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Experiences and Future of Using VR in the Construction Sector

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1 ABSTRACT

Living in the era of digitalization shapes more or less all the aspects of one's life. The multitude of available technologies extends the range of tools, established processes, and available affordances in many spheres. Cities of the future will not only impact the living patterns of their inhabitants but also require special conditions and requirements for their planning and design. Virtual reality as an interactive tool for visualization and urban planning is no more tomorrow’s technology, as it can be seen from the appearance of cheaper and portable virtual reality devices. However, we still lack established routine and multidisciplinary best practices for designing VR educational applications. There are also not enough “visionary approaches” attempting to cross-sectoral exploitation of technologies. In this paper we will try to extrapolate and extend learning use cases of construction and mechatronics to the broader areas of construction and planning sector. We will discuss our experiences and use-cases of integrating innovative visualizations tools in the learning context of construction and planning related fields. Based on this, we will discuss potential applications and links to other disciplines and their integration into the construction and planning sector.

Keywords: Digitisation, Digital Reality, Construction, Education, Virtual Reality

2 INTRODUCTION

Virtual reality as a special type of digital reality attracts steady interest from both the general public and scientific community. People have long been drawn to alternative realities (e.g., storytelling), but physically and technically it has become possible to plunge into another world relatively recently. Though the term “Virtual reality” was coined about 30 years ago, the technology itself has not reached its technical peak yet; neither has been it widely accepted by the community and unleashed its full potential.

Challenges arise starting from the definition of the basics. The majority of definitions given to VR are rather descriptive: digitally generated 3D environment (see e.g., KAVANAGH, LUXTON-REILLY, WUENSCHE, & PLIMMER 2017), as the terminology around the technology also still young and being used inconsistently. A common definition being used in urban planning sciences is the one highlighting the essence of VR as a visualization and simulation technique (PORTMAN, NATAPOV, FISHER-GEWIRTZMAN 2015). Sherman & Craig (2018), the authors of one of the most seminal and comprehensive works about virtual reality, gave their definition of VR emphasizing its integral characteristics as an interactive immersive (both mentally and physically) medium of communication providing synthetic sensory stimulation. We would also delineate our understanding of VR in a narrower and broader sense: the former includes completely immersive (and interactive) instances of VR (frequently referred as those being used with a head-mounted display), whereas the latter brings together under its wing all the other forms of VR (as, e.g., less immersive screen-based ones; MAKHKAMOVA, EXNER, GREFF, & WERTH 2020).

Virtual reality research (as any other research) can be outlined as two general approaches: fundamental, focusing on the VR as it is - as the end target of research and on the understanding on how it works, especially which effect it has on living creatures (e.g., cognitive and behavioural changes when being exposed to VR), including usability concerns, sense of presence, technology advancements etc.; or as a tool - as a utilitarian approach of its application to various domains in form of proof of concept (e.g., what are the effects of using VR as a marketing tool).

Some of the virtual reality features have determined a certain interest in it as a learning tool and medium, and because it is believed to be improving the quality of learning. Scenarios of its application to education has a

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very wide range, and vary from surgery skills training (GURUSAMY et al. 2009) to basketball tactics (TSAI et al. 2017), from ecosystem science (DEDE et al. 2017) to robotics and kinematics (FLANDERS & KAVANAGH 2015). Among some of the positive results of using VR for learning, researchers reported learners' enjoyment, increased motivation, and long-term retention. However, some systematic studies showed that the results are less obvious and optimistic (e.g., SITZMANN 2011) indicating that the use of VR is rather favourable in terms of enjoyment than in terms of learning.

E.g., one of the advantages of integrating VR into curriculum is commonly discussed in the literature (e.g., WOLFARTSBERGER 2017) is that it enables reality-like natural interaction with 3-dimensional objects and intuitive in operation. Putting aside the question of how intuitive the typical VR input devices really are, let us focus on VR as a medium that delivers decent 3D-output. That is why VR is being used in such domains as construction and adjacent fields, providing great potential for planning, design, and construction management.

3 VR AND CONSTRUCTION

Virtual reality has been recognized as a promising tool to use in the construction and planning industry. Possible implementation are seen especially in the conceptual phase and also in the light of vizualizations for participation purposes, but also for education and training, as well as for adopting it for just widely connected further purposes. This could include, for example, vehicle and utility communications simulation, urban design and planning, as well as digitization and model making of virtual twin-cities.

Thomson, Horne, and Fleming (2006) provided an overview of using VR for urban modeling. Based on the interests of various stakeholders of urban models (e.g., city authorities) and their motives (e.g., attract more tourists), they presented an extensive list of use cases where VR city modeling can be beneficial. Besides, they discuss some important reasons for the practical adoption of VR modeling and some obstacles when doing so. Particularly interesting is the voiced concern about the ownership of the city model.

Wang et al. (2018) conducted a systematic review of 347/66 journal articles published between 1997 and 2017 on the use of VR in construction engineering education and training (CEET). They found that the most adopted approach to VR systems was Building Information Modeling (BIM)-enabled VR. They point out that the possibility to reflect real-time changes in a model may be the biggest advantage of that, but at the same time also the challenge needs to be overcome due to compatibility and connection issues (also discussed in XIE, SHI, & ISSA 2011).

Portman, Natapov, and Fisher-Gewirtzman (2015) focused on the showcasing VR because of the inaccessibility reason (e.g., yet not existent places) in the context of learning architecture, landscape architecture, and environmental planning. They also raised the question of how realistic visualization should be for these purposes (as always: context matters).

Regarding educational purposes, the most common scenario at first glance seems to be safety training. E.g., Sacks, Perlman & Barak (2013) compared construction site safety training in a traditional classroom settings with visual aids and VR training, and found positive effects of VR over baseline for the courses of stone cladding work and for cast-in-situ concrete work, but not for general site safety training, in terms of recall and attention. Rüppel & Schatz (2011) describe the process of the creation of an environment to practice fire emergency evacuation based on a serious game approach. Discussing the capabilities of BIM for data-driven design, they also propose to increase the realism of simulation in a way that affects the human senses, such as binaural and 5.1 surround sound, olfactory exposure (smell of smoke), and feelings of heat and movement. By doing so, it is expected to make the simulation from only "visually satisfying" to more "real", immerse the users to evoke a greater sense of presence - which, in turn, critical to performance in case of emergency.

Nonetheless, the amount of critical papers addressing VR specifically in application for construction and planning purposes in the urban context, seems not to be great. E.g., a cursory search (as of January 2020) conducted in REALCORP database resulted just in 7 papers total with term "Virtual Reality" in their names. In the following sections we will present 2 use-cases from adjacent areas of construction and mechatronics which results could inspire and provide an impulse for further discussion of VR use for broader urban-scale planning context.

4 USE CASE 1: D-MASTERGUIDE - DEVELOPMENT AND TESTING OF DIGITAL LEARNING STATIONS FOR THE ACQUISITION OF MEDIA COMPETENCE IN THE FINISHING TRADE

The research project D-MasterGuide aims to prepare apprentices of crafting professions for the world of future work, where many processes are digitized. Digital visualization tools will influence the planning and construction process more in the future and hence also non.-research-related branches are using these methodologies more frequent in the project work and especially in the training for ongoing experts. Based on Germany-located vocational training centers of the building and renovation trade, it focuses on the encouragement of the apprentices not only to gain required expert knowledge but also methods expertise, media literacy, and self-competence when working with new digital technologies. In order to achieve that, eight domain-specific digital learning stations (DLSs), based on the essence of processes of plastering trade, were created and integrated into master preparatory course framework, with help of a learning management system. DLSs contain anchored instructions, work orders or exercises in order to augment blended learning lessons with a situated learning experience. Apprentices and trainers switch between digital learning sequences and activities in the workshop to review and discuss their results afterward in meetings. This scenario enables new learning dynamics and competence development of the participants. Moreover, lessons are enriched with virtual reality experiences, video animations of the working area, role-playings, open exercises and a self-organized learning environment. Finally, self- and external assessments are the basis for deeper discussions as well as for an increase of self-reflection.

Technical basis of the approach is the Smart Guided Learning System (SGLS) which combines a learning management system with a process guidance component. The architecture is enhanced by various devices, applications and services providing optimal tools depending on task and place of action. Apprentices and trainers are involved in a participatory development process to give direct feedback and derive improvements for the next implementation stage.

Theoretical basis of the approach is Anchored instructions (AI) representing a situated learning content in the form that “anchors” a problem-solving task into a short story or adventure. Every DLS starts with a narrative describing an authentic problem behind the learning content, which was supposed to familiarize the prospective masters with the content of DLS and motivate them by providing also contextualized essence of their future work (e.g., client consultation, agreeing upon the end result of plasterworks). VR experience pieces of training here were conceived as a special type of AI aimed to provide the utmost “reality-like” grounding. That would allow the apprentices to solve real-world problems actively and independently. The relation of those narratives with further knowledge acquisition helps to apply new knowledge in practise. Assuming the apprentices to be novices to that technology, the experience were designed to tailor lack of experience with peripherals etc.

The VR experience is grounded in the story of a house on-site inspection. The learners make a virtual walkthrough around a house that was filmed with help of a 360° camera. The end goal is to identify scope of further work and plan necessary repairs and finishing. In order to achieve that, the apprentices start by outlining all the problem spots on the exterior of the house. Every correctly identified spot was gamified as an question-answer sequences in order solidify the obtained knowledge and also reduce the chance of false positives answers. Figure 1 gives a glance of the VR user interface and snapshot of its use. This used methodologies enables a transferability in related use cases, such as education of architects or also on the job training for building inspectors.

Fig.1: VR experience of a house inspection

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4.1 Results of evaluation

During continuous evaluation of the approach, we were focused on the user experience and acceptance of the apprentices, as well as their motivation (SCHMIDT et al. in press; SPILSKI et al. 2019). The Proof-of-Concept results indicate that the scenario has a potential of integrating that form of learning into curriculum. The evaluations involving more than 60 prospective masters mostly did not reveal discomfort, motion sickness, low motivation or low acceptance in the target group.

An additional thesis study compared the learning outcomes of on-site house inspection with that one in virtual environment. The apprentices who learned within the VR environment overperformed the control condition in terms of correctly identified problem spots ($d = 1.15$) and correctly answered questions ($d = 0.85$). All in all, the usability of the VR environment can be considered as above average ($M = 72.85$, $SD = 10.79$).

4.2 Implications for practitioners regarding learners acceptance and integration VR into class

It is specifically important to note that the didactic setting depicts specific work processes. To this end, a virtual learning environment was implemented in such a way that it enables action-oriented learning in a vocational training institution, including for planning tasks. This includes, for example, recording the building structure of an existing old building facade and planning the necessary next steps.

So far, we have focused on the learners perspective: However, during our studies we found that the actual gatekeepers for the acceptance and integration it into the practice are the teachers and lecturers. If they do not translate the value of accepting the technological innovations even when using them and propagating their use in the class, the use of the technology and the acceptance of those by their students will be rare. The problem is that teachers often do not get the time resources to develop expertise with these new methods, or has not developed self-competence, i.e., confidence in use and believe that it can be beneficial.

We also noticed during our evaluations that when using VR application instructors seem to feel a break in regular dynamics between instructors and apprentices. The common routine instructing method in the craftsmanship environment is obviously the three-step-method: Demonstrating – Imitating – Exercising. Therefore instructors tend to adopt the same frontal presentation method in a typical classroom setting where they reinforce their subjectively self-experienced learning from their own learning history. This scenario is one that traditional handcraft instructors would intuitively choose. Nevertheless the VR-application under consideration encourages learners to experience the VR-application on their own, individually. This kind of individualized learning results in a massive loss of control at the instructors side on the one hand and with the chance of compensating looking at the learners as unique persons following their specific learning challenges and having the patience to answer their numerous feedbacks in the learning process being on a par with young people on the other hand. Whereas learners obviously enjoy the kind of new experience an educational institution is saving time-consuming excursions by the VR-application as a substitute a comparable learning sequence would exist in the analog world. Presumably repeated use of VR-glasses will lower this existing motivational effect but strengthen the demand of effectiveness of learning. Consequently, the instructors would have the need as in other typical autonomy fostering environments to improve their own 4C-competencies (4C-didactical model) - communication, collaboration, creativity and critical thinking – in order to cope with the unfamiliar accompanying of the learning process. Nevertheless if the VR-interactions at the frontage seem from the professional point of view to be incomplete the building expert would judge it´s not more than a play and could lose his interest. That is why for sustainable implementation in a VET-course realistic and complete work through by the authoring editors for VR environment is necessary in advance enabling in this case VR-interaction to replace traditional visuals-aided way of teaching.

Although the trainers are very experienced in training small groups of about 15-20 apprentices, they focus mainly on improving manual skills. Therefore, mainly facade construction techniques are taught. In contrast, little or no consideration is given to preparatory and follow-up cognitive work processes (e.g., planning).

Furthermore, vocational training institutions are currently still investing predominantly in analogue, "tangible" technologies. Even for relatively small 4-digit amounts, it is often not greatly affordable. However, current funding policy trends could bring about a change in the investment culture.

5 USE CASE 2: INKRAFT – INCLUSION IN VOCATIONAL TRAINING IN THE CONCRETE CASE OF AUTOMOTIVE MECHATRONICS USING VIRTUAL REALITY TECHNOLOGY

In the project InKraFT, a VR application was developed and used for the training of prospective automotive mechatronics engineers. The virtual environment enables students to learn practical skills as a part of the official training course. Prior to integration, the practical activities and sequence of processes and actions were recorded and documented in detail by an experienced mechanic. Then, the sequence of the individual steps was transferred to the VR environment and embedded in an overarching didactic concept. Specifically, that includes processes of dismantling and assembling an engine and a brake system, measuring and testing the cylinders and performing a compression pressure test. First evaluation results show a strongly increased motivation of the users as well as an increased knowledge transfer into practice. A distinguishing feature of the project is the barrier-free design and the development of alternative input methods and assistance systems in order to match special needs the target learning audience has. Thus, the additional focus of the project is inclusion of people with disabilities into vocational learning. Though this tailor-made solution is designed for the automotive context, the theoretical concept could be transferred also to the planning context because an disassemble engine model could be a disassemble architectural model in another context and the shown principles as well as partly the study results could be transferred in another domain.

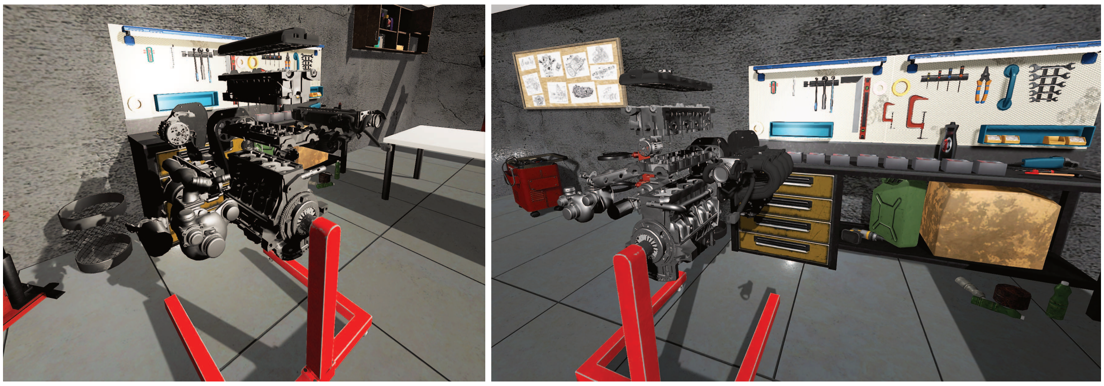

Fig.2: VR experience of an engine dismantling

In addition to the virtual work environment where students can train their practical skills, the VR application is also equipped with a learning room where 360-grad videos with theoretical content can be watched. The videos have been created by other students and provide small learning nuggets on various topics related to the basic course as well as content that builds on this with more advanced topics. The combination of a theoretical, immersive environment and the practical workshop showcases how digital technologies can be used in order to enhance the learning and motivation and at the same time give people with special needs access to the job market, as e.g., as prospective masters with strong diagnostic or teaching orientation.

Fig.3: Use of the VR app and a snapshot of explanatory 360-grad video

5.1 Results of evaluation

A total of 20 subjects (1 female, 19 male) were tested an interim version of the VR environment between March and April 2019. The participants' age ranged between 16 and 56 (M = 29.10; SD = 14.55), with 14 (70%) of participants either working as car mechanics or currently training to become one. Education had a

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similarly broad range with 8 participants not having a certified vocational education yet, 8 participants with a finished vocational education and 4 participants with either a Bachelor or higher university degree. Participants reported no major visual, auditive or physical 5 impairments, 7 wore prescription glasses due to hyperopia or myopia and one participant reported Tinnitus. Therefore, no participant had to be excluded from participation. All twenty subjects volunteered to participate in this study and either received work time compensation for their participation or participated on their own accord as part of a roadshow, where the VR environment was showcased to the public.

In the pre-questionnaire participants reported some experience with VR (M = 2.40, SD = 0.99; on a scale from 1-4) with 5 people reporting no previous experience with VR systems at all and two participants reporting having their own VR headset at home. No participant reported experiencing major feelings of dizziness during or after interacting with the VR environment with one participant feeling "everything was spinning" during their interaction in VR, possibly due to a technical problem, which was resolved quickly. We used an adapted German version of the igroup presence questionnaire (IPQ) where items were changed to be tailored towards our specific VR use case (exemplary item: "How real did the virtual mechanic workshop seem to you?"). As these are preliminary results without a comparison group, participant scores for the IPQ were taken as single factor and a mean was calculated from all 13 items without the use of the standard three factor structure. Participants overall reported a tendency towards a sense of presence (M = 4.14, SD = 0.65; on a scale from 1-6). We added an open space for feedback and comments on the VR environment at the end in which participants particularly noted the realistic engine and that they had fun while doing the task, while some wished more detailed visualisation for the future. One participant with several years of expertise as mechanic noted "A large step into the right direction. Needs more time & refinement" (translated from German by the authors).

5.2 Implications for design of VR

Virtual Reality applications pose a great challenge for developers when concerned barrier-free design as a priority, because the use of the hardware often requires a strong physical effort. Experience has shown that there are no perfect settings that fits everyone, and the most important thing is to offer alternatives that the user can use to individually adapt the 3D application to his needs. Two essential features of every VR environment are movement and interaction. A barrier-free implementation of these features depends also on the question on which target system the software should run on, since the hardware can be very different. The tasks in a virtual learning environment are versatile and often very complex. For this reason, the tasks should be divided into small steps and always be presented in a way that the user can perceive them with at least two of his senses. In InKraFT all sub-steps are read out aloud by the system, so that people with reading disabilities still have a chance to understand the next necessary steps. All text content and audio instructions are implemented in several languages , so that language barriers can also be avoided. If the user completes a partial step, this is confirmed with a positive sound feedback. If he completes a whole task, he receives an achievement to increase the motivation and the perseverance of the learners. The removal and fitting of crucial screws usually also requires some physical effort, which mechanics with more work experience get a "feeling" for (SPILSKI et al., 2019), which might be difficult to replicate in a virtual space. Since our environment was designed as an out-of-the-box solution for usage in the field of vocational education, we did not include specific forms of haptic feedback and will rely on the HTC Controller or Knuckles as available. For possible solutions to this problem, see e.g. the work of Choi and colleagues (2017) as well as Lee and colleagues (2019) for manual manipulation and haptic controllers. In addition to a solid theoretical foundation it is important to get feedback from the population which the environment is designed for.

This approach towards more participatory and compensatory designing processes is crucial to guide action to meet the needs and preferences of various groups of people. This particular use-case can be extrapolated to the sphere of public participation in planning. The well-known in the software development user-centered approach can be particularly applicable here. Individuals from various stakeholder types should be involved into the planning, designing and decision making processes from the very beginning, not only when the model is ready and needed to be validated on the final steps with finishing touches. Only that can ascertain the hearing real-human concerns and needs.

An important highlight here to takeaway is also possibility of transferring regular processes and procedures in the digital world, as well as replication of "feeling" the place and object in the virtual world.

Though spatial representation of information and certain special abilities was not primarily considered during our approaches when designing and evaluating both VR applications for D-MasterGuide and InKraFT, we could not help but notice that users need additional contextual information for orientation in space. This was especially noticeable in D-MasterGuide, when subjects could not immediately understand that they were moving around just one object in space. For them, it was difficult to combine many mosaic projections from different perspectives into one full-fledged cognitive model.

6 SO HOW TO DESIGN & USE VR FOR URBAN PLANNING AND CONSTRUCTION?

Based on the lessons learned, in this section we will outline our vision when designing and integrating VR experience into practice. We chose the mentioned projects because they represent from a technological point of perspective two different settings with different technological solutions which concepts could be transferred in respective use case in the construction and planning sector. This studies tries to assess the potential fields of application with an evaluation of the potential use. Advocating the “problem first” approach, it would be ideal to start the development of VR application with the questions "Do we actually need VR here?" and "What goals we want to achieve with it?" to gauge whether VR is appropriate medium for that. In the context of such disciplines relying heavily on spatial representation of information as design, construction and urban planning sciences, the utmost reason to integrate VR is to improve ability to examine and explore 3D data.

The main reason for using VR in the first project D-MasterGuide was essentially to have positive effect on the motivation of apprentices but also to bring more authentical practice to the learning without necessity to leave the class. The relevant in that regard is also the emphasis of planning activities, starting with the inspection and determination of weak spots for identification of scope of work. The added value in the long term is the better acceptance and self-competence when using the technologies of such type. As we can imagine, the today’s apprentices will be the practicing professionals in the future, and their ability to be confident with the technologies will determine the ease of which they would integrate them to their daily working routine, e.g., to plan and communicate the vision of project with clients.

Another feature of the project is use of 360-grad VR. We can extend this use-case to the 360-grad construction documentation and also for “digitizing” entities bigger in scale than regular buildings, as in our case. Google Panoramas actually has done a vast amount of work capturing virtual tours of incredible amount of places on Earth (and even further). However, this does present challenges such as problems with wayfinding/navigation and constructing a mental map of the area/object. Although it involves more computational power, using this type of virtual reality to reflect the fourth dimension (i.e., time) in a virtual model is potentially of a big interest, as this could bring up capturing “real” development of the entity. This, obviously, would be more appropriate for the domains where this “reality-likeness” has significant importance. Especially the use for collaborative Virtual Environments (CVEs) is very promising in this field, because they support the non-local communication between planners and public (HÖHL, BROSCHART 2015). This can be used for either greater urban master plans as well as detailed architectural questions with respective level of detail. Especially if planners is personally affected by a project, the visualization techniques can make use of their potential during communication with the general public. In this way, citizens can be sensitized to thoroughly serious urban planning issues in a playful way and form their own opinion, which they can then express in further planning phases.

The focus of the second project InKraFT was, on the other hand, on the acquisition of procedural knowledge with bringing potentials created by the VR application to a very special category of users. Though the latter is not the main focus of this use case in that context and that work, it is still can be reasonable to consider that when applying VR to other areas. Designing with inclusiveness in mind however is not that easy even nowadays, especially for those use to leave without special needs. We can imagine including VR into curricula of urbanists in order to, e.g., familiarize them with daily challenges individuals with special needs face living in various environments. Specifically, some studies have shown that “walking in someone else's shoes” (i.e., perspective-taking induced by means of VR) can lead to a boost in empathy towards special ones (VAN LOON et al. 2018,), especially on the long-term scale (HERRERA et al. 2018).

Turning back to the question of procedural knowledge, the potentials of VR-technology can be supported in a application to such highly complex modelling and problem-solving oriented areas as urban planning,

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especially what concerns the possibilities to interact with the virtual world in the way it is not possible in real, e.g., scaling up and down, implementing various perspectives, even at once. Virtual reality, as any other technologies, for sure will not substitute all the processes and routines - architects still use 2D blueprints to convey the necessary details without over cluttering the things, but the it can help to go where no one else has gone, to add and to reduce details to the visualization as we wish, experiment in the safe environment and play “what if scenarios”.

The main lesson that we learned from the D-MasterGuide is basically the importance of transportation of theoretical knowledge and skills into virtual word, making them testable in real practice, aside from open-mind attitude toward technologies. InKraFT raised some further questions regarding interactive conceptual participatory design. The results from both ongoing projects show that practice and integration them into real-world for sustainable use surely raises subsequent problems that could not be foreseen from the theoretical positions. Here that can be mitigated by involving expertise from other disciplines, e.g., psychologists and pedagogues in order to observe behavioural and cognitive challenges and phenomena going deeper than mere acceptance and enjoyability of the experience. This is especially important to reflect that from the stances of environmental psychology. Churchman (2002) voices those issues and convincingly discusses that such important things as concepts and perceptions of places, territoriality, people in these places, their feelings are not always intuitively or obviously relevant to urbanists. This interdependences and dualism posits indeed demanding and sophisticated mission to solve when we adding into the equation the Unknown “X” in the form of digital technologies.

7 CONCLUSION

Even though the use of VR seems promising for learning purposes and usually receives positive feedback from participants, it is uncontroversial that the research on VR in education and its further integration into practice is still limited. There range of possible applications in the sector of construction and urban planning is considerably wide and can embrace the stages from early planning and concepting to the construction itself, as well as showcasing and validation on later levels. Though, what can be said for sure is, that the variety of fields in these sectors will grow and together with it, the requirements for training and further education. In this paper we argued that exploratory dip in adjacent areas can enrich and revive the veins of VR for UP research. We tried to give a brief overview of state-of-art research focusing on the use of virtual reality in construction and urban planning context, and discussing some of the interesting use-cases as e.g., integration of human senses other than vision for better sense of presence. Based on our experience of two projects that are adjacent to the areas discussed, we broadly outlined some implications that we consider to be fruitful to deepen further, i.e., more interdisciplinary focus involving pedagogical and psychological perspectives; more critical view considering which added value the use of such technologies can bring and what actual ultimate goal is to achieve (and not just integration of those for integration’s sake); once more voiced necessity of the user-centered iterative design; bridging the gap between research and actual incorporation of its results into the practice and curriculum, where the main driver in acceptance and digital transformation is still the person who translates them as valuable as a teacher and tutor. Besides, we outlined some problematic areas which are worth further investigation: i.e., question of wayfinding and construction of cognitive models when using the complex VR models; and potentials of VR not only for inclusion but also for empathy and perspective-taking reasons. The given results indicates, that a deep practical integration of the mentioned approaches will always bring up new obstacles for implementation, which cannot be foreseen in the theoretical frameworks. Though, using the visualization methods not only helps for the respective project (public participation of 3D-city models, BIM-analysis etc), but it also could help to improve the willingness of people to be open to new technologies. To achieve this mindset will be crucial for urban planners in the coming decades.

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