buildings

MDPI

Article

Teaching Building Information Modeling in the Metaverse—An Approach Based on Quantitative and Qualitative Evaluation of the Students Perspective

Niels Bartels * **and Kristina Hahne**

Faculty of Civil Engineering and Environmental Technology, University of Applied Sciences Köln, 50679 Cologne, Germany; kristina.hahne@th-koeln.de

* Correspondence: niels.bartels@th-koeln.de

Abstract: The teaching of civil engineering consists of different didactic approaches, such as lectures, group work or research-based teaching, depending on the respective courses. Currently, the metaverse is gaining importance in teaching and offers the possibility of a new teaching approach for civil engineering and especially for the teaching of courses from the areas of "Digital Design and Construction". Although the advantages of teaching in the metaverse, such as location and time independence or a higher learning outcome, are mentioned in the literature, there are also challenges that must be considered when teaching in the metaverse. Against this background, this paper examines the implications of using the metaverse as a teaching tool in teaching "Digital Design and Construction". The impact of teaching BIM in the metaverse is evaluated by (1) a literature review and workshops to evaluate use cases and demands for extended reality (XR) and the metaverse, (2) integrating XR and the metaverse in the courses and valuation by quantitative evaluations and (3) analyzing student papers of the courses and outcomes of a World Café. Due to these steps, this paper presents a novel approach by reflecting the students' perspective. Furthermore, this paper presents a validated approach for integrating BIM and the metaverse in teaching.

Keywords: metaverse; building information modeling (BIM); digital design and construction; education; augmented reality (AR); virtual reality (VR); extended reality (XR); immersive teaching

check for updates

Citation: Bartels, N.; Hahne, K. Teaching Building Information Modeling in the Metaverse—An Approach Based on Quantitative and Qualitative Evaluation of the Students Perspective. *Buildings* **2023**, *13*, 2198. https://doi.org/10.3390/buildings13092198

Academic Editor: Chang-Su Shim

Received: 9 August 2023
Revised: 24 August 2023
Accepted: 28 August 2023
Published: 29 August 2023

1. Introduction

For education in the architecture, engineering, construction and operations (AECO) courses, different didactic approaches and digital technologies are used. The spectrum here ranges from classical teaching with lectures, exercises and group work to project-based work, teaching research-based courses and the use of virtual reality (VR) or augmented reality (AR) glasses [1,2]. Especially in the field of building information modeling (BIM) education, various technologies are used to educate and teach the students [3]. Building information modeling hereby means a method that combines various IT technologies and processes in a way that data and information can be exchanged by the professionally involved architects, engineers, owners, facility managers and further persons by using data exchange formats [4,5]. Especially for the education of BIM various hard skills (e.g., knowledge of software applications, regulations or process modeling) as well as soft skills (e.g., teamwork or communication) are needed [6]. That means that the education of BIM focuses not only on learning outcomes from a technical point of view but also with regard to soft skills and the ability to analyze, evaluate and create content.

Depending on the teaching method, different learning outcomes may arise. For measuring the learning outcome and evaluating the learning objectives, the "Taxonomy of educational objectives" is used in educational research [7,8]. Learning outcomes describe the competencies and learned knowledge that students are expected to have acquired at the end of a course [9]. Bloom (1956) rates the "Taxonomy of educational objectives" in the six taxonomy levels. The first taxonomy level (Remember) means that students have memorized a definition or formula and can reproduce it in an exam. In the second taxonomy level (Understand), students can express the definitions or formula in their own words. The third taxonomy level (Apply), students can independently apply a definition or formula to solve a problem. In the fourth taxonomy level (Analyze), students can analyze an unfamiliar situation and decide which definitions and formulas are needed to solve the situation. This is the minimum level of qualification for academic learning according to the German Qualifications Framework (Deutscher Qualifikationsrahmen DQR). The fifth taxonomy level (Evaluate), requires students to develop their own hypotheses in order to fulfill the task and to justify this decision. In the sixth level of taxonomy (Create), students develop criteria by which plans or hypotheses can be evaluated and thereby design and produce new work [9,10].

Theoretical lectures that are not supported by project-based learning or gamification with a written exam at the end of the course often only reach the levels 1 or 2. The integration of project-based learning, which is used in various BIM and IT courses, could increase the learning outcomes and therewith the taxonomy level [3,11]. Another aspect that could increase learning outcomes and taxonomy levels is the use of gamification. Gamification hereby describes the integration and usage of gaming elements or features, as known from computer games [12,13]. Studies show that the integration of gamification features could increase the learning outcomes and motivation [13,14]. On that point, the metaverse could support the education in order to reach the highest level of expertise and increase the learning outcomes [15,16].

However, what is the metaverse, and how can the metaverse improve the education in AECO and especially BIM? The term metaverse is not finally defined in scientific research [17]. Since 2021, the term metaverse is associated with Facebook, when Facebook was rebranded as Meta Platforms [18]. However, other companies, such as Microsoft and NVIDIA have invested in the metaverse (or Omniverse) [19]. In addition to that, various other platforms, such as Decentraland, Second Life, Minecraft, Roblox and Sandbox, are referred to as metaverse [20]. In the research, various definitions have been stated. Steve Benford 2021 defines the metaverse with five things, namely (1) the characteristic, that it is "a virtual world", (2) that a virtual headset is needed, (3) the metaverse is social, (4) that it is possible to visit the metaverse whenever one wants to (persistence) and (5) there is a connection to the real world [21]. Mark Billinghurst wrote in 2021 in a Twitter statement, that he thinks that the metaverse will be a completely open platform [22]. Moreover, in 2021, Tony Parisi published the seven rules of the metaverse, namely (1) there is only one metaverse, (2) the metaverse is for everyone, (3) nobody controls the metaverse, (4) the metaverse is open, (5) the metaverse is hardware-independent, (6) the metaverse is a network and (7) the metaverse is the internet [23]. In 2022, Florian Buchholz et al. defined the metaverse as consisting of seven parts, namely (1) combination of real and virtual world, (2) the metaverse is a social medium for communication and collaboration and trade, (3) a metaverse is persistent and long-lasting, (4) a metaverse integrates various technologies, such as XR, (5) capturing the state of the user and the real environment are key actions for the metaverse, (6) metaverse participation is multi-model and participants can change the form and intensity of their participation and (7) a metaverse is tightly coupled with reality [24]. In 2023, Thien Huynh-The et al. presented a review for blockchain for the metaverse and the impact of blockchain on the metaverse [25]. Based on those definitions and practical applications the following definition of a metaverse is made for this paper:

The metaverse is a combination of the real and virtual world, in which applications, such as digital marketplaces, digital properties, branding and marketing, as well as education, are included. The metaverse is based on open standards, digital ownership, persistence, multimodality and social interaction. The technical basis for the metaverse consists of devices for extended reality (XR), blockchain, cloud computing, cryptocurrency, Web 3.0 and artificial intelligence. This definition is shown in Figure 1.

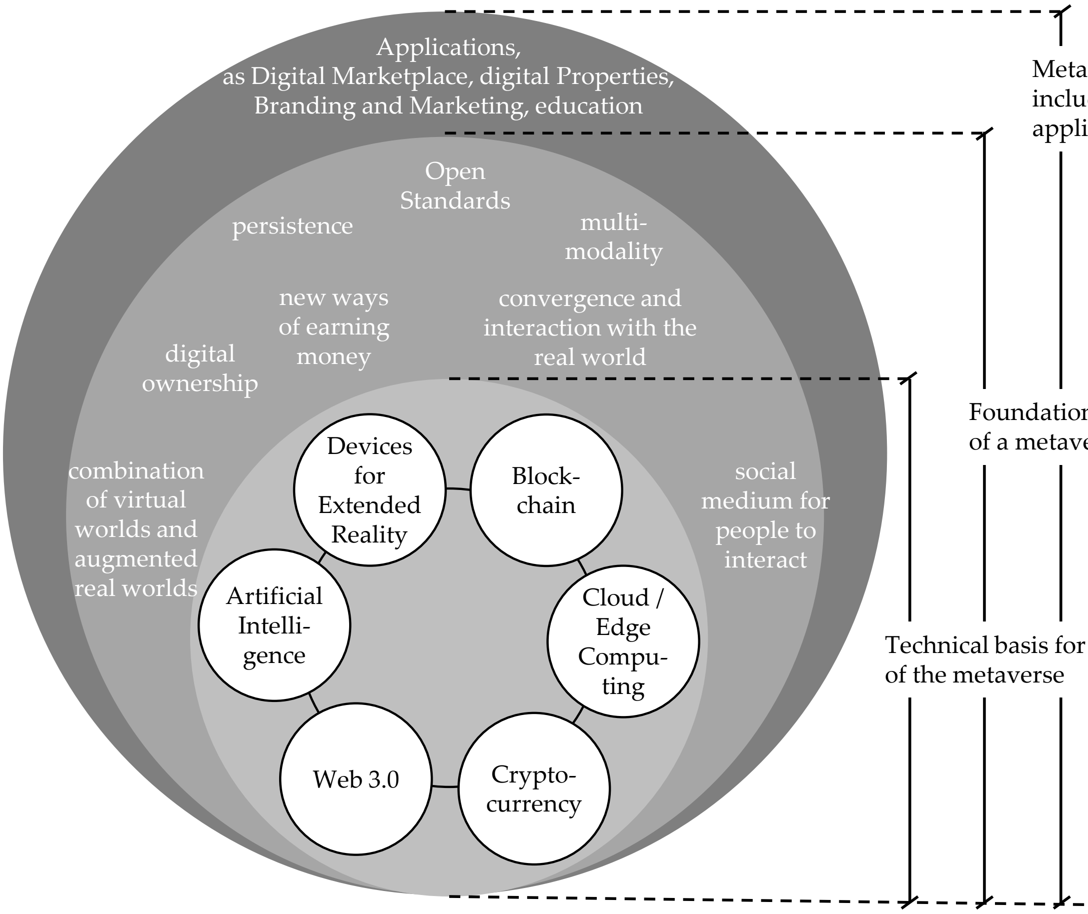

Figure 1. Components and structure of the definition of metaverse.

The social interaction, multimodality and the combination of the virtual and real world are the main reasons why the integration of the metaverse in education in various courses and universities could increase the learning outcomes. In addition, in the education of architecture, engineering, construction and operations, the metaverse and XR have been adopted in first research projects [26]. Based on that, this paper describes the first application of BIM teaching in the metaverse, which was implemented in a university course and evaluated from the students' perspective. While the currently published papers mainly consider use cases of the metaverse in general, this paper continues the research based on the existing literature with regard to teaching content. For the first time, the necessary prerequisites and content relevant to teaching are identified, as well as potential advantages and disadvantages associated with teaching in the metaverse and linking BIM and the metaverse for students. Essential and unique to this paper is the shift in perspective that looks at both the requirements of the metaverse and teaching in the metaverse from the perspective of practitioners and teachers as well as from the perspective of students.

2. Materials and Methods

Three steps were conducted to determine the practical, teachers' and students' perspectives for integrating the teaching of BIM into the metaverse.

In step 1 (Section 3), the necessary use cases for the metaverse and XR were evaluated by the teaching staff. Therefore, a literature study was conducted in order to find our definitions of the metaverse and possible applications, as well as the opportunities and limitations for its application in education and the construction industry. In addition to, expert workshops were conducted to evaluate possible use cases in education and practice.

In step 2 (Section 4), a concept for integrating aspects of the metaverse and XR into the existing course for "Building Information Modeling" and "Digital Design and Construction" was developed by the teaching staff and an external company that is specialized on metaverse and extended reality as a consultant. The course content of the existing courses "Building Information Modeling" and "Digital Design and Construction" was not adapted. Only metaverse content was integrated to support the teaching in order to enable a technology-driven and innovative way of teaching the course content in a digital environment. In this step, firstly a structure for lectures was developed in order to teach the basics and definitions of the metaverse and XR. This included a lecture as well as a tutorial, in which the students could design their own metaverse. Secondly, a workshop concept was developed that aimed to present the contents of the lecture in a practical way and to make it tangible. The workshop concept and the learning outcomes were evaluated by the teaching staff; the results are shown in Section 4.

In step 3 (Section 5), the students were asked to write a paper about teaching BIM in the metaverse. Therefore, the course was divided in 46 groups of 4 to 7 students per group. In these groups, the (1) necessary requirements and conditions for teaching BIM in the metaverse, (2) the challenges and limitations, (3) the expected and experienced advantages of metaverse-based BIM teaching and (4) suitable education content for teaching in the metaverse were evaluated and discussed. The paper assignments were handed out to the students at the beginning of the semester and were worked on by the groups during the semester as one part of the examination (beside a written exam). The papers were handed in after the final lectures had been completed. In addition, the results were presented and discussed by the individual groups with a poster presentation during the semester in a World Café.

The three steps are shown in Figure 2.

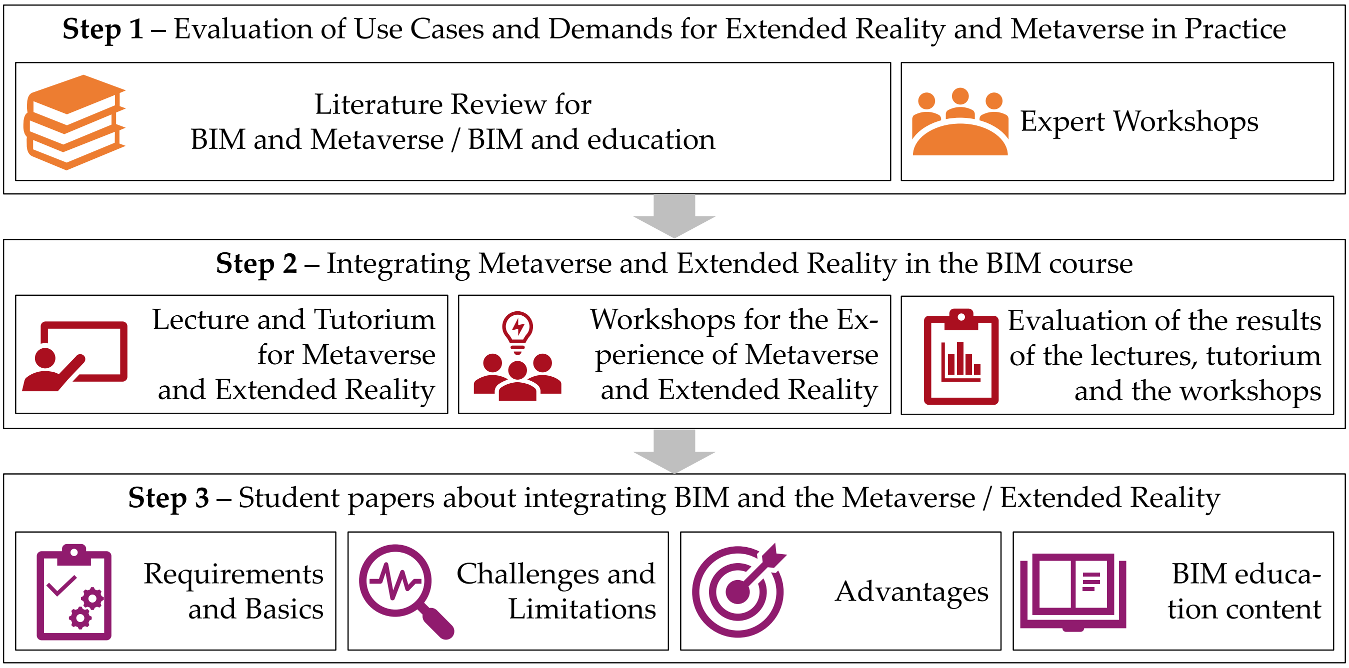

Figure 2. Steps and methodology of this paper.

The course was held during the summer term of 2023 with bachelor students in their fourth and sixth semesters. The lectures, as well as the workshops, were conducted in person. A total of 227 students were enrolled for the course.

3. Step 1: Evaluation of BIM-Based Use Cases and Demands for XR and Metaverse in Practice and Literature

As defined in Section 1, the metaverse is defined by various aspects. In education especially, there are seen to be many advantages. Therefore, this section aims to find out the advantages and limitations of education in the metaverse. Afterwards, the combination of the metaverse and the AECO industry is discussed based on a literature review and workshops with practitioners. Finally, the last part of this section combines education in the metaverse with aspects of the AECO industry and BIM education, and a literature review about these topics is conducted. The literature review was divided into reviewing the impact of the metaverse on civil engineering and reviewing aspects of teaching in the metaverse. In this literature review, papers and books from Scopus, Google Scholar and SpringerLink were evaluated.

3.1. Education in Metaverse

The literature review that was conducted as the basis for this paper showed that various studies have been conducted to evaluate the implications, limitations and applications of the metaverse for education and that the first immersive or metaverse campuses and applications are available [27–30]. The majority of the studies show that education could be improved by using immersive technologies, such as VR, AR or the metaverse [31–34]. This is also proven by studies which compared the learning outcomes and discovered that students who are educated in the metaverse have better learning outcomes than a comparison group [16,26,35]. The main focuses of the studies are language learning applications (e.g., [36]), business applications, such as teaching marketing (e.g., [37]), nursing and healthcare education (e.g., [38]), science education in museums (e.g., [39]), text games (e.g., [40]) and manufacturing training applications (e.g., [41,42]). To evaluate the limitations and applications, the first campuses in the metaverse have been set up and analyzed in the research [27,43]. In addition, there are metaverse classroom providers and consultants that offer educational space in the metaverse and aim to create a virtual learning experience (e.g., [44]).

The literature review also stated that there are advantages and disadvantages to education in the metaverse. The main advantage is that immersive learning improves learning outcomes. This is caused by a new flexibility as potential for a location-independent and asynchronous learning environment [45]. In addition, the immersive learning that comes from using VR, AR or the metaverse could increase the situational interest of students so that they are more interested in the taught courses [32,46,47]. On the other hand, there are three major disadvantages. First, challenges in interpersonal communication must be considered [48]. Second, the metaverse could lead to fatigue due to sensory overload [49]. Third, there are actually monopoly position of providers, which needs to be critically questioned for public education [48].

3.2. Metaverse in AECO—Expert Workshops and Literature Review

For the architecture, engineering, construction and operations industry, there are various possible applications and use cases. These applications were discussed in workshops with various practical partners. Overall, four workshops were executed, respectively, one with a project developer, one with a design and planning company, one with a construction company and one with a facility management (FM) provider. The workshops were conducted between January and February 2023. Overall, nine experts from the different sectors took part in the workshops. In addition, the answers were validated and discussed based on a literature review. The results are shown in Table 1.

Table 1. Possible applications and use cases of metaverse (own table-based workshops with German real estate developers, design and construction companies and FM companies, as well as: [50–58]).

Stakeholder	Actual Challenges in Practice without Digitization	Opportunities and Solutions by Using the Metaverse
Real estate development	• Reduction of areas to be developed and price increases of existing areas.	• New, virtual building plots that can be developed.
	• Need for generating new opportunities for income.	• Leasing of advertisement space for generating new incomes.
	• Difficult marketing process for real estate in conventional sales channels, especially a limited customer base.	• Advertisement by using the virtual parametric 3D representation of the building for virtual tours to minimize the dependence on site visits as well as greener solutions.
	• New billing and contracting methods are needed.	• The blockchain technology that is used in the metaverse offers new billing methods as well as storing contract and building data (e.g., material passports) more efficiently and sustainably.
	• Long duration of building permits.	• Collaboration with the public stakeholders via metaverse.
Design	• Difficulties in presenting the current planning status to customers who are not from the AEC environment as well as obtaining approvals for the current planning status.	• Virtual representation of the building, including rooms and spaces, to experience their effect of the customer and tenants.
	• Travel routes to meetings with planning stakeholders.	• Implementation of virtual design meetings with avatars.
	• No data for future decisions.	• Using data in the metaverse to store and analyze data for using these data for the optimized design of new constructions.
Construction management	• Long distances between the various construction sites for the project management, construction management and representatives of the client.	• Digital construction meeting on virtual construction site to avoid long travels by using avatars and augmented reality.
	• Difference of opinion about the current execution planning and the current execution status.	• Discussion of the current execution design and possible adjustments by using one communication space.
	• Detached communication of the planning participants with regard to sustainability, so that only individual solutions are considered.	• Integration of sustainability aspects by combining the various project participants as well as the virtual building model.
Facility management	• No digital data of the building, especially lack of information for maintenance.	• Digital representation of the building with maintenance instructions, possible routing and clear information about obstructed objects.
	• Only static data and no integration of AR/VR applications.	• Integration of live data into the digital building model.
	• Hard to reach all building users in case of fire safety and health education.	• Integrating the metaverse for firefighting safety education by deploying an experience.

The basis for the integration of the applications presented in Table 1 into the metaverse is the use of one standard that enables the integration of a BIM-based digital building model into immersive and metaverse technologies. The focus is on developing an open and vendor-neutral standard, so that lossless data exchange is possible and no considerable additional efforts are required for the integration of digital building models into the metaverse and other immersive technologies. The relevance of that topic can be seen in the number of publications about BIM and their combination with immersive technologies, which has increased rapidly in recent years [59]. At the beginning, the publications focused on the combination of BIM and VR, but actually, BIM and AR are integrated in the publications, too [59,60].

3.3. Metaverse Education in AECO

Although there are some projects in an engineering context (e.g., [28]), in the case of the architecture, engineering, construction and operation industry, only the first steps of the integration of the metaverse in the teaching and education of students and in general have been made. When specifying the search terms for the literature search, the terms "metaverse", "construction", "BIM" and "education" were searched on Scopus, Google Scholar and SpringerLink in different variations. The results show that:

1. Most of the research was conducted and published in the years 2022–2023 (Scholar: approx. 55%, Scopus: approx. 95% for the keywords "Metaverse" + "Construction" + "Education"), which means that education in the metaverse, as well as the combination of the metaverse and the AEC industry, is a newly topic;
2. There are research projects that deal with metaverse-based education in general or with education in software applications (e.g., [61,62]), but, especially for the use of the metaverse in education in the AECO industry, only few papers were available (e.g., [63]);
3. The first publications for the AECO industry show that the metaverse components of virtual reality, blockchain and the Internet of Things (IoT) are used as single components and not as a holistic metaverse concept in educational and research projects [52,54,64].

These results show that there is a research gap that needs to be addressed. As mentioned, the metaverse and immersive teaching concepts could support education in various ways. Therefore, it is necessary to develop concepts to integrate the education of architecture, civil engineering, mechanical, electrical and plumbing (MEP) and heating, ventilation and air conditioning (HVAC) engineering, as well as facility management into the metaverse. In the context of building information modeling, there is no fully comprehensive teaching concept available.

4. Step 2: Development of a Teaching Content for BIM in the Metaverse by Workshops

Based on the literature review (step 1) and the expert workshops, a teaching concept for BIM in the metaverse was developed. The concept aims to integrate the students' points of view in order to avoid the disadvantages of teaching BIM in the metaverse. Therefore, in step 2, a lecture and tutorial as well as workshops for the students were designed and evaluated. The lecture about integrating BIM as well as AECO aspects in the metaverse was given at the end of March. The workshops were executed between the lecture and the tutorial on the metaverse. The tutorials were conducted in June; in these tutorials, the students built their own metaverse environment. Furthermore, the students could interact with lecturers and other students, which helped the students to understand working with the metaverse, as well as elaborating and discussing their questions with regard to the integration of BIM and the metaverse. The following sections will show the results of the evaluation of step 2.

The advantages and disadvantages that were found in the literature review were considered to develop and evaluate a workshop concept. This concept aims to teach the relevant components of the metaverse for BIM education. The workshops were designed to be 3 h long and 15 students could participate in each workshop. They were conducted from April 19 to April 26. Participation in the workshops was voluntary and outside of regular lecture and tutorial times. During the workshops, various metaverse applications were shown to the students. The workshop was structured in three stations: visualization in the metaverse, trainings with XR and maintenance with AR. In these workshops, educational content of the BIM method was also integrated. The main content is presented in Figure 3; in all this content, parts of the BIM method were integrated. For example, the design of virtual building models with immersive technologies, the integration of FM data in AR environments, the communication in BIM projects with the metaverse and visualization of BIM content in an immersive environment were shown to the students in the workshop.

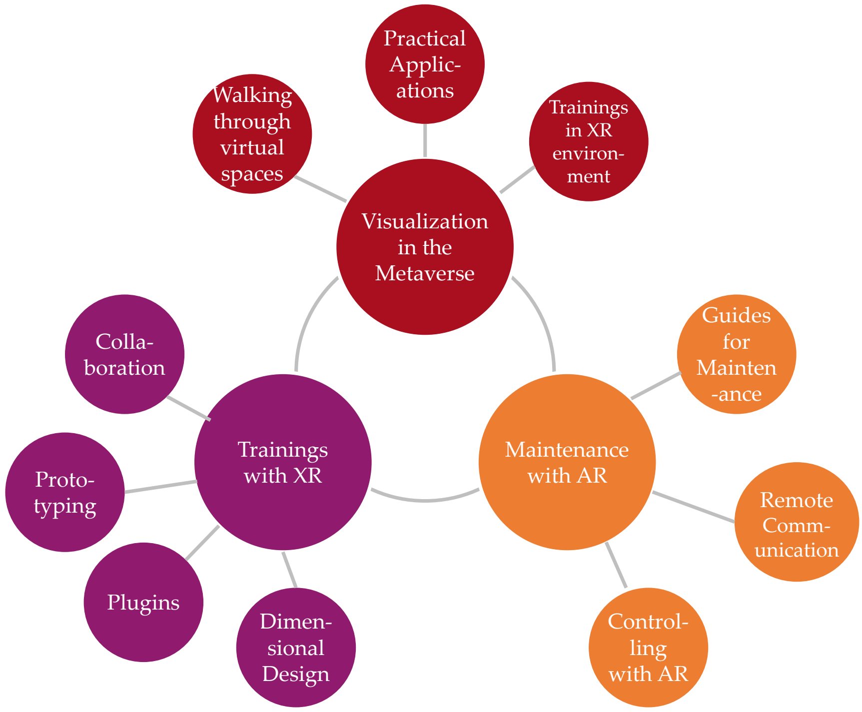

Figure 3. Content of the XR and metaverse workshops.

Overall, 49 students visited the workshops and 44 answered the questionnaire to evaluate the workshops. After the workshops, the students were asked to answer various questions. In one of the questions, the students were asked to respond how relevant they think various metaverse tools are for the BIM education in the courses “Digital Design and Construction” and “Building Information Modeling”. The results are shown in the following Figure 4. In this figure, it can be seen that the coordination of the design in VR glasses, the handling of renderings from Revit in the metaverse and the creation of maintenance workflows with AR glasses are relevant use cases for the students. On the other hand, the implementation of FM services with AR and communication via AR glasses are not that relevant for the students.

Another question asked the students to rate the learning outcomes and success of the workshops. The following Figure 5 shows an extract of the questions and results. Prior to the workshops, the students did not have a full understanding of BIM and the metaverse. Approx. 20% of the students completely did not agree to the statement that they already had a clear understanding of BIM and the metaverse before the workshops, while approx. 16% agreed with the statement that they had a clear understanding of BIM and the metaverse before the workshops. The results show that the workshops strengthened their understanding of the subject. After the workshops, approx. 94% of the students agreed completely or very much with the statement that the workshops improved their understanding of the topic. Furthermore, the workshops made the students feel more confident with the subjects, and they thought that the topics of the workshops would be relevant for their future practice. In addition, approx. 87% of the students agreed completely or very much with the statement that the workshops increased their interest in the topics of BIM and metaverse.

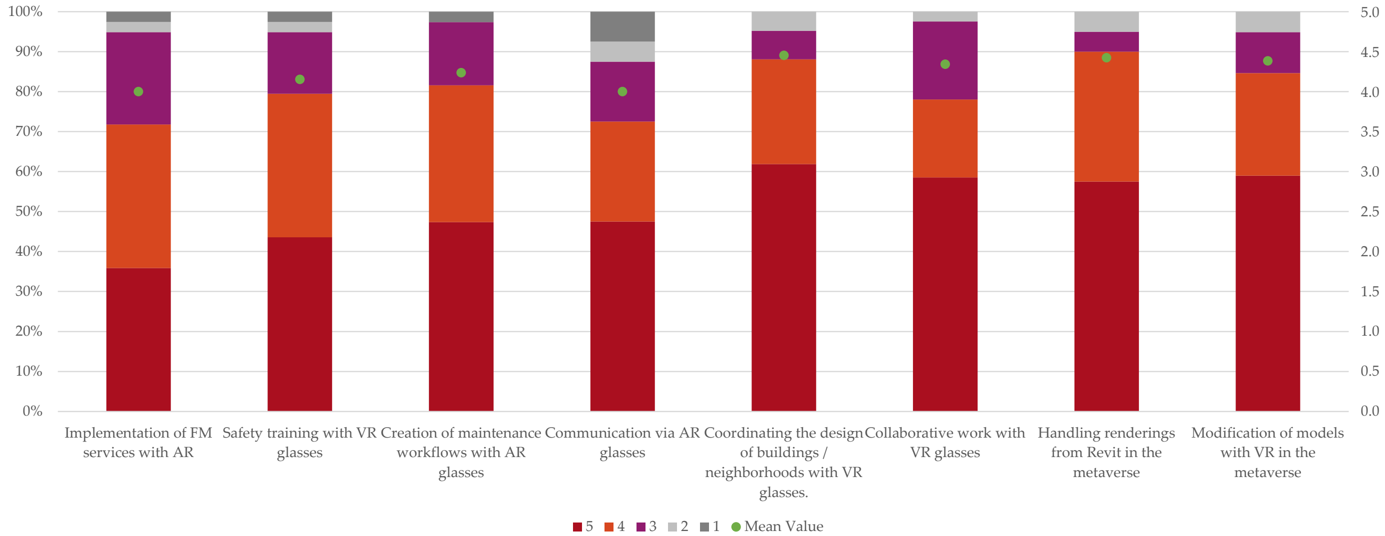

Figure 4. Answers to the question, "How relevant do you consider the following use cases in teaching? (5 = crucial, 1 = not important at all)", n = 44 students.

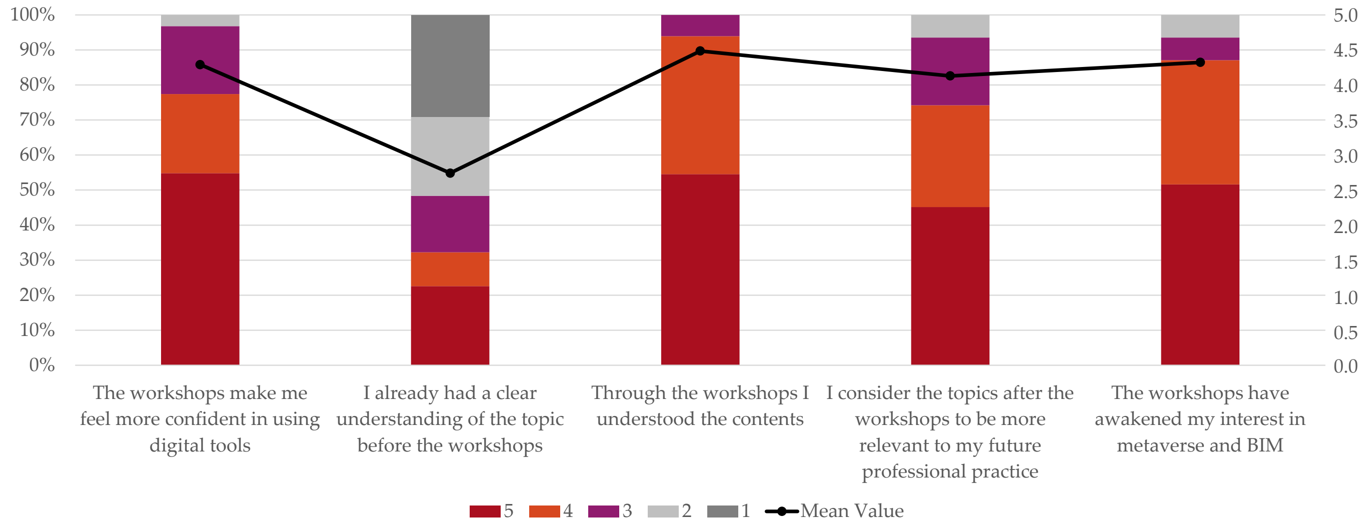

Figure 5. Answers to the question "How much do you agree to the following statements? (Scale: 5 = agree completely, 1 = disagree completely)", n = 44 students.

In addition, the students were also asked which parts of the metaverse were improved in their understanding as a result of the workshops. In the case of mixed reality and VR, 100% of the students answered that the workshops improved their understanding, while 97% answered that the workshops improved their understanding of AR. Moreover, the understanding of BIM tools was improved. A total of 94% answered that the workshops improved their knowledge about BIM collaboration software and BIM authoring tools. In contrast, only 52% answered that the workshops optimized their understanding of blockchain.

The results show that the workshops—based on the content of the lecture—in and with the metaverse could improve learning outcomes.

5. Step 3: Student Papers, Presentations and Discussion of the Results

To implement a fully structured course for BIM in the metaverse, the basics need to be cleared. Therefore, the students of the two courses were—besides their written exams—asked to write papers about requirements and basics, challenges, advantages for teaching BIM in the metaverse, as well as evaluate relevant BIM educational content for the metaverse. Therefore, the students were divided in 46 groups. The paper was written by each group during the summer semester, based on the lectures, the tutorial and the workshops. At the end of the semester, the results were presented and discussed with each other group with a poster presentation in a World Café. The results of the papers, the posters and discussions are analyzed in the following sections.

5.1. Requirements and Basics for Teaching BIM in the Metaverse

Throughout the discussions and in the analyzed papers, various requirements and basics were mentioned by the students that are necessary for teaching BIM in the metaverse. The tutorials for building a metaverse platform influenced the student assessments were especially mentioned. The results of the studies can be broken down into three main aspects:

1. The relevant technologies must be available. First, from the students' point of view, it is necessary that the metaverse is available and used as a platform. Second, it is necessary that hardware and software are available to a suitable extent. Here, the focus is particularly on the acquisition and financing of tablets, PCs and VR/AR glasses. Third, there must be a stable internet connection with a good bandwidth to perform education in this metaverse. These aspects were evaluated as the main requirements for teaching BIM in the metaverse by the students based on the tutorials, but in other educational projects these factors were also evaluated [27,43]. Fourth—and this is a point that is especially needed for teaching BIM in the metaverse—suitable software products must be made available, such as databases and clouds, that are able to integrate digital building models (based on IFC or proprietary standards) into the metaverse.
2. Standards and basics with regard to data protection, responsibility for errors and open communication must be created. In particular, students saw the threat of data theft and loss in the metaverse as a danger. The students also saw a lack of interest and willingness on the part of the AEC industry to go along with the digital changes and engage in teaching in the metaverse as a further challenge. From the students' point of view, it is necessary that a digital change takes place in the AEC industry.
3. From the students' point of view, soft skills are another essential basis. These include, in particular, the didactic abilities of the teacher and learners (students) and the associated need to offer training for teaching in the metaverse. In addition, from the students' point of view, it is necessary to involve appropriate partners who can create an optimal, immersive environment for teaching. In addition, it is necessary to define quality criteria for teaching BIM in the metaverse.

These requirements and basics are shown in Figure 6. The three main aspects are divided in six sub-aspects that are necessary requirements for teaching BIM in the metaverse, namely hardware, software, legacy, open communication, organizational basics and didactics.

The evaluation shows that most of the aspects can be fulfilled by universities and the teaching staff. Universities need to be responsible for the procurement of the technology, both hardware and software. The teaching staff is responsible for their own didactical training. However, the open communication and legacy aspects need to be solved in a global way. Therefore, it is necessary to implement working groups that engage in the education of BIM in the metaverse in order to implement criteria and rules regarding data privacy as well as open standards. During the students' discussions it became clear that the responsibility of teaching must not be given into private hands (the companies of the metaverse), but must be regulated and defined by public institutions.

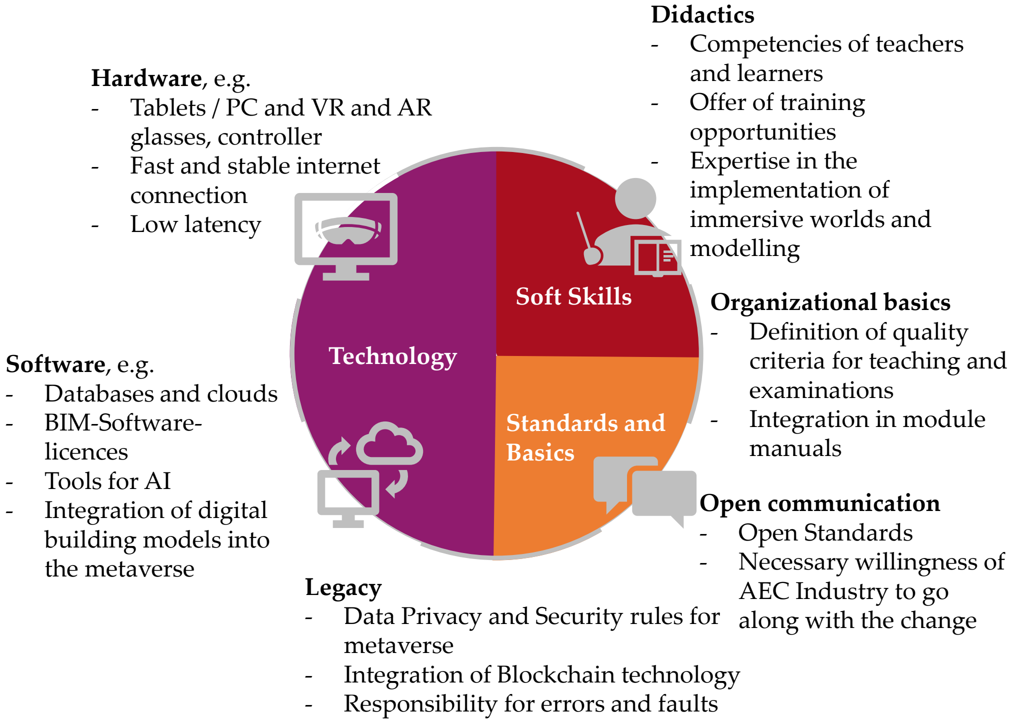

Figure 6. Requirements and basis for teaching BIM in the metaverse.

5.2. Challenges and Limitations for Integrating BIM Education in the Metaverse

It can be found that the challenges and limitations are directly related to the requirements and basics for teaching BIM in the metaverse. The challenges and limitations for integrating the BIM education in the metaverse can be summarized into five main theses:

1. The implementation costs were one challenge that was stated by all students. The purchase of AR and VR glasses was especially indicated, but the implementation of high-performing internet connections and the provisioning of a metaverse campus and cloud space were also mentioned.
2. Most of the students mentioned the lack of educational skills as a challenge for the BIM education in the metaverse.
3. Data security and policy is another main challenge from the students' perspective. Especially in a public metaverse space, rules regarding data security and policy need to be defined.
4. Another challenge that was mentioned by most students was the monopoly position of the providers and concern that examinations could be given out of the responsibility of the universities. From a student perspective, it is necessary that clear ethical and legal regulations are defined
5. The most discussed challenge was the handling of the social aspects. Therefore, these aspects are discussed in the following sections.

From the students' perspective, three social aspects need to be especially considered. The first social aspect deals with the isolation of the students if teaching is performed in the metaverse. The courses "Digital Design and Construction" and "Building Information Modeling" benefit from a project-based learning approach. The students work together in small groups of 4–7 students in order to learn the social and processual aspects that are necessary for the implementation of the BIM method, as well as the exchange of information by using various software products. In particular, with regard to the BIM method, the project-based learning approach is a suitable and common practice in teaching because it increases motivation in students to study BIM courses, fosters the comprehension of the theoretical and practical foundations of the BIM method by transposing the theoretical background into practical projects and supports the use of BIM tools and software [3,65,66].

After the COVID-19 pandemic and the closure of schools and universities for in-person courses, the students are afraid that education in the metaverse will lead to a new isolation. This is also supported by studies that show a negative impact on people's health when working predominantly in the metaverse. The damage is caused, in particular, by a lack of exercise, as well as a neglect of social contacts, which can lead to isolation [67,68]. Therefore, from the students' point of view, it is necessary to create education in the metaverse in such a way that the courses in the metaverse are a supplementary offer and not the main teaching point.

The second social aspect that was mentioned and discussed by the students deals with the accessibility of the metaverse. The metaverse is designed to improve social participation [69]. However, the accessibility might be restricted for a specific group of people due to an age difference and thus unfamiliarity with how to use the metaverse on the one hand. On the other hand, it is necessary to make regulations about how to deal with students who cannot afford the equipment needed to teach and learn in the metaverse. The purchase of equipment, such as VR/AR glasses and a stable and fast internet connection, might be too expensive for students with low incomes, so students are concerned that they may be excluded from the course. Therefore, it is necessary to find regulations to support students with low incomes and budgets, e.g., by public funding or hiring the hardware from the university. In addition, training opportunities need to be created to enable students the access of the metaverse.

The third social aspect mentioned by students addresses the question of how to deal with bullying as well as offensive content, propaganda or financial crimes that may cooccur during the course of teaching in the metaverse (e.g., on other metaverse properties). Here, it is necessary to protect both minor students and students who are exposed to potential bullying or to the other mentioned risks. Final regulations on legal aspects and on aspects of handling in the metaverse do not yet exist, but are being discussed in various places [70,71]. However, rules are indispensable in order to enable a way of dealing that makes teaching in the metaverse possible. Therefore, it is currently still necessary to choose a platform for teaching in the metaverse that was built by the university or public sector. Only these platforms are able to support educational purposes.

5.3. Advantages of the Metaverse-Based Education of BIM

Based on these challenges, the students also evaluated and discussed the advantages of BIM education in the metaverse. One of the advantages is already shown in Section 4, namely that the learning outcomes and the understanding of the topic could be increased. The advantages that were evaluated and discussed by the students show the reasons for the optimization of the learning outcomes and improvement of understanding. The five main aspects are shown in Figure 7.

In Figure 7 it can be seen, that the metaverse has advantages in various ways. These advantages are explained in detail in the following sections.

5.3.1. The Metaverse Offers a More Attractive Learning Environment That Contributes to an Improved Understanding of the Content

The metaverse has a positive effect on the motivation and the interest in the BIM content. In addition, the experiences of the students show that the external distraction faced by students decreased if the education takes place in the metaverse. This might be influenced by the fact that teaching and learning in the metaverse is currently a new opportunity that offers exciting prospects for students. However, not only do the external distractions need to be considered, but the extraneous cognitive load needs to be reduced. The extraneous cognitive loads describes the externalities of the learning material, the learning environment and the general conditions [72]. That means, that the materialities and functions in the metaverse need to be reduced to a minimum to avoid cognitive expenditure on resources for superfluous processes [30].

Figure 7. Advantages of metaverse-based BIM education.

This observation of the students is also supported by the cognitive theory of multimedia learning, which describes learning as a generative processing of information by using pictorial and verbal channels, whereby the amount of information that can be processed is limited [73,74]. The metaverse enables, especially through the VR environment, an experience that leads to successful learning in the sense of being on the spot and the possibility to control one's own actions, since it can address multiple channels, which also describes the cognitive affective model of immersive learning (CAMIL) [15]. In terms of teaching, this means that the metaverse can address both the pictorial and verbal channels and could lead to a better education [30].

5.3.2. The Independence of Teaching Is Increased by Using the Metaverse

The students of the courses "Digital Design and Construction" and "Building Information Modeling" state that the individualization of the teaching in the courses could be increased. That means that the daily or weekly load of BIM content and the speed of learning could be determined for the students individually. This individualization that was mentioned by the students is seen as one of the most important advantages for the education in the metaverse [45,75]. This is especially so for the education of BIM. With its theoretical background and practical applications, advantages in the education are seen by the students.

In addition, the students also state that social participation in education could be increased by using the metaverse because the education is independent from time and location, which means that every student can enter the teaching metaverse, whenever and wherever the student wants. In addition, social participation could be increased. This advantage is also mentioned in reports, e.g., [76]. This teaching is also independent from external factors, such as a pandemic, war or bad weather conditions, which may not allow the student to attend a lecture in person.

5.3.3. The Teaching in the Metaverse Strengthen the Realistic Teaching of BIM Content

From the students' perspective, the metaverse allows realistic visualization and practical applications, which lead to hands-on teaching. The students mention especially the opportunity of the metaverse to offer a unique, realistic experience by presenting the theoretical framework in simplified and tangible environment as a positive enrichment for BIM teaching, e.g., they state, that communication and simulations on construction sites could be shown in the metaverse. Research in other fields also mention that advantage of the metaverse to simulate realistic learning scenes in the metaverse [77–79].

Furthermore, the students mention, that the metaverse allows a zero-risk-environment, in which mistakes could be made without high costs or dangers. This encourages the students to try out various ways to solve a problem and learn from mistakes.

5.3.4. The Metaverse Enables a Future-Orientated Education of BIM Content and Trains the Soft Skills of the Students

The students indicated the opportunity to learn future-orientated technologies, such as the metaverse, as one important advantage. By learning BIM content in the metaverse, the students are enabled to attain security in the handling of digital technologies. In addition, the students see career opportunities by using a digital technology, such as the metaverse, in the BIM education. This enables students to integrate their knowledge into practice and obtain a head start for their careers.

The trans-disciplinary approach of the metaverse offers the students possibilities to increase their teamwork with other professions and students of the course. The students state that education in the metaverse could train their soft skills, such as communication and the integration of other team members. In addition, the students state that the exchange between universities could be increased by using the metaverse as a learning platform for BIM education. An example for a shared campus can be found in [80].

5.4. Relevant BIM Educational Content in the Metaverse

The relevant BIM educational content from the students' perspective can be summarized in three main aspects.

Firstly, the students indicate all collaborative content, such as the data exchange by modeling with the BIM method, the quality and collision check of digital building models or communication with the construction site as sensible educational content. In their papers, as well as in the discussions as part of the World Café, the students stated that the metaverse could improve collaboration, not only in teaching but also in their future work lives. This is especially true due to the fact that the students also modeled and exchanged data in the courses "Digital Design and Construction" and "Building Information Modeling" via open exchange standards, such as industry foundation classes (IFC) or BIM collaboration format (BCF) as a realistic assessment of the potential for optimization can be given. Furthermore, they stated that connection with other universities could be improved so that a collaborative course for BIM and digital design and planning education could be easier established. Nevertheless, in the discussions, it was seen that this educational content, in particular, was heavily discussed, as the social aspect and collaborating together in the real world is a major need for students (see Section 5.2).

Secondly, the students indicate complex content as possible content for education in the metaverse. They stated that various use cases are possible for education in the metaverse, e.g., the creation and writing exchange requirements. In this case, the students stated that additional content and gamification in the metaverse could have helped them in the execution of the task. In addition, the students stated that virtual field trips (e.g., a construction meeting in which work is conducted on a model) or time leaps (e.g., different states of construction of the project and the digital building model) could improve the education of BIM. Due to their experience in the study program, they also added content from our civil engineering, HVAC and MEP courses, such as observing welding from the perspective of the welder, the load curves in the bearing structure or physical progressions of building.

Thirdly, the students indicate costly and elaborate content as possible educational content for the metaverse. On one hand, this could be the work on a digital building model, but especially in other fields of civil engineering, as well as HVAC and MEP, the students believe that metaverse content could improve their learning outcomes. One example that was given was destruction tests on different materials.

6. Conclusions

The metaverse could change the way of education. This paper showed that the combination of BIM education and the use of the metaverse could increase the learning outcomes of the students. The understanding of the topics was increased by using the metaverse and the workshops about the metaverse. The independence of time and location, the novelty of the teaching approach, the new possibilities of communication and the experience using all senses lead to the optimization of the BIM education. With that knowledge, an educational concept for BIM with the integration of visualizations, timelines and the state of construction, as well as processes and team communication, can be implemented by using the metaverse. On the other hand, the statements and experiences of the students in the courses "Digital Design and Construction" and "Building Information Modeling" showed that education in the metaverse should only be conducted as an additional tool and should not replace traditional lectures and project-based working. In particular, fears of social isolation and the need for personal contact were raised when discussing integrated education in the metaverse in the courses.

Therefore, it is necessary to conduct further research about the social aspects of education using the metaverse. In this context, it is also necessary to conduct long-term studies which take education at universities into account but also the integration of the students into the work life. The communication between various places and universities could be increased by the utilization of the metaverse, but on the other hand, personal contact is lost because of the lack of excursions.

Furthermore, the integration of companies and future employees is necessary. Although the teaching content regarding BIM in the courses "Digital Design and Construction" and "Building Information Modeling" is continuously coordinated and validated with the industry, the integration of the metaverse and the impacts on the students' future way of work needs to be evaluated in further research. This paper only takes the students' perspective and therewith an educational perspective into account. It can be seen that the metaverse is not used in actual practice, especially in the AECO sector or in BIM projects. This means that further research about use cases as well as the integration of the metaverse into the lifecycle of buildings needs to be performed.

Author Contributions: Conceptualization, N.B. and K.H.; methodology, N.B.; validation, N.B. and K.H.; formal analysis, N.B.; writing—original draft preparation, N.B.; writing—review and editing, N.B. and K.H.; visualization, N.B.; project administration, N.B. All authors have read and agreed to the published version of the manuscript.

Funding: This project was supported by the TransferING program of TH Köln (University of Applied Sciences Cologne).

Data Availability Statement: The data presented in this study are available on request from the authors.

Acknowledgments: We would like to thank our students and the various experts from the AEC industry for supporting our research and World of VR GmbH for the support by organizing the workshops and tutorials.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Diao, P.-H.; Shih, N.-J. Trends and Research Issues of Augmented Reality Studies in Architectural and Civil Engineering Education—A Review of Academic Journal Publications. *Appl. Sci.* **2019**, *9*, 1840. [CrossRef]
2. Dinis, F.M.; Guimaraes, A.S.; Carvalho, B.R.; Pocas Martins, J.P. Virtual and augmented reality game-based applications to civil engineering education. In Proceedings of the IEEE Global Engineering Education Conference (EDUCON), Athens, Greece, 25–28 April 2017; IEEE: Piscataway, NJ, USA, 2017; pp. 1683–1688, ISBN 978-1-5090-5467-1.
3. Maile, T.; Bartels, N.; Wimmer, R. Integrated life-cycle orientated teaching of the big-open-BIM method. In Proceedings of the European Conference on Computing in Construction and the 40th International CIB W78, Heraklion, Greece, 10–12 July 2023.

4. Borrmann, A.; König, M.; Koch, C.; Beetz, J. *Building Information Modeling*; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2021; ISBN 978-3-658-33360-7.
5. Bartels, N. *Strukturmodell zum Datenaustausch im Facility Management*; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2020; ISBN 978-3-658-30829-2.
6. Wimmer, R.; Bartels, N.; Maile, T. Hochschulübergreifende Ausbildung in der Big-Open-BIM Welt: Neue Professuren für Digitales Planen und Bauen. Available online: https://www.bsdplus.de/fachartikel/hochschuluebergreifende-praxisnahe-und-zukunftsgerichtete-ausbildung-in-der-big-open-bim-welt.html (accessed on 18 July 2023).
7. Bloom, B.S. (Ed.) Taxonomy of Educational Objectives: The Classification of Educational Goals. In *Taxonomy of Educational Objectives: The Classification of Educational Goals*; David McKay Company: Philadelphia, PA, USA, 1956.
8. Volk, B. Ordnung von Lernzielen—Ordnung des Wissens: Die Bedeutung der Taxonomie von Bloom für die Wissenschaftlichkeit und Praxis der Hochschuldidaktik. In *Klassiker der Hochschuldidaktik?: Kartografie einer Landschaft*; Tremp, P., Eugster, B., Eds.; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2020; pp. 219–233.
9. Wunderlich, A.; Szczyrba, B. Learning-Outcomes 'Lupenrein' Formulieren. Available online: https://www.th-koeln.de/mam/downloads/deutsch/hochschule/profil/lehre/steckbrief_learning_outcomes.pdf (accessed on 18 July 2023).
10. Armstrong, P. Bloom's Taxonomy. Available online: https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/ (accessed on 18 July 2023).
11. Matthes, E. *Python 3 Crashkurs: Eine Praktische, Projektbasierte Programmiereinführung*; dpunkt.verlag: Heidelberg, Germany, 2020.
12. Raczkowski, F.; Schrape, N. Gamification. In *Game Studies*; Beil, B., Hensel, T., Rauscher, A., Eds.; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2018; pp. 313–329. ISBN 978-3-658-13497-6.
13. Alsawaier, R.S. The effect of gamification on motivation and engagement. *Int. J. Inf. Learn. Technol.* **2018**, *35*, 56–79. [CrossRef]
14. Sailer, M. (Ed.) Wirkung von Gamification auf Motivation. In *Die Wirkung von Gamification auf Motivation und Leistung*; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2016; pp. 97–126. ISBN 978-3-658-14308-4.
15. Makransky, G.; Petersen, G.B. The Cognitive Affective Model of Immersive Learning (CAMIL): A Theoretical Research-Based Model of Learning in Immersive Virtual Reality. *Educ. Psychol. Rev.* **2021**, *33*, 937–958. [CrossRef]
16. Wu, B.; Yu, X.; Gu, X. Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *Br. J. Educ. Technol.* **2020**, *51*, 1991–2005. [CrossRef]
17. Weinberger, M. What Is Metaverse?—A Definition Based on Qualitative Meta-Synthesis. *Future Internet* **2022**, *14*, 310. [CrossRef]
18. Kraus, S.; Kanbach, D.K.; Krysta, P.M.; Steinhoff, M.M.; Tomini, N. Facebook and the creation of the metaverse: Radical business model innovation or incremental transformation? *Int. J. Entrep. Behav. Res.* **2022**, *28*, 52–77. [CrossRef]
19. Yue, K. Breaking down the Barrier between Teachers and Students by Using Metaverse Technology in Education. In Proceedings of the 13th International Conference on E-Education, E-Business, E-Management, and E-Learning (IC4E), Tokyo, Japan, 14–17 January 2022; ACM: New York, NY, USA, 2022; pp. 40–44, ISBN 9781450387187.
20. Fernandez, C.B.; Hui, P. Life, the Metaverse and Everything: An Overview of Privacy, Ethics, and Governance in Metaverse. In Proceedings of the IEEE 42nd International Conference on Distributed Computing Systems Workshops (ICDCSW), Bologna, Italy, 10 July 2022; IEEE: Piscataway, NJ, USA, 2022; pp. 272–277, ISBN 978-1-6654-8879-2.
21. Benford, S. Metaverse: Five Things to Know: And What It Could Mean for You. Available online: https://theconversation.com/metaverse-five-things-to-know-and-what-it-could-mean-for-you-171061 (accessed on 18 July 2023).
22. Billinghurst, M. The Metaverse Will Have Arrived When a Avatar Created on an Adobe Platform Will Be Able to Walk from a Facebook/Meta Social Space into a SteamVR Game, and Be Viewed in AR/VR Headsets from Apple, Microsoft, Vive and Others. It Will Be a Completely Open Platform. Available online: https://twitter.com/marknb00/status/1453845441192230912 (accessed on 18 July 2023).
23. Parisi, T. The Seven Rules of the Metaverse. Available online: https://medium.com/meta-verses/the-seven-rules-of-the-metaverse-7d4e06fa864c (accessed on 18 July 2023).
24. Buchholz, F.; Oppermann, L.; Prinz, W. There's more than one metaverse. *i-com* **2022**, *21*, 313–324. [CrossRef]
25. Huynh-The, T.; Gadekallu, T.R.; Wang, W.; Yenduri, G.; Ranaweera, P.; Pham, Q.-V.; Da Costa, D.B.; Liyanage, M. Blockchain for the metaverse: A Review. *Future Gener. Comput. Syst.* **2023**, *143*, 401–419. [CrossRef]
26. Weber-Lewerenz, B.C. (Ed.) Bauwesen 4.0—Schlüsselfaktoren für den digitalen Wandel. In *Wertakzente im Bauwesen 4.0*; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2022; pp. 215–407. ISBN 978-3-658-38237-7.
27. Díaz, J.E.M.; Saldaña, C.A.D.; Ávila, C.A.R. Virtual World as a Resource for Hybrid Education. *Int. J. Emerg. Technol. Learn.* **2020**, *15*, 94–109. [CrossRef]
28. RWTH Aachen University—Lehr—& Forschungsgebiet Ingenieurhydrologie. MyScore: Avatar Basiertes Lehren und Lernen. Available online: https://vredu.lfi.rwth-aachen.de/ (accessed on 8 July 2023).
29. Kruse, R.; Schmidt, S. uniVERSEty: Entwicklung, Etablierung und Vernetzung von Virtuellen Räumen an Hochschulen. Available online: https://universety.org/ (accessed on 8 July 2023).
30. Müser, S.; Fehling, C.D. AR/VR.nrw—Augmented und Virtual Reality in der Hochschullehre. *HMD* **2022**, *59*, 122–141. [CrossRef]
31. Hellriegel, J.; Čubela, D. Das Potenzial von Virtual Reality für den schulischen Unterricht—Eine konstruktivistische Sicht. *MedienPädagogik* **2018**, 58–80. [CrossRef]

32. Chavez, B.; Bayona, S. Virtual Reality in the Learning Process. In *Trends and Advances in Information Systems and Technologies*; Rocha, Á., Adeli, H., Reis, L.P., Costanzo, S., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 1345–1356. ISBN 978-3-319-77711-5.
33. Hamilton, D.; McKechnie, J.; Edgerton, E.; Wilson, C. Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *J. Comput. Educ.* **2021**, *8*, 1–32. [CrossRef]
34. Müser, S.; Maiero, J.; Fehling, C.D.; Gilbert, D.; Eroglu, S.; Bachmann, D.; Wiederspohn, S.; Meyer, J. Konzeption und Evaluation einer virtuellen Lernumgebung für die Hochschullehre. *MedienPädagogik* **2023**, *51*, 345–372. [CrossRef]
35. Johnston, A.P.R.; Rae, J.; Ariotti, N.; Bailey, B.; Lilja, A.; Webb, R.; Ferguson, C.; Maher, S.; Davis, T.P.; Webb, R.I.; et al. Journey to the centre of the cell: Virtual reality immersion into scientific data. *Traffic* **2018**, *19*, 105–110. [CrossRef] [PubMed]
36. Li, M.; Yu, Z. A systematic review on the metaverse-based blended English learning. *Front. Psychol.* **2022**, *13*, 1087508. [CrossRef]
37. Hwang, S.; Koo, G. Art marketing in the metaverse world: Evidence from South Korea. *Cogent Soc. Sci.* **2023**, *9*, 2175429. [CrossRef]
38. Koo, H. Training in lung cancer surgery through the metaverse, including extended reality, in the smart operating room of Seoul National University Bundang Hospital, Korea. *J. Educ. Eval. Health Prof.* **2021**, *18*, 33. [CrossRef] [PubMed]
39. Choi, H.; Kim, S. A content service deployment plan for metaverse museum exhibitions—Centering on the combination of beacons and HMDs. *Int. J. Inf. Manag.* **2017**, *37*, 1519–1527. [CrossRef]
40. De Graaf, H. Social Inclusion through Games and VR. In Proceedings of the 8th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), Barcelona, Spain, 7–9 September 2016; IEEE: Piscataway, NJ, USA, 2016; pp. 1–2, ISBN 978-1-5090-2722-4.
41. Siyaev, A.; Jo, G.-S. Neuro-Symbolic Speech Understanding in Aircraft Maintenance Metaverse. *IEEE Access* **2021**, *9*, 154484–154499. [CrossRef]
42. Lee, H.; Woo, D.; Yu, S. Virtual Reality Metaverse System Supplementing Remote Education Methods: Based on Aircraft Maintenance Simulation. *Appl. Sci.* **2022**, *12*, 2667. [CrossRef]
43. Jovanović, A.; Milosavljević, A. VoRtex Metaverse Platform for Gamified Collaborative Learning. *Electronics* **2022**, *11*, 317. [CrossRef]
44. Gather Presence Inc. Build a Space That Brings Your Class Together. Available online: https://www.gather.town/use-cases/education (accessed on 26 June 2023).
45. Thomas, O.; Metzger, D.; Niegemann, H. (Eds.) *Digitalisierung in der Aus- und Weiterbildung: Virtual und Augmented Reality für Industrie 4.0*, 1st ed.; Springer: Berlin/Heidelberg, Germany, 2018; ISBN 978-3-662-56551-3.
46. Mulders, M. Investigating learners' motivation towards a virtual reality learning environment: A pilot study in vehicle painting. In Proceedings of the IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR), Utrecht, The Netherlands, 14–18 December 2020; IEEE: Piscataway, NJ, USA, 2020; pp. 390–393, ISBN 978-1-7281-7463-1.
47. Makransky, G.; Terkildsen, T.S.; Mayer, R.E. Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learn. Instrum.* **2019**, *60*, 225–236. [CrossRef]
48. Röthler, D. Informelle Begegnung in hybriden Bildungs-Settings. In *Hybrid, Flexibel und Vernetzt?* Egger, R., Witzel, S., Eds.; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2022; pp. 39–47. ISBN 978-3-658-37203-3.
49. Hennig-Thurau, T.; Aliman, D.N.; Herting, A.M.; Cziehso, G.P.; Linder, M.; Kübler, R.V. Social interactions in the metaverse: Framework, initial evidence, and research roadmap. *J. Acad. Mark. Sci.* **2023**, *51*, 889–913. [CrossRef]
50. Huang, H.; Zeng, X.; Zhao, L.; Qiu, C.; Wu, H.; Fan, L. Fusion of Building Information Modeling and Blockchain for Metaverse: A Survey. *IEEE Open J. Comput. Soc.* **2022**, *3*, 195–207. [CrossRef]
51. Kit, K.T. Sustainable Engineering Paradigm Shift in Digital Architecture, Engineering and Construction Ecology within Metaverse. *World Acad. Sci. Eng. Technol.* **2022**, *16*, 112–115.
52. Wang, X.; Wang, J.; Wu, C.; Xu, S.; Ma, W. Engineering Brain: Metaverse for future engineering. *AI Civ. Eng.* **2022**, *1*, 2. [CrossRef]
53. Chen, Y.; Huang, D.; Liu, Z.; Osmani, M.; Demian, P. Construction 4.0, Industry 4.0, and Building Information Modeling (BIM) for Sustainable Building Development within the Smart City. *Sustainability* **2022**, *14*, 10028. [CrossRef]
54. Zhang, R.; Wen, K.; Cai, R.; Liu, H. The Application of Metaverse in the Construction Industry: Exploring the Future Architectural Trends of Virtual and Real Integration. *J. Civ. Eng. Urban Plan.* **2023**, *5*, 65–72. [CrossRef]
55. Moradi, M.A.; Niazkar, N.; Dehmardan, A. Blockchain, a transformation of new financing and management progress of megaprojects in the context of smart contracts with the usage of metaverse and oracle. In Proceedings of the European Conference on Computing in Construction, Turin, Italy, 24 July 2022; University of Turin: Turin, Italy, 2022.
56. Baghalzadeh Shishehgarkhaneh, M.; Keivani, A.; Moehler, R.C.; Jelodari, N.; Roshdi Laleh, S. Internet of Things (IoT), Building Information Modeling (BIM), and Digital Twin (DT) in Construction Industry: A Review, Bibliometric, and Network Analysis. *Buildings* **2022**, *12*, 1503. [CrossRef]
57. Chen, Y.; Wang, X.; Liu, Z.; Cui, J.; Osmani, M.; Demian, P. Exploring Building Information Modeling (BIM) and Internet of Things (IoT) Integration for Sustainable Building. *Buildings* **2023**, *13*, 288. [CrossRef]
58. Moon, P.-J.; Kong, H.-S. Effects of fire fight safety education when applied metaverse in Korea: Focusing on the construction industry. *J. Educ. e-Learn. Res.* **2023**, *10*, 344–351. [CrossRef]
59. Liu, Z.; Gong, S.; Tan, Z.; Demian, P. Immersive Technologies-Driven Building Information Modeling (BIM) in the Context of Metaverse. *Buildings* **2023**, *13*, 1559. [CrossRef]

60. Johansson, M.; Roupé, M.; Tallgren, M.V. From BIM to VR—Integrating immersive visualizations in the current design process. In *eCAADe 2014: Fusion, Proceedings of the 32nd International Conference on Education and Research in Computer Aided Architectural Design in Europe (eCAADe), Newcastle upon Tyne, UK, 10–12 September 2014*; Thompson, E.M., Ed.; eCAADe: Newcastle upon Tyne, UK, 2014; Volume 2, pp. 261–269.
61. Wu, T.; Hao, F. Edu-Metaverse: Concept, architecture, and applications. *Interact. Learn. Environ.* **2023**, 1–28. [CrossRef]
62. Fernandes, F.A.; Werner, C.M.L. A Scoping Review of the Metaverse for Software Engineering Education: Overview, Challenges, and Opportunities. In *PRESENCE: Virtual and Augmented Reality*; MIT Press: Cambridge, MA, USA, 2023; pp. 1–40. [CrossRef]
63. Onecha, B.; Cornadó, C.; Morros, J.; Pons, O. New Approach to Design and Assess Metaverse Environments for Improving Learning Processes in Higher Education: The Case of Architectural Construction and Rehabilitation. *Buildings* **2023**, *13*, 1340. [CrossRef]
64. Hajirasouli, A.; Banihashemi, S. Augmented reality in architecture and construction education: State of the field and opportunities. *Int J Educ Technol High Educ* **2022**, *19*, 39. [CrossRef]
65. Tsai, M.H.; Chen, K.L.; Chang, Y.L. Development of a Project-Based Online Course for BIM Learning. *Sustainability* **2019**, *11*, 5772. [CrossRef]
66. Wu, W.; Hyatt, B. Experiential and Project-based Learning in BIM for Sustainable Living with Tiny Solar Houses. *Procedia Eng.* **2016**, *145*, 579–586. [CrossRef]
67. Biener, V.; Kalamkar, S.; Nouri, N.; Olef, E.; Pahud, M.; Hu, J.; Kristensson, P.O. Quantifying the Effects of Working in VR for One Week. *arXiv* **2022**, arXiv:2206.03189. [CrossRef]
68. European Parliament. Metaverse: Opportunities, Risks and Policy Implications. 2022. Available online: https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733557/EPRS_BRI(2022)733557_EN.pdf (accessed on 5 July 2023).
69. Sinning, H. XR-Technologien in Partizipationsverfahren—Potenziale und Restriktionen einer smarten Stadtentwicklung mit den Bürgerinnen und Bürgern. In *Mobility, Knowledge and Information Hubs in Urban and Regional Development: Proceedings of the 27th International Conference on Urban Planning, Regional Development and Information Society*; Schrenk, M., Popovich, V.V., Zeile, P., Elisei, P., Beyer, C., Ryser, J., Eds.; CORP—Competence Center of Urban and Regional Planning: Schwechat, Austria, 2022; ISBN 978-3-9504945-1-8.
70. Dwivedi, Y.K.; Kshetri, N.; Hughes, L.; Rana, N.P.; Baabdullah, A.M.; Kar, A.K.; Koohang, A.; Ribeiro-Navarrete, S.; Belei, N.; Balakrishnan, J.; et al. Exploring the Darkverse: A Multi-Perspective Analysis of the Negative Societal Impacts of the Metaverse. *Inf. Syst. Front.* **2023**, 1–44. [CrossRef]
71. Schaack, J. Welche Gesetze Brauchen Wir im Metaverse? Available online: https://www.weltderwunder.de/welche-gesetze-brauchen-wir-im-metaverse/ (accessed on 5 July 2023).
72. Sweller, J. Element Interactivity and Intrinsic, Extraneous, and Germane Cognitive Load. *Educ. Psychol. Rev.* **2010**, *22*, 123–138. [CrossRef]
73. Mayer, R.E. (Ed.) Cognitive Theory of Multimedia Learning. In *The Cambridge Handbook of Multimedia Learning*; Cambridge University Press: Cambridge, UK, 2014; pp. 43–71. ISBN 9781139547369.
74. Baddeley, A. Working memory: Theories, models, and controversies. *Annu. Rev. Psychol.* **2012**, *63*, 1–29. [CrossRef]
75. Eichler, S.; Schlauer, J.; Tillmann, M.; Albrecht, M.; Bass, C.; Bliesch, F.; Zoll, M.; Classen, D.; Fell, T.; Gottschalk, A. *Metaverse & Lernen: Ein- und Ausblicke in die Zukunft des Corporate Learnin*; Bitkom e. V: Berlin, Germany, 2023; Available online: https://www.bitkom.org/sites/main/files/2023-03/BitkomLeitfadenMetaverseundLernen.pdf (accessed on 6 July 2023).
76. Anderie, L.; Hönig, M. *Untersuchungen zum Potenzial von Metaverse*; Frankfurt University of Applied Sciences, Faculty of Business and Law: Frankfurt, Germany, 2023.
77. Zhang, X.; Chen, Y.; Hu, L.; Wang, Y. The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Front. Psychol.* **2022**, *13*, 1016300. [CrossRef]
78. Lv, Z.; Qiao, L.; Li, Y.; Yuan, Y.; Wang, F.-Y. BlockNet: Beyond reliable spatial Digital Twins to Parallel Metaverse. *Patterns* **2022**, *3*, 100468. [CrossRef]
79. Shin, D. The actualization of meta affordances: Conceptualizing affordance actualization in the metaverse games. *Comput. Hum. Behav.* **2022**, *133*, 107292. [CrossRef]
80. Jeong, Y.; Choi, S.; Ryu, J. Work-in-progress—Design of LMS for the Shared Campus in Metaverse Learning Environment. In Proceedings of the 8th International Conference of the Immersive Learning Research Network (iLRN), Vienna, Austria, 30 May–4 June 2022; IEEE: Piscataway, NJ, USA, 2022; pp. 1–3, ISBN 978-1-7348995-3-5.