitch but also to learn for exams. To further increase the number of useful applications, the participants suggested to implement different types of presentation scenarios (e.g., job interview, presentation in class, small audience, large audience). One student also suggested to replace the intelligent agent with a real audience to increase the realism of the experience (A3). She imagined that other students could join the presentation session, ask questions, and give feedback at the end of the session. However, this suggestion was heavily discussed because for the other students the possibility to practice in a safe environment without a real audience would be the actual benefit of the proposed application.

[1] In the following, we refer with *Ab* to Table 2, p. 6, whereas $A \in$ {A,B,C} is the group and *b* is the participant number.

One participant explained: *"I would really have to be in an isolated room and be sure that nobody could enter during that time. If I knew that someone could listen or look at me while I was presenting, that would inhibit me enormously"* (A1).

5.2. VR tweet emergency team

VR Tweet Emergency Team was perceived as useful by all students in focus group B. Three students pointed out that the application would help to understand the relevance of their study program because very often they ask themselves in lectures: *"How can I use this theoretical concept in a future job? For which kind of job do I actually need this?"* (B2). They liked that the VR case study showed them a meaningful use case for social media analytics in the real world (B2, B4, B5). One student added that *"it would also be much more exciting than just learning the theory"* (B1). Another student agreed and could also imagine *"that you remember it longer than if you had learned it theoretically. It just stays in your head, because it's something different"* (B6). For one student, the usefulness of the application depended on the possibility to simulate the outcomes of different analysis approaches: *"Because I love learning with 'Okay, that didn't work, let me try something else.' If you could see at the end of the scenario how many people you saved with your analysis, I think that would be very cool"* (B4).

To afford reflective observation, the participants emphasized that the realistic scenario should end with feedback about the team performance and the consequences of their decisions (B2, B4). Furthermore, the participants highlighted the importance of animated and visual instructions explaining each analysis method to afford abstract conceptualization (B3, B4, B6). Otherwise, they focused on improvements to increase Marcel's learning motivation and awareness about his learning progress. The participants suggested virtual rewards (e.g., points, levels) for each successfully completed scenario allowing Marcel to compare himself with other students (B1, B2, B6). Moreover, the focus group participants imagined that Marcel could unlock more advanced analysis methods with each level (B3, B4). The collaborative aspect of the initial prototype raised discussions in the focus group because some participants preferred to practice analysis methods in an individual learning space first before engaging in a more complex group exercise (B3, B6). Therefore, the participants agreed on a distinction between an individual and a group learning space. In the individual learning space, all students could sit at their own workplace in the virtual emergency control room. However, they could raise their hand and other students could decide if they want to walk over and answer the question of their fellow student. If students feel prepared for a group exercise, they could enter the group learning space where all students could manipulate the tweets and social network graph together while discussing their joint decision.

5.3. VR classroom simulator

The participants of focus group C liked that VR Classroom Simulator would allow them to practice different teaching situations *"without the nervous feeling that you are really standing in front of people"* (C4). However, two students emphasized that they would only feel comfortable to practice teaching in VR if they could use the application at home or in a locked room (C3, C4). One participant found the initial prototype extremely useful *"because then you also notice whether the teaching profession is really something for you or not. Learning is one thing and putting it into practice is another thing"* (C2). The other participants agreed and also appreciated that the application would allow them to apply theoretical knowledge in practice. It was perceived as particularly useful that students could see the consequences of their decisions and develop theories on how to improve their teaching (C2). Only one participant was sceptical whether difficult teaching situations could be represented realistically enough in the virtual environment but still liked the idea (C3). All participants agreed that VR Classroom Simulator should not only allow Giselle to practice difficult teaching situations but also to give a complete lesson. This would enable Giselle to improve the declarative knowledge about her teaching subject and her presentation skills as well.

During the group discussion, the students improved the initial prototype's affordance for concrete experience. They suggested to exploit the full potential of VR by increasing the realism of the virtual environment and the interaction with the intelligent agent. For example, Giselle should be able to speak with the intelligent agent instead of having to select multiple choice options (C4). Furthermore, the application should not be based on 360° videos because the students' behavior would be the same every time. Instead, the participants imagined a realistic virtual classroom environment inhabited by intelligent agents whose behavior could be randomized to a certain degree (C1, C3, C4). To feel more like a real teacher, the participants proposed that Giselle should be able to write at a virtual chalkboard (C1, C3, C4). One participant suggested that haptic feedback would allow her to experience consequences from her decisions in a more realistic way (e.g., if an argument escalates and a student throws something at her) (C3). Furthermore, the participants imagined that the application enables her to walk over to individual students for a more private conversation (C2, C4). The focus group participants also thought about how to afford reflective observation for Giselle's fellow education science students. They suggested that other students could join her teaching sessions, learn by observing her behavior and give feedback at the end of the session (C1, C2, C4). For three participants, it was also important that the intelligent agent provides theoretical explanations for wrong decisions to afford the learning mode of abstract conceptualization (C1, C2, C4). Furthermore, the focus group participants suggested to implement a score system that enables Giselle to assess her learning performance and motivates her to improve in the next scenario (C1, C2, C4).

6. Discussion

The aim of this research was to examine how students and lecturers imagine the future of VR-based learning and how VR can afford experiential learning processes. We applied a user-centric design thinking approach and conducted three workshops which resulted in three innovative VR prototypes that address the needs of students: 1. VR Business Pitch, 2. VR Emergency Team, and 3. VR Classroom Simulator. Over the course of three focus group discussions, students evaluated the prototypes and refined these in a way that they better address *their needs* and afford all four experiential learning modes. As summarized in Table 8, the analysis of the prototypes resulted in nine VR design elements that are crucial to afford the four experiential learning modes, namely 1. concrete experience, 2. reflective observation, 3. abstract conceptualization, and 4. active experimentation. In the following, we will derive design principles based on our findings and discuss them in light of previous research. For each design principle, we state whether it primarily aims at designers of VR applications for higher education or the educators who use them (which is not mutually exclusive).

6.1. Principle of technical and pedagogical considerations: identify both the unique technical opportunities of VR and pedagogical requirements (designers and educators)

Previous researchers already emphasized that there should be an alignment between student needs, learning habits, learning tasks, learning processes, and technology affordances (Antonenko et al., 2017; Dalgarno & Lee, 2010; Fowler, 2015; Kirschner et al., 2004). Nevertheless, a recent systematic literature review of educational VR applications revealed that the development is often not explicitly grounded in learning theories (Radianti et al., 2020). Especially when it comes to emerging technologies such as VR, we argue that it is important to design with purpose. It might be compelling to ask: *"What can we do with this emerging technology?"* In our view, it is at least equally important to

Table 8
Summary of design elements providing experiential learning affordances.

	Experiential learning affordances			
Design elements	Concrete experience	Reflective observation	Abstract Conceptualization	Active Experimentation
Realistic surroundings	Virtual meeting room, emergency room, or classroom	–	–	–
Passive observation	–	Observing the sessions of other students	–	–
Character movement	Walking over to other students	–	–	–
Basic interaction with objects	Interaction with chalkboard, tweets, and social network	–	–	Interaction with tweets and social network
Interaction with other users	Group tasks; presenting in front of other students; voice chat	Feedback from other students; voice chat	Discussion with other students; voice chat	–
Interaction with intelligent agents	Realistic facial expressions; scenario manager; randomized behavior; voice input	Realistic facial expressions	Theoretical explanations for wrong decisions	Realistic facial expressions; scenario manager; randomized behavior; voice input
Instructions	–	–	Videos; animated explanations	–
Feedback	–	Feedback report; realistic facial expressions; feedback from other students	–	Feedback report; realistic facial expressions; feedback from other students
Realistic scenario	Different crisis, teaching, or presentation scenarios	Different endings based on performance	–	Different crisis, teaching, or presentation scenarios

ask: *What kind of learning outcome should be achieved and what is the most effective learning process to achieve this outcome?"* It then makes sense to evaluate whether the unique opportunities of VR enable this learning process in a better way than alternative delivery methods. In our study, we applied this design principle and identified VR design elements that could be implemented to afford a holistic experiential learning process. In the following, we will derive more specific design principles from our findings that address how the unique opportunities of VR can provide an added value for experiential learning.

6.2. Principle of knowledge contextualization: enable students to apply theoretical knowledge in realistic job scenarios (designers)

The design thinking workshops and focus groups revealed that students do not feel well prepared for their future job. Students reported that they often miss the connection between theoretical knowledge, particularly those they have to learn by heart, and the application of this knowledge in practice. This aligns with San Chee (2001) who argued that students often *"know about"* phenomena from textbooks but lack an *"understanding"* of how to apply their knowledge in practice. He advocated the use of VR for learning through direct experience and saw a lot of potential in simulation-based applications (San Chee, 2001). Other researchers also highlighted the contextualization of learning processes as a unique strength of VR (Aiello et al., 2012; Dalgarno & Lee, 2010). Although we conducted design thinking workshops with students and lecturers of different study programs, the three developed prototypes have one thing in common: They allow students to experience difficult situations in their future job (concrete experience) and experiment how to deal with them in the best possible way (active experimentation). The developed prototypes can be described as job simulators and aim to improve practical-procedural skills, analytical thinking, and collaboration skills. They thereby also bring together theory and practical application closer in time, which could bolster the learning success. A previous literature review of VR applications in higher education revealed that most applications prioritize procedural-practical skills over declarative knowledge (Radianti et al., 2020), but most apps discussed in the literature are still in the research stage. Therefore, most of them are not yet available in VR app stores. In contrast, a recent study on VR app markets found that the majority of accessible apps on the market aim to improve declarative knowledge rather than procedural-practical skills (Radianti, Majchrzak, Fromm, Stieglitz, & Vom Brocke, 2021). This highlights a gap between student needs, research and available VR apps on the market. Further research should uncover best practices on how to implement the VR-based application of theory to real-world problems.

6.3. Principle of realism and interactivity: provide a realistic and interactive virtual environment to afford concrete experience and active experimentation (designers)

To afford concrete experience and active experimentation, the participants suggested realistic surroundings and interactive scenarios as key design elements. This finding aligns with Radianti et al. (2020) who identified realistic surroundings and basic interaction with objects as most frequently used design elements in VR applications for higher education. Likewise, Chavez and Bayona (2018) identified interactive capability and immersion interfaces as the most important characteristics of VR in education. Kwon (2019) proposed that enhanced vividness and interactivity in virtual environments improve the learning effectiveness as students perceive the learning experience as closer to reality. In our study, we identified three aspects that contribute to a realistic experience: 1. appearance, 2. interactivity, and 3. behavior. The participants preferred a highly realistic appearance of avatars including gestures and facial expressions although they anticipated current technical limitations. With regard to the environment, realism rather meant that the environment should be clearly recognizable as such. For example, a virtual classroom environment should include a chalkboard and books because these objects make a classroom what it is. This aligns with Bricken (1990) who argued that our flexible minds allow us to interpret the simplest cartoon worlds. However, virtual objects should not only serve as decoration, but students would like to interact with them in expectable ways, aligning for example with real-world physics (such as, a student should be able to write with a chalk object). The participants perceived interactive objects as central to increase the realism of the experience but also to offer various opportunities for active experimentation in the virtual environment. For example, one prototype included a virtual phone that students could use to make their final decision in the scenario (increased realism). The participants suggested other objects such as an interactive social network graph to enable students to try different analysis approaches (active experimentation). Another aspect of realism that received less attention in previous research represents the behavior of non-human actors in VR applications. For example, Li et al. (2019) developed an educational VR application for children with autism spectrum disorders allowing them to play through interactive social stories and respond in socially appropriate ways by tapping rating buttons. Instead of multiple-choice options or sequential scripted interactions, the participants in our study imagined intelligent agents who are able to process speech of students and react in appropriate ways. These considerations not only put much focus on the work of the designers, but they also imply that increased VR usage in education would benefit from comprehensive frameworks that aid in the generation of apps.

6.4. Principle of integration: cycle between concrete experience and active experimentation activities in VR and reflective observation and abstract conceptualization activities in class (designers and educators)

In the design thinking workshops, the participants focused on developing affordances for concrete experience and active experimentation. In the focus group discussions, the participants tried to refine the prototypes in a way that they also afford reflective observation and abstract conceptualization. However, they had difficulties to imagine design elements that truly exploit the unique strengths of VR. For example, they suggested to afford abstract conceptualization by implementing pop-up windows with textual explanations. It might be possible to implement these in VR but they do not necessarily provide an added value. This aligns with Bell and Fogler (1997) who pointed out that "it would be a huge waste for VR to duplicate what students can learn from other media". In addition, Petersen et al. (2020) found that providing learning material before an educational VR experience improves knowledge transfer and reduces cognitive load. In the focus groups, some students expressed that they would not use the prototypes often because they might not be well suited to learn the declarative knowledge required for exams. Instead, the participants imagined using VR *in addition* to their lectures to better understand how their future job could look like and how their theoretical knowledge might become relevant in their future work life. This supports the findings of Jarmon et al. (2009) who found that students engage in concrete experience and active experimentation in Second Life while reflective observation and abstract conceptualization rather took place outside of the virtual environment. Particularly for educators this principle implies *"thinking out of the box"* instead of expecting that merely virtualizing existing content would provide added value.

6.5. Principle of psychological comfort: provide students with the opportunity to practice skills in private spaces before allowing other students to join their learning space (designers and educators)

Previous studies typically address motion sickness as a physical discomfort factor when using VR (Shin, 2017). However, our study draws attention to a psychological comfort factor that is related to the extent in which VR offers a safe and protected space for learning. This includes a private space in the real world but also an individual learning space in the virtual environment which enables learning with intelligent agents instead of real students. In the focus group discussions, many students expressed that they would feel uncomfortable to wear a VR headset in public. For example, they were concerned that other students could watch them while they practice presentation skills. As a solution, they suggested providing students with a headset at home or rented access to locked rooms at the university library. If we expect that students immerse in a virtual world, stimuli from out of this world might be perceived as intrusive – in a way like a person who immersed in a thrilling book would be very upset with suddenly being startled. Furthermore, we argue that it is important to consider the learning habits of students. In our study, many students reported that they usually summarize lecture slides and learn them by heart before they engage in learning groups to gain a deeper understanding of the content. As a result, the focus group participants heavily discussed whether they want to incorporate a peer assessment approach into the prototypes. Previous studies already incorporated a peer assessment approach into educational VR applications and found a positive effect on learning effectiveness, perceived self-efficacy, and critical thinking (Chang et al., 2020). Although the peer assessment approach might be effective, most participants in our study preferred learning with an intelligent agent first before allowing other students to evaluate their performance. As a result, many participants suggested offering students the possibility to switch between an individual and a group learning mode. This principle challenges designers and educators alike in providing non-linear, multiple options learning.

6.6. Principle of Gamification: embrace the gaming character of VR to increase learning motivation (designers)

Most participants associated VR with gaming and suggested the implementation of typical rewarding game elements (e.g., scores, levels, achievements). The participants did not associate these game elements with experiential learning affordances. However, they argued that game elements would make learning more fun and motivate them to use the application. In a previous study, Su and Cheng (2019) found that a gamified experiential learning approach also resulted in better learning outcomes. Likewise, Dalgarno and Lee (2010) highlighted the potential of 3D virtual learning environments to increase intrinsic motivation and engagement (Dalgarno & Lee, 2010). Therefore, we recommend designers to embrace the gaming character of VR also in serious contexts.

7. Conclusion

The goal of our research was to examine the potential of VR technology to afford a holistic experiential learning cycle. We approached this goal from a user-centered perspective, and thus conducted three design thinking workshops with interdisciplinary teams of students and lecturers. The workshops revealed that students demand a shift from traditional lectures to learning spaces that foster experiential learning. Together, students and lecturers developed three innovative VR prototypes to address real student needs and support an experiential learning process. These prototypes were evaluated and refined in three focus groups with students. Based on a qualitative analysis, we created a systematic mapping of VR design elements and experiential learning affordances. Thereby, we contribute a deeper understanding of how educational VR applications could be designed to afford each experiential learning mode: 1. concrete experience, 2. reflective observation, 3. abstract conceptualization, and 4. active experimentation. Furthermore, we extended the analysis framework for the identification of educational VR design elements by Radianti et al. (2020). We added the design element interaction with intelligent agents proposing that the combination of VR and artificial intelligence offers unique opportunities to afford a holistic experiential learning cycle.

These findings are also of significance for the scholarship of Internet-enabled higher education teaching and learning. Usually, experiential learning activities in higher education include real-world experiences such as field trips. Internet-based VR applications enable the transfer of such experiences into online courses. The Internet is of particular importance when collaborative activities are a fundamental part of the experience - as exemplified by the "VR Emergency Response Team" prototype. Furthermore, the Internet is relevant for the realistic implementation of intelligent agents as part of VR-based experiential learning applications. As suggested by the participants, intelligent agents could retrieve information from the Internet to verify the accuracy of student responses in experiential learning applications (as proposed, for example, in the "VR Business Pitch" prototype). Intelligent agents could also communicate with each other via the Internet to simulate social behavior in learning scenarios (e.g., realistic student behavior as in the "VR Classroom Simulator" prototype). Our results thus point to relevant areas for future research on Internet-enabled experiential learning in higher education.

Our research has some limitations, which need to be mentioned – and which are the foundation for future research. The workshop and focus group participants were *subject matter experts* but not necessarily *technology experts*. Therefore, their suggestions for educational VR applications might not reflect the technological possibilities and limitations in their entirety. However, we think that a lack of technological feasibility at the present time should not restrict our thinking about innovations in higher education but rather reveals new fields for future research (e.g., the design of intelligent agents in educational VR applications). Nevertheless, future research could integrate technology experts in user-centered design processes as they might have further ideas on how to exploit the unique possibilities of VR for experiential learning. Furthermore, we created the mapping of design elements and experiential learning affordances based on the participants' discussion of the developed low-fidelity prototypes. Future research could implement the proposed VR applications and evaluate in real courses to what extent these afford each experiential learning mode and their impact on learning outcomes. Furthermore, the development of flipped classroom concepts that integrate VR experiences at meaningful times in the curriculum could provide an added value.

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Appendix A. Appendix

The appendix compiles the coding guides for VR design elements (Table 9) and experiential learning affordances (Table 10).

Table 9
Coding guide for VR design elements.

Category label	Category definition	Anchor example	Coding Rule
Realistic surroundings	Students can learn in a virtual environment that looks as realistic as possible. This design element covers high-quality graphics, realistic avatars, and representational fidelity. The latter aspect means that the virtual environment should be clearly recognizable, for example, a virtual classroom should have chairs, tables, and a chalkboard.	"I wouldn't do that with cartoonish avatars, because it's no problem anymore to *make them look realistic* with deep fakes" (C3).	Applies when participants talk about the visual appearance of the virtual environment or other users.
Passive observation	Students can look around in the virtual environment but they have no interaction possibilities. For example, when students can join sessions and learn by observing other students.	"I think it's a good approach to have a *fixed position* and not 10,000 other functions that you can do instead" (B1).	Applies when students do not have any interaction possibilities.
Character movement	Students can move around in the virtual environment. For example, students can walk over to other students, teleport through the room, or switch to a multiplayer room by interacting with a door.	"I would find it really cool if you just click on a door where you can visualize that you are *changing rooms*" (B6).	Applies when students can change their position in the virtual environment.
Basic interaction with objects	Students can select, pick up, or manipulate virtual objects using their controllers or hand gestures. For example, students can select a door to switch rooms, pick up a phone to log in a decision, or write on a chalkboard to take notes.	"Maybe you can visualize which vehicles you send where. Kind of like if you had to *place little cars on a little map*. Or you *pick up a phone* and you say 'Send all emergency services there and there'" (B6).	Applies when students use their hands or controllers to do something with a virtual object. Does not apply when students use their voice to interact with other students, characters, or intelligent agents.
Interaction with other users	Students can talk to each other via chat or microphone. The design element also covers interaction with other students as part of group work or multiplayer scenarios.	"I think it would be cooler, if you can *call other people with your headset* and say 'Yes, can you help me?'" (B2).	Applies when students speak or work with other humans. Does not apply when students interact with objects or intelligent agents.
Interaction with intelligent agents	Students can interact with intelligent agents that have a visual representation. The intelligent agents are able to process the speech and body language of the students, analyze how well they perform a certain skill and show a realistic reaction. For example, if a student practices presentation skills in front of an intelligent agent, the agent reacts with changing facial expressions based on the student's performance (e.g. bored vs. excited expression).	"One could also implement an adaptive CEO. The *artificial intelligence* would then know, 'Oh, he seems to be able to present super well, so I'll switch to a bit more strict behavior'" (A2).	Applies when students can speak with an intelligent agent which is defined as follows: *"A computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives"* (Wooldridge, 2009). To be intelligent, an agent further has to be reactive, proactive and social (Wooldridge, 2009).
Instructions	Students can receive instructions on how to use the VR app and explanations regarding the learning content. A non-player character can talk to the students and provide them with instructions. The instructions can also be displayed as written text or videos.	"Maybe you could start with a *tutorial* from a character, who appears and explains what different techniques are available and then you have to apply the different possibilities in the game" (B3).	Applies when students receive explanations on how to do something. Does not apply when students receive feedback on how well they have done something (feedback).
Feedback	Students can receive feedback about their learning performance. Feedback can be provided in textual, visual or auditory form. Students can receive feedback during a learning session or afterward.	"Maybe some *feedback* on the screen? There could be a little avatar next to the screen that says *'well done'*" (B6).	Applies when students receive feedback about how well they have done something. Does not apply when students receive explanation on how to do something (instructions).
Realistic scenario	Students can select different scenarios to practice a specific skill. For example, presentation skills can be trained in a different presentation scenarios such as business pitches, job interviews, or conference talks.	"I also think there could be *different endings*. Especially with things like that, whether or not you saved a lot of people in the end, *based on the decision you made*" (B4).	Applies when participants specified scenes, characters, situations, sequences of events, and in some cases different endings. Does not apply when participants only discussed the visual appearance of the virtual environment or characters.

(*continued on next page*)

Table 9 (*continued*)

Category label	Category definition	Anchor example	Coding Rule
	The ending of the scenario depends on the performance or decisions of the students.		
Virtual rewards	Students can receive virtual rewards for completing learning tasks successfully. For example, they can gain levels, ranks, and scores. They can also be rewarded through unlocking new learning content or scenarios.	"I think the aspect of being able to level up is really cool, even with scores and stuff like that" (B6).	Applies when rewards are tied to the learning performance of students. Does not apply when students automatically unlock new content over time.

Table 10
Coding guide for experiential learning affordances.

Category label	Category definition	Anchor example	Coding rule
Concrete experience affordance	Applies to all text passages where participants described that a certain design element would enable them to experience how their future job would feel like	"I find it useful because it is a situation that is difficult to get into as a student. *Being invited to a pitch* to a CEO is not an everyday *experience*" (A5).	Applies when design elements allow students to experience their future work environment, their future job tasks, and the consequences of their work-related actions. Does not apply when design elements allow students to experiment with different task approaches (active experimentation).
Reflective observation affordance	Applies to all text passages where participants described that a certain design element would enable them to learn by observing others or reflect about their learning performance	"Maybe you could also get *feedback* during the presentation, like 'Watch your arms', so that you *realize that you are not presenting so well*" (A3).	Applies when design elements allow students to assess how well they did a certain learning task. Does not apply when design elements allow students to develop new theories on how they could improve their performance (abstract conceptualization).
Abstract conceptualization affordance	Applies to all text passages where participants described that a certain design element would enable them to develop new theories or approaches on how they could improve their learning performance	"Maybe there should be an *instructional video*, where you go into certain individual aspects. For example, if you have a shaky voice when you speak, there are different exercises. That really helps to *understand how you can improve your weaknesses*" (A4).	Applies when design elements allow students to develop new theories on how they could perform better during a learning task. Does not apply when design elements allow students to assess how well they performed (reflective observation) or try out their new theories in practice (active experimentation).
Active experimentation affordance	Applies to all text passages where participants described that a certain design element would enable them to try out different approaches and learn from the resulting outcome	"If you can test how different analyses lead to *different endings*, that would be cool. If you would let two groups use different approaches and afterwards so and so many lives have been saved. I love learning with *'Okay this didn't work, I'll try something else'*" (B4).	Applies when design elements allow students to try out new approaches in practice. Does not apply when design elements allow students to develop new approaches on how to perform better during a learning task (abstract conceptualization).

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