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Virtual Worlds in Education - A systematic Literature Review

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Research Paper

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Abstract

Virtual worlds (VWs) are no novum in higher education but regain interest through COVID-19 restrictions, emerging technologies, and the metaverse hype. Therefore, we conduct a systematic literature review to gain the current status quo of research in higher and further education to identify the educational activities, research areas, learning environments, technologies toward the metaverse, subjects taught, and the current state of design knowledge. The initially found 587 records were systematically filtered to 89 fully coded articles. Based on our results, we identify research gaps and derive research streams. Our results reveal a lack of research on social integration, course design, non-technical target groups, and general design knowledge within the given context. The metaverse trend has reached educational research in the way that from 2016 onwards, new technologies are investigated selectively for educational purposes.

Keywords: Virtual World, Metaverse, Education, Collaboration, Literature Review.

1 Introduction

Due to the COVID-19 pandemic, educational institutions that had formerly preferred face-to-face teaching had to switch to online formats quickly (Kinnett and Steinbach, 2021). This led to high investments in digitalization and enhanced flexibility. Both are reasons why educational institutions stick to online solutions even after the pandemic (Luebcke et al., 2022). With increased online learning shares, social integration becomes more challenging (Rinn et al., 2022). Successful social integration is a major factor in students' retention and therefore socially relevant (Tinto, 1975; Isleib et al., 2019).

Virtual worlds (VW) are digital environments mimicking physical spaces where people can interact with other individuals and objects (Lee, 2004; Bainbridge, 2007). Due to VWs' ability to create social presence, VWs could reinforce social integration (Girvan et al., 2013). Another reason why VWs regain research interest is the metaverse hype, also reflected in the Gartner Hype Cycle (Perri, 2022). Besides COVID-19, this trend is driven by technological advances such as virtual and augmented reality (Wohlgenannt et al., 2020). These technologies complement the VWs toward the metaverse vision. VWs have been researched and implemented in practice for years (Schultze et al., 2008; Kohler et al., 2011). In particular, *Second Life* (SL) gained substantial attention in the 2000s in diverse domains including education (Schultze et al., 2008; Stieglitz and Lattemann, 2011). There are literature reviews on VWs in education that are outdated (e.g., Dalgarno and Lee, 2010; Hew and Cheung, 2010; Clutterbuck et al., 2015), unsystematic (Dalgarno and Lee, 2010), include a low number of articles (Hew and Cheung, 2010 with 15 articles), or have a very specific focus (Clutterbuck et al., 2015). Current articles on the metaverse in education discuss potential application areas including social aspects like social activities, events, and interaction (Hwang and Chien, 2022; Zhang et al., 2022). These articles take a future-oriented perspective. Therefore, we address the lack of an up-to-date overview of current research on VWs and the metaverse. We also consider social aspects, which have increased in importance since the outbreak of COVID-19. Hence, we conduct a systematic literature review (SLR) focusing on multi-user environments.

We aim to identify existing research for scholars and practitioners in the field to build upon. Based on this state-of-the-art, we intend to identify research gaps. We derive recommendations for future implementations of VWs in practice and contribute to the knowledge base in research. Therefore, we address the following two **research questions (RQs).**

RQ1: What is the status quo of research on virtual worlds in multi-user environments?

RQ2: What research streams can be derived from that status quo of research?

The remainder of the article is structured as follows. First, we describe the theoretical background of VWs and related concepts (Chapter 2). In Chapter 3, we will explain our methodological approach to conducting the SLR. Chapter 4 focuses on the results for different foci building on the taxonomy of Duncan et al. (2012) for VWs to contribute to answering RQ1. After that, we will discuss the results and derive future research streams to answer RQ2. The conclusion (Chapter 5) summarizes our contribution.

2 Theoretical Background

There are several different understandings of VWs and related terms (e.g., virtual environment), leading to the lack of a clear definition (Girvan, 2018). This inconsistent use in research, especially in education, makes results ambiguous or even impossible to build upon (Oliver, 2005; Girvan, 2018). To overcome this as much as possible, we follow the rather generic definition of Pannicke and Zarnekow (2009), that VWs are 3D environments that can be entered using avatars to navigate and communicate with. The communication aspect imputes multi-user capabilities and synchronicity. Avatars are an inherent part of VWs; they embody users, enable social interaction, and promote immersion and presence (Girvan and Savage, 2019). The VW is usually displayed on a standard computer screen (Okutsu et al., 2013). The related term virtual reality (VR) adds visual, aural, and haptic devices to improve immersion (Riva et al., 2007). The popularity of VWs in education arises from the advantages these solutions have. Besides the general advantages, like presence, immersion, and location independence (e.g., Lattemann and Stieglitz, 2012), there are more specific ones. These are dependent on the application scenario, like risk-free medical training (e.g., Bridge et al., 2007), action-oriented training on virtual 3D models that simulate real machines (e.g., Pletz and Zinn, 2020) or laboratories (Liu and Zhong, 2014) as well as the suitability for social interaction and networking (e.g., Mantymaki and Merikivi, 2010). The advantages in education do not mainly arise from the VW itself but from the pedagogical concept (Kerres and Preußler, 2012). The hype-term *metaverse* is blurry and in some papers used as a synonym for VW (e.g., Badilla Quintana and Meza Fernández, 2015; Augenstein and Morschheuser, 2022). A general definition of metaverse describes it as a “broad concept” (Davis et al., 2009, p. 91) without further specification or clear delimitation to VWs. Dionisio et al. (2013) propose a concretization by naming necessary features for connecting VWs to a metaverse, i.e., realism, ubiquity, interoperability, and scalability. Dwivedi et al. (2022) name technologies, like VR headsets or haptic devices, as a prerequisite for creating a metaverse. We conclude that VWs are a subset or a precursor of the metaverse.

3 Methodology

To answer the RQs, we conducted an SLR as proposed by Webster and Watson (2002), Page et al. (2021), and Schoormann et al. (2021). Since there is a substantial amount of research contributions, we targeted high-quality journal and conference papers covering IS, human-computer interaction (HCI), education and e-Learning, and game- and media-related outlets. Table 1 sums up our search strategy.

Scopus	"Basket of Eight"	International Journal on Human-Computer Studies
	Internet and Higher Education	International Journal of Game-Based Learning
	Smart Learning Environments	Simulation & Gaming
	Human-Computer Interaction	Media & Communication
	Computers in Human Behavior	ACM Transactions on Computer-Human Interaction
	Games & Culture	
ERIC	Computers & Education	British Journal of Educational Technology
	Journal of Computer Assisted Learning	International Journal of Virtual and Personal Learning Environments
Taylor & Francis	Journal of Research on Technology in Education	
Springer	Proceedings of DESRIST	
AIS eLibrary	Proceedings of ICIS, ECIS, PACIS, HICCS, AMCIS, Wirtschaftsinformatik	

Table 1: Databases, Journals, and Conference Proceedings searched

We performed the search in July 2022 and applied the following search string to the title, abstract, and, in case available, keywords. The synonyms for VWs in the given context were mainly extracted from Mystakidis et al. (2021), Girvan (2018), Lückemeyer (2015), and Lecon and Herkersdorf (2014). Since we found publications that use the term virtual (learning) environment synonymously with VW, we included this term in our search, although we also found authors using it as a synonym for learning management system (LMS) (e.g., Weller et al., 2005; Love and Fry, 2006; Leese, 2009; Strang, 2011). Those publications meaning an LMS were excluded subsequently since an LMS is not a VW. We connected these synonyms with an AND-operator to synonyms for education and added related words for social interaction. We combined education and social interaction with an OR-operator at the same level to ensure we included all articles covering socializing aspects, even in cases where the education aspect is not named in the title, abstract, or keywords. This was the resulting search string and its results below:

TITLE-ABS-KEY ("virtual immersive environment?" OR "virtual learning environment?" OR "immersive world?" OR "immersive education" OR "virtual environment?" OR "virtual world?" OR "metaverse" OR "immersive learning" OR "immersive online environment?" OR "virtual environment?" OR "virtual 3D environment?" OR "virtual 3D world?") AND TITLE-ABS-KEY ("Education" OR "Learning" OR "Teaching" OR "Instruction" OR "Collaboration" OR "Social Interaction" OR "Social Integration" OR "Cooperation")

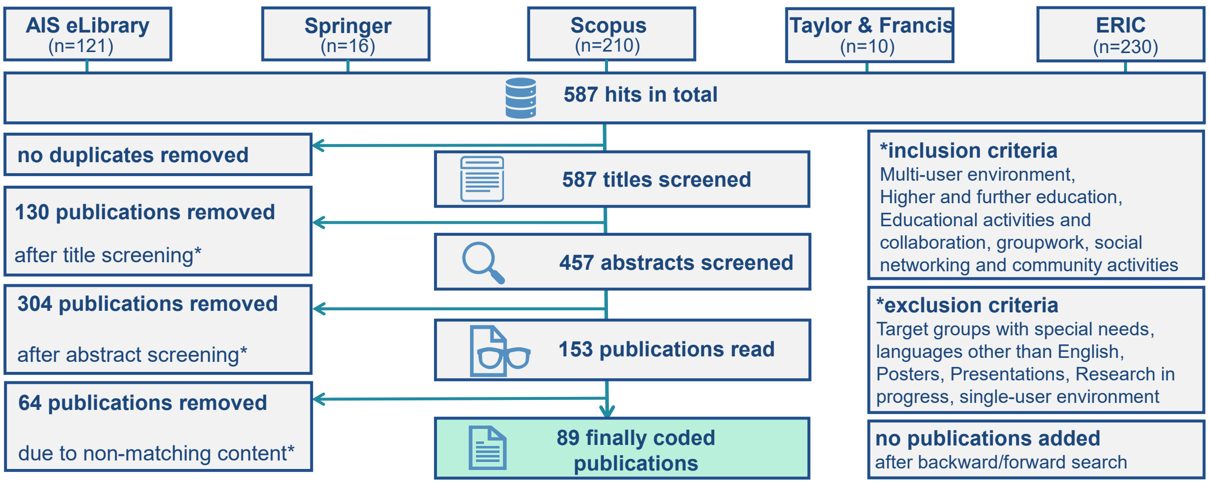

Figure 1: PRISMA Statement

The PRISMA statement (*Figure 1*) illustrates the search and selection process proposed by Page et al. (2021). The initial 587 hits contained no duplicates due to the search strategy.
The column in the middle illustrates the reduction process to relevant outlets from top to bottom. This process was controlled via predefined inclusion and exclusion criteria and peer-reviewed internally. The exclusion criteria were articles covering target groups with special needs or which explicitly describe single-user or LMS environments. Due to their special needs, we decided to exclude the numerous articles on target groups with impediments to ensure we can generalize the results. Furthermore, we excluded papers in languages other than English, outlets like posters and presentations, research in progress, and target groups other than higher and further education. With these criteria, we set a focus on the RQs and ensured that only VWs meeting our definition were included. The criteria were based on a team discussion and decision.
The coding process of the finally selected 89 publications was done using the software MAXQDA (Bandara et al., 2015; Mayring, 2020). The coding system was developed deductive at the beginning based on the taxonomy proposed by Duncan et al. (2012) and our RQs. For coding the mentions of the term *metaverse,* we used the word frequency function in MAXQDA. The code system was documented in a code manual to ensure a shared understanding while coding (Mayring, 2015). Subcategories were added exploratory in the ongoing coding process in agreement with the team (Mayring, 2020) and continuously documented in the coding manual. This coding manual consisted of the codes and the corresponding definitions and usages with an example where applicable and contained information on the categories, e.g., if mandatory. We coded the articles in August and September 2022. One "codebook author" of the team synthesized the results subsequently while checking for conformity with the coding manual.

4 Results

To answer **RQ1**, we examined the following categories:

- **(1) Educational Activities:** This category contains the types of activities used for teaching and learning. These activities might be similar to face-to-face education, like lectures in a classroom (Duncan et al., 2012), or completely different, e.g., learning in a video game (Oliver and Carr, 2009).
- **(2) Research Area:** The research area is the aspect under study, e.g., formulated as a research question (Duncan et al., 2012) or measured qualitative (e.g., Bower et al., 2017) or quantitative (e.g., Shen and Eder, 2008).
- **(3) Learning Environments:** This category names the learning environments used for prototyping and categorizes them based on their distribution. We identify underlying trends.
- **(4) Technologies toward the Metaverse:** Since the metaverse idea dilutes the boundaries between real and virtual, immersive technologies like VR play an essential role in bringing the metaverse to practice. The supporting technologies found, hint at the state of research on implementation in education. Hence, we analyze the terms and its definition in the coded papers.
- **(5) Subjects:** The subject taught, and the content also allow us to conclude the target group. Hence, we aim to point to possible research gaps and the suitability of VWs in certain areas.
- **(6) Design Knowledge:** As with any IT artifact, the question arises of how to design them. Therefore, we coded if the Design Science Research (DSR) approach was applied to identify design knowledge that was created scientifically rigorously and generalizable for other projects (Gregor, 2006; Kuechler and Vaishnavi, 2008). Furthermore, we included the kernel theories found. Kernel theories ensure scientific relevance by justifying design decisions for future developments (ibid.).

The following morphological box following Ritchey (2011) previews the coding categories.

Educational activities	Collaborative learning	Lectures	(Collaborative) simulation	Problem-based learning	Game-based learning
	Learning groups/ communities	Virtual labs	General usage	Incidental learning	
Research area	Learning outcome	Usability/ acceptance	Room/ environment design	System development	Avatar
	Framework evaluation	Collaborative community	Pedagogy	Institutional aspects	
Learning environments (LE)	Established LE	Less known developments	Own developments	Games	Not defined
Technologies toward the metaverse	Chat	VoIP	Audio/ video stream		
	File sharing	Conversational agent	Emerging technologies		
	Metaverse not mentioned	Metaverse mentioned	Metaverse defined		
Subjects	STEM	Business administration	Culture & communication		
	Social science	Teacher education	Various		
Design Knowledge	DSR applied	DSR not applied			
	Instruction and learning	Communi-cation	Behavior	HCI	Others

Table 2: Morphological Box on resulting Categories

4.1 Educational Activities

We defined *educational activities* as a mandatory category to give a complete view of any educational activity possible in higher and further education and uncover suitability and research gaps. We applied a deductive approach and summarized codes where possible. Due to our research objective including social integration, we also analyzed *learning groups or communities* and *collaborative learning*. We added *general usage* as a code exploratively and assigned that code to articles that focus on a general evaluation or the demonstration of the educational potential of VWs. One article dealt with *incidental learning*, so this category was added exploratively. The following table reveals the results:

Educational Activity	**Quantity**	**Reference Examples**
Collaborative learning	27	(Jarmon et al., 2009; Girvan et al., 2013; Bower et al., 2017)
Lectures	23	(Zhang, 2008; Herold, 2010; Pellas, 2014)
(Collaborative) simulation	21	(Limniou et al., 2008; Mon, 2010; Rogers, 2011)
Problem-based learning	13	(Dickey, 2005; Omale et al., 2009; DeMers, 2010)
Game-based learning	11	(Berns et al., 2013; Warden et al., 2013; Merchant et al., 2013)
General usage	9	(Walia et al., 2009; Nadolski et al., 2012; Sun, 2016)
Learning groups/ communities	3	(McPherson and Nunes, 2004; Zhang, 2013; Pakanen et al., 2020)
Virtual labs	3	(Mon, 2010; Mundkur and Ellickson, 2012; Liu and Zhong, 2014)
Incidental learning	1	(Thomas and Boechler, 2014)

Table 3: Results: Educational Activities

Collaborative learning is a teaching approach to make groups of learners solve a problem or complete a task (Laal and Ghodsi, 2012). The high presence of collaborative learning might result from the research focus on multi-user environments and social aspects but is also rooted in the social character of VWs (Warburton, 2009). A VW is, e.g., chosen in distance education because of its advantages in collaborative learning over other online solutions (Hu et al., 2011). Lorenzo et al. (2012) collaboratively evaluate the pedagogical value of VWs to conclude on their effectiveness. Shen and Eder (2008) investigate the intention to use the VW to evaluate the acceptance for accomplishing a group assignment. Collaborative learning has the most intersections with other methods, i.e., problem-based learning (6), game-based learning (5), and lectures (3). Intersections with problem-based learning are, e.g., DeMers (2010) which activates students to commonly fulfill tasks like creating map projections in geography. Game-based learning in combination with collaborative learning is covered by e.g., Berns et al. (2013), who designed a quiz-like activity that has to be solved in groups, and Charles et al. (2011), who integrated game-based feedback into their group work of collaborating students. The combination with lecturers is used for instructional purposes to explain the collaborative task (e.g., Lattemann and Stieglitz, 2012; Cho et al., 2015).

Lectures can be found either online only (Dickey, 2005) or in combination with face-to-face classes (Papachristos et al., 2014). They may include, e.g., discussions (Burgess et al., 2010) similar to face-to-face classes or a virtual field trip (Kumar, 2012), which goes beyond the possibilities of face-to-face.

(Collaborative) simulations include "[…] any process or technology that recreates a contextual background allowing the learner to make decisions, experience success, make mistakes, receive feedback, and gain confidence […]" (Almousa et al., 2021, p. 2). It can either be based on the standard functionalities of the VW, like Ip et al. (2008) describe running a real business in SL, or based on custom-made simulations like Pletz and Zinn (2020). They train service technicians on cyber-physical systems. Although collaborative learning is not mentioned in every case of problem-based learning, most of them describe group problem-solving scenarios (e.g., Bridge et al., 2007; Franceschi et al., 2009; Kennedy-Clark, 2011). Cheng and Wang (2011) present a virtual supermarket with a CA as a virtual client that allows students to cultivate their problem-solving abilities.

Problem-based learning makes the learner (usually a group) actively solve a real-world problem (Woods, 1994). Since the VW imitates the real world, the scenarios possible in problem-based learning are diverse. Students can practice solving complex problems repeatedly in a real-life environment (Cheng and Wang, 2011). It is used, e.g., for artifact construction (Girvan and Savage, 2019) or for radiotherapy students to practice virtually in a group (Bridge et al., 2007).

Game-based learning "[…] approaches seek to leverage the fun aspects of games into an educational learning process […]" (Charles et al., 2011, p. 639). We found it took place either in commercial games, like described in a study by Oliver and Carr (2009) in WoW or own developed game-like environments, like the VR-based culture training by Gao et al. (2021), but also in established environments, like SL where a crossword puzzle is implemented like in the article by Franceschi et al. (2009).

General usage articles investigate the overall opportunities for learning in VWs (Munoz Rosario et al., 2008, 2009) and the acceptance (Saeed et al., 2009), but also address the barriers from different perspectives like Technology, Culture or Economy (Warburton, 2009).

Learning groups or communities are self-organized groups with collective self-set learning targets (Rohde, 2003). In (virtual) communities, members feel belonging and attachment to the group, whereas the purpose of the community is not predefined (Blanchard, 2007). McPherson and Nunes (2004) used their own developed solution for a cohort to connect with others to support the learning process. Pakanen et al. (2020) designed a virtual copy of the real campus which should bring together participants from different faculties and which should promote getting to know new students. Zhang (2013) offered SL for voluntarily practicing foreign language skills with peers beyond mandatory lessons.

Virtual labs, e.g., in chemistry, virtually replicate the real laboratory environment (Dalgarno et al., 2009). Liu and Zhong (2014) developed a prototype of a virtual chemistry lab. Mundkur and Ellickson (2012) describe their project to create a virtual laboratory to foster experiential learning and prepare students for real-life complexity in further education. Mon (2010) generally constitutes that SL would offer a virtual lab for investigative research. In summary, Liu and Zhong (2014) contributed the only article describing the actual development of a virtual lab with the corresponding apparatus.

Incidental learning is unintentional learning while doing something else (Thomas and Boechler, 2014). Thomas and Boechler (2014) investigated the influence of learning styles and digital literacy on incidental learning. Learning style is the characteristic technique a student shows for learning (Hartley, 1998).

4.2 Research Area

The research area was also defined as mandatory, for the same reason as the previous category on educational activities. The deductive foundation was exploratively supplemented and clustered. Since a sense of identification with the avatar is positively related to the feeling of presence (Nadolny and Childs, 2014), all articles concerning identity, embodiment, and presence were subsumed under the code *avatar*. Since the perceived ease of use is one factor influencing acceptance in the Technology Acceptance Model (TAM) by Davis (1989), usability and acceptance studies are inseparable and therefore coded jointly. Due to our additional focus on social integration, we added the code *collaborative community*. The results are revealed in the following table.

Research Area	Quantity	Reference Examples
Learning outcome	49	(Ip et al., 2008; Hu et al., 2011; Magana et al., 2019)
Usability/acceptance	13	(Zuiker and Ang, 2011; Pellas, 2014; Shonfeld and Greenstein, 2021)
Room/environment design	13	(De Lucia et al., 2009; Chen et al., 2011; Bower et al., 2017)
Avatar	9	(Omale et al., 2009; Kartiko et al., 2010; Traphagan et al., 2010)
System development	8	(Warden et al., 2013; Liu and Zhong, 2014; Sun, 2016)
Framework evaluation	2	(Esteves et al., 2011; Badilla Quintana and Meza Fernández, 2015)
Collaborative community	2	(McPherson and Nunes, 2004; McClannon et al., 2013)
Pedagogy	2	(Mon, 2010; Girvan and Savage, 2019)
Institutional aspects	1	(Pakanen et al., 2020)

Table 4: Results: Research Area

Learning outcome is measured, e.g., via quizzes (Jestice and Kahai, 2010), comparing exam scores with face-to-face participants (Okutsu et al., 2013), pre-post-tests on learning and motivation (Berns et al., 2013), or own developed items for perceived achievement (Bridge et al., 2007). Jestice and Kahai (2010) use validated items on perceived learning (Alavi, 1994).

Usability/acceptance: The TAM by Davis (1989) is the most common acceptance model in the coded articles (e.g., Munoz Rosario et al., 2008; Shen and Eder, 2008; Saeed et al., 2009; Saeed and Sinnappan, 2013; Pletz and Zinn, 2020). Saeed et al. (2009) propose an extension to the TAM, including hedonic consumption behaviors for entertainment-oriented technologies, and empirically evaluate this model. In a later study, Saeed and Sinnappan (2013) build upon that and extended another factor, namely utilitarian behavior. Shen and Eder (2008) extended TAM by perceived enjoyment. The usability studies by Liu and Zong (2014) focus on multi-level adaptation by progressively adding functionality to not overload educators. Warden et al. (2016) examine that differences in gender, software ownership, and gaming experience lead to slight disadvantages in VW lectures that can be easily overcome by offering training.

Room/environment design: Examples of room and environment design are Papachristos et al. (2014) who evaluate a university auditorium against an open-air setting for lectures. Another study on place design was conducted by Prasolova-Førland (2008) in the context of collaboration. Walia et al. (2009) conducted an explorative study on designing VWs, including project management plus organizational and institutional aspects.

Avatar design is an important aspect of online identity and perceived presence. DeNoyelles and Seo (2012) conducted a study on online identity and the difference between gamers and non-gamers. The study of Nadolny and Childs (2014) emphasizes the importance of identity for developing a sense of presence. Most studies in that field address the concept of presence (e.g., Franceschi et al., 2009; Burgess et al., 2010; Cho et al., 2015; Gao et al., 2021).

System development articles either focus on the underlying architecture (Nadolski et al., 2012) or the VW development itself (Almousa et al., 2021), but the development process can also be the task for the students in the course (Scullion et al., 2014). Toolkits like Open Wonderland, OpenSim, or HeroEngine support the development process (Scullion et al., 2014).

Framework evaluation: Badilla Quintanza and Meza Fernández (2015) propose a pedagogical model to create virtual environments where participants can train their teaching practices. Esteves et al. (2011) present a framework for teaching and learning computer programming in SL.
Collaborative community development and the corresponding factors are evaluated in the research by McClannon et al. (2013). McPherson and Nunes (2004) specifically examined the students' social interaction and their development of social networks in parallel communication channels.
Pedagogy in the sense of course design is rarely found. Mon (2010) contributes a conceptual article with alternative teaching options, including creative activities. Girvan and Savage (2019) apply the constructivist theory by making learners create persistent objects using the block-based programming tool *Scratch for Second Life*.
Institutional aspects addressed cover the needs of researchers and staff members for the design, service, and functionalities of a hybrid reality approach (Pakanen et al., 2020).

4.3 Learning Environments

This category was mandatory for the same reason as the previous one. All subcategories were added exploratively and clustered at the end. The learning environments we found can be categorized as shown in Table 5. Two further articles (Munoz Rosario et al., 2009; Lorenzo et al., 2012) did not define the environment used.

Learning Environments	**Quantity**	**Reference Examples**
Established learning environments	55	(Zhang, 2008; Mon, 2010; Stieglitz and Lattemann, 2011)
Own developments	29	(Bridge et al., 2007; Pletz and Zinn, 2020; Gao et al., 2021)
Less known developments	3	(Zuiker and Ang, 2011; Kennedy-Clark, 2011; Shonfeld and Greenstein, 2021)
Video games	1	(Oliver and Carr, 2009)

Table 5: Results: Learning Environments

Established learning environments are those that are researched by various authors like *Second Life* and *Activeworlds* or commercial solutions like *AvayaLive*. 47 articles were based on SL by Linden Lab, which gained that importance due to the high user numbers and the ability to create their own content (Lattemann and Stieglitz, 2012). Besides SL, we found other established solutions, i.e., *Activeworlds* (Dickey, 2005; Prasolova-Førland, 2008; Munoz Rosario et al., 2009; Omale et al., 2009; McClannon et al., 2013), *There* (Munoz Rosario et al., 2008, 2009), *TelePlace* (McClannon et al., 2013), *AvayaLive* (Bower et al., 2017), and *Finpeda Virtual Space* (Pakanen et al., 2020).
Own developments are when the development itself is the focus of the article (e.g., Nadolski et al., 2012) or when very specific features are evaluated, e.g., motion training with full-body motion sensing (Sun, 2016) or haptic feedback (Magana et al., 2019). Toolkits support the development process for building the virtual world in some cases. *OpenSim* was used for that purpose and named in six articles (e.g., Hu et al., 2011; Koutsabasis and Vosinakis, 2012; Berns et al., 2013), and *Open Wonderland* in five publications (e. g., Chen et al., 2011; Parsons and Stockdale, 2012; Warden et al., 2013). Game-based learning and gamification make learning more engaging (Chen, 2022), but game-based toolkits could not be found, although ROBLOX is seen as a first step toward the metaverse (Dean, 2021).
Less-known developments like *TEC Island* are less distributed than established solutions but open to the public and free of charge (TEC ISLAND, 2022) or developed for several research projects like *Quest Atlantis* (Zuiker and Ang, 2011). We found *Virtual Singapura* (Kennedy-Clark, 2011), *TEC Island* (Shonfeld and Greenstein, 2021), and *Quest Atlantis* (Zuiker and Ang, 2011).
Video games: *World of Warcraft (WoW)* was the only commercial video game. Oliver and Carr (2009) investigated the social effects on learning on couples playing the game.
Figure 2 illustrates the publication year of all coded articles and the proportion of those based on SL. Especially in the hype years 2009 and 2010, SL made up 87% which makes us conclude that SL was one driver for VWs in higher and further education. Although there has been a regain of research interest

since 2019, most likely due to COVID-19 restrictions, only one article has included SL since 2016. After the SL hype in 2011, own developments gained importance for more flexibility, e.g., to include new technologies analyzed in the following section.

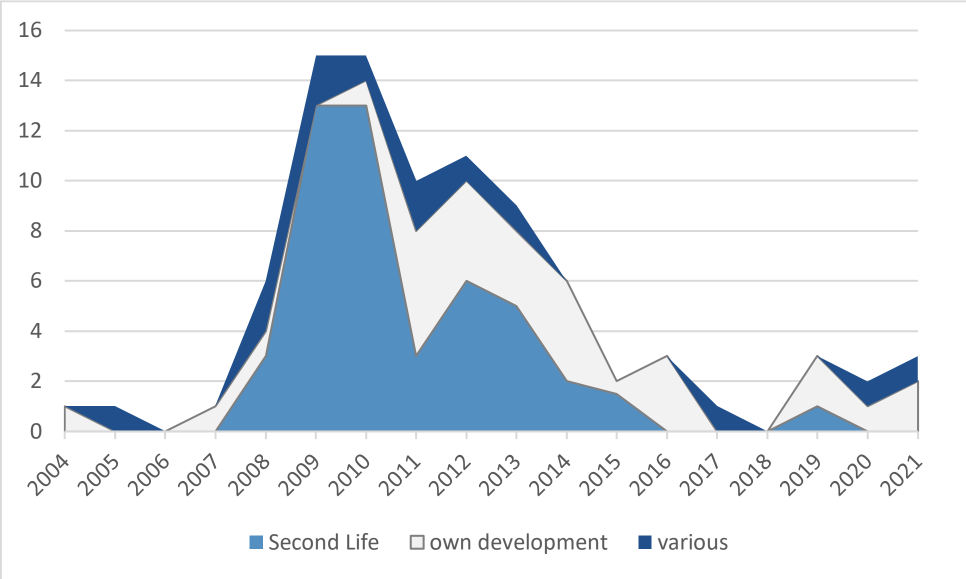

Figure 2: Learning Environments per Year of Publishing (Stacked Area Diagram)

4.4 Technologies toward the Metaverse

Dwivedi et al. (2022) consider emerging technologies as a foundation for the metaverse. Therefore, the technologies in this category were coded exploratively to achieve actuality, and we distinguish two different states, first the plain mentioning of the term *metaverse* and second, the presence of a definition for further content analysis.

Although the term *metaverse* is found in one publication (Badilla Quintana and Meza Fernández, 2015), no definition is included. Instead, VW is defined, and metaverse is used as a synonym.

The technologies that are covered in the articles can be separated into two sections, before and after 2016. The shift from SL (see Figure 2) to own developments leads to greater flexibility for implementing emerging technologies. Therefore, we structured the technologies accordingly.

Prior 2016 or commonly used: The technologies in use are *chat* (31 articles), *VoIP* (13), *audio or video streaming functionality* (10), *file sharing* (6), *Conversational Agents (CAs)* (2), *VR* (2), *CAVE* (1).

Chat functionality usage is described for different purposes, e.g., for evaluation purposes (Koutsabasis and Vosinakis, 2012), for instructions (Kumar, 2012), or for peer collaboration (Badilla Quintana and Meza Fernández, 2015). Kennedy-Clark (2011) in contrast experiences that a chat functionality can be distracting provoking off-task messages. VoIP is used, e.g., for bi-directional instructor communication (Almousa et al., 2021), for collaboration purposes (Nelson et al., 2011) or unidirectional instructor communication, while participants communicate via chat (De Lucia et al., 2009). Esteves et al. (2011) experience the necessity for tranquility when using VoIP and refer to the chat functionality in case of noisy surroundings. Audio and video stream integration is found, e.g., for videoconferencing via webcam (Lorenzo et al., 2012), for presenting photos and audio recordings to support learning vocabulary (Berns et al., 2013) or for providing multimedia content (De Lucia et al., 2009). File sharing is mainly described as exchanging or co-working on documents or resources. There is no description of how this is done in the corresponding environment (Mundkur and Ellickson, 2012; McClannon et al., 2013). Using third-party tools like Google Documents (Lorenzo et al., 2012) or Moodle for distributing course documents (Badilla Quintana and Meza Fernández, 2015) are alternatives to the built-in functionalities of the VW. CAs are intelligent dialogue systems using natural language to communicate with the user, either text or voice-based (McTear et al., 2016; Gnewuch et al., 2017). We found a CA as a virtual customer in a problem-based learning scenario (Cheng and Wang, 2011) and for quest introductions in a game-based learning scenario (Nelson et al., 2011). Virtual reality (VR) emerged in research with two articles (e.g., Bridge et al., 2007), with more to follow. CAVE is a system that achieves virtual reality via wall projection in a cubic room with the advantage of allowing one-to-many presentations for all persons in the room (Cruz-Neira et al., 1993) and was used for visualizing chemical reactions (Limniou et al., 2008).

From 2016 onwards: In the articles from 2016, after the SL era with own developments dominating, we found more advanced technologies, namely *VR* (5 articles), *full-body motion sensing* (2), *cyber-physical systems* (1), *force feedback* (1) and *eye tracking* (1). The VR-based research done by Almousa et al. (2021) is in medical training, where simulators offer the opportunity to train procedures in a risk-free environment. Pletz and Zinn (2020) practice repair operations on a cyber-physical system with VR support. A cyber-physical system "[…] addresses the close interaction and deep integration between the cyber components such as sensing systems and the physical components such as varying environment and energy systems" (cf. IEEE, 2022). Gao et al. (2021) developed a system for experiencing cultural differences in a gamified learning environment. For full-body motion sensing, capturing body gestures, in both cases Microsoft XBOX Kinect hardware was used in an own developed environment (Ke et al., 2016; Sun, 2016). Sun (2016) evaluates the learning performance of motion training, Ke et al. (2016) combined motion sensing with eye tracking using the ASL Mobile Eye Tracking hardware in a mixed reality setup. The article, including force feedback, deals with ultrasonography gestures in a simulation scenario (Ourahmoune et al., 2019).

4.5 Subjects

We exploratively coded the subjects and clustered them at the end of the coding process. The resulting subcategories are reflected in the table. We describe the remainder category below.

Subjects	**Quantity**	**Reference Examples**
STEM incl. informatics	27	(Chen et al., 2010; DeMers, 2010; Pletz and Zinn, 2020)
Business administration	13	(Shen and Eder, 2008; Webber, 2010; Lattemann and Stieglitz, 2012)
Culture & communication	13	(Dickey, 2005; Berns et al., 2013; Gao et al., 2021)
Social science	10	(Jamaludin et al., 2009; Rogers, 2011; Ourahmoune et al., 2019)
Teacher education	9	(Burgess et al., 2010; Zuiker and Ang, 2011; Kumar, 2012)

Table 6: Results: Subjects

Besides the dominance of Science Technology Engineering Mathematics (STEM) subjects, we found two different perspectives of teacher education: the most common one is that (pre-service) teachers are educated in using VWs for the lessons they hold (e.g., Kumar, 2012; Papachristos et al., 2014; Ke et al., 2016). The other one is for teacher education itself with the content they deliver in their classes, e.g., English Language and Literature (Cho et al., 2015). In the remainder category, we found motion training (Sun, 2016), design courses (Triggs et al., 2010; Koutsabasis and Vosinakis, 2012), scientific research and ethical decision-making (Nadolny and Childs, 2014), as well as media studies (Herold, 2010).

4.6 Design Knowledge

Only one article uses a DSR approach to describe the iterative development of a VW prototype for agile programming (Parsons and Stockdale, 2012). As it is relevant to refer to existing theories when designing artifacts, we additionally analyzed used kernel theories. 43 documents were solidly based on at least one of the upcoming kernel theories. The explorative coding resulted in kernel theories from the following four areas: *instruction and learning* (30 articles), *communication* (11), *HCI* (5), and *behavioral theories* (7), which we elaborate on in the following. In addition, DeNoyelles and Seo (2012) refer to the theory of gender identity (Butler, 1987) to argue that learners, e.g., design their avatars influenced by the norms of the real world.

Instruction and learning theories: Different learning theories address how learning takes place, i.e., how knowledge is communicated, and skills, and competencies are developed. For many years, learning theories were shaped primarily by the approaches of behaviorism (e.g., Chen et al., 2010), cognitivism (e.g., Cheng and Wang, 2011), and constructivism (e.g., Stieglitz et al., 2010; Rogers, 2011; Scullion et al., 2014), which are also found in the articles. Experiential learning (Kolb, 1984) focuses on the active involvement of the students to achieve the best learning results. In VWs, it is often used to simulate real-world situations, such as difficult conversation situations (Jarmon et al., 2009). Creating a meaningful learning experience means developing social, cognitive, and teaching presence, as referenced by, e.g., Omale et al. (2009) and Traphagan et al. (2010), according to the community of inquiry model (Garrison et al., 2000). Constructionism (Papert and Harel, 1991) is inspired by constructivism, emphasizing the creation process and sharing the result with others (Amineh and Asl, 2015). Within constructionism, constructed results can be shared asynchronously due to their persistent character (Girvan et al., 2013). Cognitive load theory (Sweller, 1988) is used to explain the splitting of tasks or animations to decrease complexity (Limniou et al., 2008; Magana et al., 2019). Prasolova-Førland (2008) points out that learners perform activities initiated by a motive or need and that several variables are used to explain the success or failure of a specific activity following the activity theory (Leont'ev, 1978). Five theories are only mentioned once in the context of instruction and learning: cognitive theory of multimedia learning (Mayer, 2014) to study and explain the visual complexity in a VW presentation (Kartiko et al., 2010), situated learning theory (Lave and Wenger, 1991) emphasizes knowledge acquisition within authentic situations, such as field trips to the Forbidden City of China (Jestice and Kahai, 2010). Incidental learning happens unintended while engaging in VWs (Thomas and Boechler, 2014). Action learning process (Pedler et al., 2013) is described to analyze resulting data, and outcomes (Ip et al., 2008). Salmon's (2004) five-stage model (access and motivation, online socialization, information exchange, knowledge construction, and development) is used to structure learning activities in the virtual environment (Edirisingha et al., 2009).

Communication theories: Four different communication theories are considered. Nine articles (e.g., deNoyelles and Seo, 2012; Cho et al., 2015; Gao et al., 2021) quoted the theory of presence (Short et al., 1976) that we assign to the field of communication because that is its origin, even though it also entered the learning theory discourse (Edirisingha et al., 2009). One article refers to the social translucence of technology (Erickson and Kellogg, 2000) because VWs connect learners to enable coherent discussions (Phang and Kankanhalli, 2009). The transactional distance theory (Moore, 1980) is used once. This theory describes the relationship between teacher and learner, stating that if their interaction level decreases, learners' autonomy must increase. As a result, different instruction techniques can stimulate different transactional distances (Chen et al., 2010). Hence, reducing the transactional distances in VWs is vital for high learning results (ibid.). The media richness theory (Daft and Lengel, 1986) is mentioned once. It describes a communication media's ability to transmit information arguing that the amount of feedback and information exchange in a VW influences student learning (Chen et al., 2010).

Behavioral theories: Two articles (Saeed et al., 2009; Saeed and Sinnappan, 2013) mentioned the theory of hedonic consumption behaviors to highlight that hedonic behaviors, such as emotional involvement or enjoyment, influence the usage of VWs as it already does in other environments like games. The theory of planned behavior (Ajzen, 1985) is referenced once to clarify that learners rationally decide their intention to use a VW for educational purposes by assessing the available information (Kennedy-Clark, 2011). Lewin's (1951) field theory is used to argue that learners' behavior is influenced by familiarity with the environment. Since VWs can be designed in a way that makes it difficult to differentiate the real from the artificial, Cheng and Wang (2011) claim that a compelling VW stimulates learning. As flow describes the optimal mental state of a person which is neither over- nor under-challenging (Csikszentmihalyi, 1990), it is crucial for motivating learning and referenced in three articles (Franceschi et al., 2009; Hassell et al., 2009; Phang and Kankanhalli, 2009). Two articles (Dickey, 2005; Girvan and Savage, 2010) draw attention to scaffolding to support a more robust understanding through thought-provoking impulses like challenges that support collaboration (Girvan and Savage, 2010).

HCI theories: Two HCI theories are used: the TAM by Davis (1989) to predict attitudes toward using the VW as a novel form of technology (Shen and Eder, 2008; Saeed et al., 2009; Saeed and Sinnappan, 2013; Shonfeld and Greenstein, 2021) as well as communities of practice (Wenger, 1999) which means that a group of people share a common interest in a topic and come together to fulfill their goals. This theory explains learners' interactions in the virtual environment (Oliver and Carr, 2009).

5 Discussion of Research Gaps

Alongside our results, we identified the following research gaps to answer **RQ2**. The structure is identical to the results chapter and represents the link between the two RQs.

(1) Educational Activities: There is a clear focus on the learning outcome, especially when learning in groups (e.g., via collaborative or problem-based learning). From higher education research, the importance of social integration for students' retention is well known (Tinto, 1997) and the social character of virtual worlds is stressed (e.g., Warburton, 2009). Nevertheless, there is little research on how VWs can be used for community building and social networking supporting out-of-class activities and self-regulated learning groups. Further research is needed on how VWs can support community building and social networking mid- and long-term and how and what other communication channels can supplement the VW. The metaverse "[…] being the next generation of social connection" (Hwang and Chien, 2022 p. 1) should be included in research on social integration from a conceptional perspective, and as soon as technologies are available, from a practical view as well.

(2) Research Area: The learning outcome is measured for specific application scenarios. These prototypes are based on kernel theories in many cases, but there is a lack of general research on pedagogy in the sense of how to design a course efficiently. This is necessary to support teachers and learners in reducing the high effort in the design and the implementation of learning scenarios in VWs and a first step toward providing learners with personalized resources (Stieglitz and Lattemann, 2011; Zhang et al., 2022). Furthermore, for a broad application, e.g., every faculty of a university, organizational and institutional aspects (e.g., central class management or technical support) must be researched. This is necessary to support practitioners in the practical roll-out to create sustainable solutions beyond the prototypical use for research purposes.

(3) Learning Environments: Since the declining use of SL in research, own developments gained importance e.g., for implementing emerging technologies. Developments can be accelerated when based on toolkits. Researchers should create an overview of different toolkits for educational purposes with relevant features like room and avatar adaptability, options to implement emerging technologies, and other relevant interfaces. This overview should also include game-based kits like ROBLOX or Fortnite that are promising for educational purposes (Dean, 2021; Augenstein and Morschheuser, 2022; Chen, 2022).

(4) Technologies toward the Metaverse: The metaverse trend has reached education only in the way that emerging technologies are selectively and prototypically implemented. The potential, as described, e.g., by Hwang and Chien (2022), is not yet applied in research. This also includes the potential of AI-based technologies like CAs (Hwang and Chien, 2022; Khosrawi-Rad et al., 2022). Technologies should be systematically identified and implemented in combination to contribute to metaverse research. Although STEM education is overrepresented in research, cyber-physical systems were only found once (Pletz and Zinn, 2020). Besides the advantage of location independence, once created, the virtual machine does not generate hardware investments, so scalability is very high.

(5) Subjects: The advantages of risk-free training (Stieglitz et al., 2010) like in healthcare, are also underrepresented. Research focuses on target groups from STEM education, which you could assume have an above-average technical affinity. Since technical skills and resources are crucial to the success of VWs in education (Shonfeld and Greenstein, 2021), less technically skilled target groups should receive more research attention to gain insights into the full potential of educational VWs and their broad suitability. E.g., the freedom from risk in medicine in terms of diagnosis and surgery should be considered for research.

(6) Design Knowledge: More than half of the articles were not grounded on kernel theories and therefore lacked a sufficient theoretical foundation. Only one article (Parsons and Stockdale, 2012) made use of DSR to develop an artifact (level 1), based on the categories by Gregor and Hevner (2013), but not reusable design principles (level 2) or a generic design theory (level 3). A first and necessary step for researchers would be to derive meta-requirements from theories, which could be extracted from this SLR. With own developments and toolkits gaining importance, it is crucial to know how to design those VWs. TAM is the only acceptance model found, the newer and more complete UTAUT (Venkatesh et al., 2003) is not covered but could be a value add to consider more influencing factors. Acceptance from learners' perspectives is researched, but the teachers' and institutional views are missing.

This publication is subject to certain limitations. Although following established procedures for searching and selecting, our search strategy might have missed relevant contributions. But also vice versa, we might have included contributions where the exclusion criteria were not explicitly mentioned (e.g., target group). Even though the selection was peer-reviewed and the coding software-based, it is always subjective. The resulting categorization of learning environments is not selective. This is especially the case for own and less-known developments.

6 Conclusion

Our aim for this SLR was to uncover the status quo of research on VWs in multi-user environments and to derive future research streams from that status quo. An actual and holistic overview was considered especially important against the background of the metaverse trend and COVID-19, resulting in social isolation.

We decided to focus on high-quality outlets and coded 89 articles. Our approach was deductive-exploratory to build upon existing knowledge but be flexible enough to include new streams and technologies and to explore trends. Our resulting research foci were educational activities, research area, learning environments, technologies toward the metaverse, subjects taught, and the level of design knowledge available. Educational activities are mainly group-oriented (e.g., collaborative learning, problem-based learning), which arises partially from the focus on multi-user environments and communities and learning groups but also the social nature of VWs (e.g., Warburton, 2009).

The results reveal that more research should be done on how VWs can initiate community building within the educational institution. Pedagogical guidelines should be created to support researchers and teachers to broadly apply VWs. Researchers should provide an overview of available development kits and their features to increase the speed toward integrating new technologies into prototypes and bring the concept of the metaverse to practice. Researchers should consider including less technical affine target groups since they are yet underrepresented but offer potential from the risk freedom of VWs (e.g., in medicine). Since there is a lack of design knowledge, meta-requirements should be derived. The theories identified in this SLR, serve as a starting point for the meta-requirement derivation. The significance to research is that we identified the status quo of VWs in education and derived concrete instructions for action. For practitioners, our contribution is a starting point for implementing VWs. Defining concrete steps on when to integrate what technology in combination would systematize research and thereby speed up the way to the metaverse.

Furthermore, sustainable concepts should include all stakeholders (e.g., technical support staff, organizers) for long-term implementations beyond prototypes.

Despite inescapable limitations, we contribute a complete overview of VWs in the broad field of higher and further education with a focus on multi-user environments.

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