# Computer-Simulated 3D Virtual Environments in Collaborative Learning and Training: Meta-Review, Refinement, and Roadmap

**António Correia, Benjamim Fonseca, Hugo Paredes, Paulo Martins, and Leonel Morgado**

## 1 Introduction

In recent years, 3D3C worlds have been mentioned in literature as viable platforms for e-learning and distance education (Callaghan et al., 2009), with expectations of a large and increasing impact on teaching and learning in higher education for the near future (Hew & Cheung, 2010). This is particularly manifested by the institutional adoption of Second Life and OpenSimulator, as well as the more sporadic use of other platforms such as World of Warcraft for educational activities (e.g., language teaching). The perceived benefits of their visual immersive components in the context of students' learning range from an augmented sense of reality (Anstadt et al., 2013) to the enhanced spatial knowledge representation, increased intrinsic motivation and engagement, improved transfer of knowledge and skills to real situations through contextualization of learning, and richer collaborative learning than is possible with 2D alternatives (Dalgarno & Lee, 2010). Immersive multi-user virtual worlds have been recently adopted as cost-effective solutions for creating simulations in a vast set of application areas, including space exploration, virtual laboratories, healthcare and emergency response, cultural heritage and

A. Correia (✉)
University of Trás-os-Montes e Alto Douro, UTAD, Vila Real, Portugal
e-mail: ajcorreia1987@gmail.com

B. Fonseca • H. Paredes • P. Martins
University of Trás-os-Montes e Alto Douro, UTAD, Vila Real, Portugal

INESC TEC, Porto, Portugal
e-mail: benjaf@utad.pt; hparedes@utad.pt; pmartins@utad.pt

L. Morgado
INESC TEC, Porto, Portugal

Universidade Aberta, Lisbon, Portugal
e-mail: leonel.morgado@uab.pt



Y. Sivan (ed.), *Handbook on 3D3C Platforms*, Progress in IS,
DOI 10.1007/978-3-319-22041-3_15

archaeology, military training, engineering, urban planning, and economics (Jarmon et al., 2009; Allison et al., 2012). These hybrid virtual ecosystems provide an experience which transcends cultural, social, language, distance, and temporal barriers through different modes of interaction (Anstadt et al., 2011), allowing a way to creatively explore critical thinking (Phillips & Berge, 2009) while supporting collaborative learning strategies and activities within which every learner agent plays an essential role. Although many studies have shown the interest of students in immersive multi-user virtual worlds, the full potential of the use of various kinds of 3D3C worlds for teaching and learning is still to be realized (Dalgarno & Lee, 2010; Allison et al., 2011; Duncan et al., 2012).

This chapter extends and allows the refinement of Correia et al.'s (2014) meta-analysis on the current challenges and opportunities of simulated environments for education and training. "Computer-based Simulated Environments: From Technology to Social Engineering" presents some background on virtual worlds with emphasis on its history and applicability. "The Unrealized Potential of Virtual Worlds for Teaching and Learning: Meta-Analysis" introduces the method and the sample dimensions concerning the metadata extracted, and "Discussion" discusses their implications in the form of theoretical framework. Finally, some concluding remarks are provided in "Final Thoughts."

## 2 Computer-Based Simulated Environments: From Technology to Social Engineering

Historically, visual multi-user virtual worlds have been around since the late 1980s, and some even before as "hardware-only systems" (Joslin et al., 2004), incorporating technical improvements such as simulators, stereoscope, 'cinerama', head-mounted displays, and trackers (Grady, 1998). Text-based and 2D perspective virtual environments date from even earlier in the form of systems such as text-based multi-user virtual worlds or Multi-User Dungeons (MUD) and similar MUD-inspired systems (Bartle, 2010). The first known studies reporting results of educational practices with virtual worlds in the form of MUD were presented in the 1990s. Such studies mentioned aspects related with changes in educational dynamics, students' and teachers' behavior, online identities, technological issues, and pragmatic concerns on the management of these platforms (Haynes & Holmevik, 1998). Other topics studied in the first decades included location and time dependencies, reality vs. virtuality, anonymity vs. true identity, human vs. technological factors, level and scale of immersion, play vs. work, and presence vs. telepresence. In this sense, Jäkälä and Pekkola (2007) argued that the research efforts on virtual worlds have transited "from considering them as tools to examining their use, from technology engineering to social engineering". While the focus relapsed on the technological aspects of 3D3C worlds, there has been a need for understanding social interaction, comparing the magnitude of co-presence (Bailenson & Yee, 2008). A key purpose of "social virtual worlds" relies on the co-construction of a shared meaning through object handling and communication between different people within a world (Damer, 2008). Stangl et al. (2012) summarizes success factors from scientific studies, pointing the support for a critical mass of residents as one of the several success factors attracting users.

Inter-user, avatar-mediated communication is essential for an understanding of the potential of virtual worlds for learning and training (Morgado et al., 2010). 3D3C worlds can be understood as immersive virtual worlds within which people can interact with software agents "using the metaphor of the real-world but without its physical limitations" (Davis et al., 2009). Furthermore, Ghanbarzadeh and colleagues (2014) define a three-dimensional virtual world as "a computer-simulated electronic 3D virtual environment that users can explore, inhabit, communicate, and interact with via avatars, which are graphical representations of the users". Such simulated environments can also be described as 3D spaces populated by avatars which support collaborative learning, work and social play (Benford et al., 2001; Duncan et al., 2012) or more generically as multi-user spatial environments within which the interaction paradigm is that of user-embodied avatars, regardless of the visual representation (e.g., the 3D space may be described via 2D perspectives or in textual form, as stressed by Morgado et al., 2010). Synoptically, 3D3C worlds can be seen as collaboration ecosystems that minimize the risk of complex tasks through simulation abilities. According to Bentley et al. (1992), such technology "may support some aspects of social interaction not readily accommodated by technologies such as audio-and video-conferencing and shared desktop applications", encouraging peripheral awareness in processes such as content sharing and artifact production.

The development of digital ecologies has been marked by media spaces, virtual worlds, mixed reality, and hybrid ecologies that merge the mixed reality with ubiquitous computing "to bridge the physical-digital divide" (Crabtree & Rodden, 2008). A computer-based simulated environment provides several features for creating an online presence that can replicate real-world scenarios in multi-user settings. Such environments enable social interaction through several communication channels (e.g., text, audio, graphical icons, visual gestures, and multisensory inputs). They also support coordination actions, and allow cooperation settings by using shared applications to track changes and manipulate (or interact with) digital artifacts for which team members can jointly look at (Schroeder et al., 2006; Jarmon et al., 2009). Immersive realism, interoperability, scalability, and ubiquity of access and identity are considered critical elements of a viable 3D3C world, and more research is needed "to provide context for considering the present state and potential future of 3D virtual spaces" (Dionisio & Gilbert, 2013). From text-based virtual worlds to the open development of metaverse platforms (e.g., Open Source Metaverse), collaborative learning has been a topic which requires a clear focus.

Earlier studies on collaboration dynamics using 3D3C worlds identified potential features for enhancing peripheral awareness (Bentley et al., 1992). Recently, research suggests that computer-based simulated environments can be well-suited for experiential learning activities (Jarmon et al., 2009), organizational learning

(Dodgson et al., 2013), business simulations (Mak & Palia, 2014), information systems auditing (Moscato & Boekman, 2014), and game-based learning (Sung & Hwang, 2013). Furthermore, healthcare approaches such as dentistry (Phillips & Berge, 2009), medical learning (Wiecha et al., 2010), cardiopulmonary resuscitation (Creutzfeldt et al., 2010), stress inoculation training (Serino et al., 2014), and healthy aging (Paredes et al., 2014; Siriaraya et al., 2014) have also been supported. Other application areas include virtual tourism (Warburton, 2009), archaeology (Sequeira et al., 2014), aerospace engineering design (Okutsu et al., 2013), training processes in the context of mechanical maintenance tasks (Fonseca et al., 2011), and military operations, tactics and strategies requiring sophisticated technologies for preparing troops to real combat scenarios (Pierzchała et al., 2011). Figure 1 presents a collaborative task performed in a computer-simulated 3D virtual environment. As argued by Fonseca et al. (2011), the adoption of a 3D virtual learning environment for training contributes to increase the efficiency of certain phases by enabling trainees to perform simulated activities without the involvement of physical resources.

Regarding the potential of such environments for higher education, researchers have been focused on the identification of requirements and potential benefits of project-based instruction and collaboration. In particular, researchers have found opportunities associated with increased sense of shared presence, social interaction and collaborative learning, partially liquefied social boundaries, and lowered social anxiety. In this context, the Collaborative Learning Environment with Virtual Reality (CLEV-R) was an example of a technical development for enhancing the afore-mentioned aspects (Jarmon et al., 2009). Benefits in the use of simulation tasks in this kind of 3D virtual learning environments range from cost saving to efficiency and security. Furthermore, the strengthening of sociability and scalability (Grimstead et al., 2005) can be far greater comparing with conventional, collaborative multi-user enabling systems.

**Fig. 1** Collaborative aircraft maintenance process in a 3D virtual learning environment

Research on K-12 and higher education has suggested that interactions in 3D3C worlds can stimulate users while producing understandings of the main subject matter (Jonassen, 2004). The characteristics of this kind of virtual environment may promote collaboration for making the work more dynamic and engaging (Reeves et al., 2008). 3D3C worlds still have the potential to support crowded online settings where hundreds of participants can reach social engagement by dynamically forming subgroups (Schneider et al., 2012). However, the lack of in-depth studies for evaluating dynamic scenarios constitutes a challenge for identifying requirements in adapting collaboration mechanisms to individuals, groups, and crowds.

## 3 The Unrealized Potential of Virtual Worlds for Learning and Training: Meta-Analysis

### *3.1 Method*

The details about the initial sample selection and review processes were presented by Correia et al. (2014), and this chapter extends the previous work by distilling conceptual evidences as meta-theoretic units of analysis. The results of this study were obtained applying a Systematic Literature Review (SLR) process based on the known guidelines (Kitchenham et al., 2009; Stapić et al., 2012). Qualitative content analysis techniques (Graneheim & Lundman, 2004; Onwuegbuzie et al., 2012) were also used as complementary approaches to extract qualitative evidences from literature. In this study, old publications and bibliometric indicators (e.g., authors' affiliation, and number of citations) were discarded from analysis. The focus relies on distinguishing what needs to be undertaken in the use and deployment of 3D3C worlds for collaborative learning and training.

In the first stage, keywords and related terms were introduced and 156 studies were retrieved in accordance to the total number of citations provided by Google Scholar's citation index. This process was complemented by a snowball sampling approach to identify potential studies from references. In the next phase, three duplicated papers were removed. The lack of quantifiable metadata for two studies was also an exclusion criterion. Subsequently, 102 studies were removed due to the inadequacy of their subjects for a meta-analysis focused on 3D3C worlds and their unsolved gaps. The remaining sample is constituted by a set of 49 publications. From this corpus, a wide range of studies related with learning (e.g., K-12, higher education) was identified.

Limitations and possibilities for research were initially extracted as meaning units (or textual excerpts) from which a condensing technique was used. As explained by Graneheim and Lundman (2004), a meaning unit can be understood "as the constellation of words, sentences or paragraphs containing aspects related to each other through their content and context". A condensed meaning unit is a description close to the text, and a category is "a group of content that shares a commonality" (Krippendorff, 1980), including sub-categories at varying levels of abstraction. Creating themes is a way to link the underlying meanings together in categories. A total number of 161 condensed meaning units, 48 categories, 11 sub-categories, and 10 themes were clustered using a method similar to Jacovi et al.'s (2006) methodological approach. A refined, meta-synthesis integrating qualitative evidences from a total of 49 publications (see Table 1) summarizes the raw data extracted by meaning unit, topic/category, and theme.

## 3.2 Three-Dimensional Immersive Virtual Learning Environments

Suggestions for future research on the use of 3D3C worlds in learning as presented by Hew and Cheung (2010) are mainly related with exploiting improvements to previous studies, doing longitudinal studies, exploring the attributes/affordances of virtual worlds, examining sociocultural factors, and studying the use of avatars (e.g., gender analysis). Furthermore, Jarmon and colleagues (2009) claimed attention for virtual world teaching and experimental learning by considering the learning curve and the current limitations in single case studies (e.g., few graduate students from distinct academic disciplines). In the meantime, Duncan et al. (2012) indicated the proposal of finely-grained classification models and surveys, better mechanisms for monitoring student learning, the development of immersion technology (e.g., 3D haptic input equipment), the study of in-world behavior and course design, the transition of in-world skills to the real world, and the inclusion of social, minority or disabled groups. In addition, Dalgarno and Lee (2010) explored the 'learning affordances' of 3D virtual environments (e.g., visual realism), while Barbour and Reeves (2009) stressed unsolved challenges for institutions, including but not limited to high start-up costs, student readiness and retention, accreditation, and universal access. Ultimately, Morgado (2013) summarized a set of current technological challenges faced by educators and organizations on employing virtual worlds in education.

Concerning the empirical research on the educational applicability of virtual reality, a 10-year critical review (Mikropoulos & Natsis, 2011) suggested the development of more studies incorporating intuitive interactivity and settings that use immersive virtual environments. They also pointed the importance of reporting positive results on users' attitudes and learning outcomes in addition to the characteristics and features of virtual reality (e.g., immersion, and sense of presence). A key challenge discussed by researchers such as Inman et al. (2010) relies on the use and adoption of Second Life in K-12 and higher education, comprising the study of participants' affective domain (e.g., learner attitudes and feelings regarding the use of virtual environments as educational learning environments), learning outcomes, and social interaction (e.g., use of communication features associated with 3D

**Table 1** Overview of qualitative content analysis

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Hew and Cheung (2010) | Enhancing descriptive studies by providing a rich, thick description of the methodology, including the duration of the study, inter- and intra-observer agreement reliability, and effect sizes so that findings can be adequately interpreted. | Qualitative research design | 1 |
| | Complementing prior studies which usually lacked a control group, uncontrolled variables (e.g., instructional strategy used), and participants with no previous correct notions about socially desirable answer. | Qualitative research design, Sampling | 1 |
| | Doing longitudinal studies (>1 year) examining not only whether students' and teachers' perceptions of virtual worlds undergo change but also whether there are any detrimental effects of using virtual world environments over a long period of time. | Qualitative research design, Long term studies | 1 |
| | Exploring the influence of 3D avatars on online perceptions, including androgyny, anthropomorphism, credibility, homophily, and users' likelihood. | Use of avatars | 2 |
| | Examining unique attributes/affordances of virtual worlds (e.g., immersion in the 3D learning content and context, and interaction with the objects in the environment). | Attributes/affordances of virtual worlds | 3 |
| | Studying the influence of sociocultural factors and country contexts. | Social and cultural contexts | 2 |
| Jarmon et al. (2009) | Gathering data about the students' levels of technical ability in Second Life prior to the educational activity, and measuring what impact the background of a student may have had on their final assessment of learning in Second Life. | Learning curve | 4 |
| | Understanding the instructional use of 3D virtual worlds, and expanding experiential learning opportunities (e.g., studying how experiential project-based collaborative activity may be applied in other instructional contexts using virtual worlds). | Educational models and activities | 5 |
| | Filling the limitations of single case studies with one graduate course and semester in length, and few graduate students from different academic disciplines. | Qualitative research design, Long term studies, Sampling | 1 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Anstadt et al. (2011) | Reducing the learning curve in the ever-expanding world of virtual reality and computer-mediated interaction. | Learning curve | 4 |
| | Considering users with developmental and physical disabilities. | Accessibility | 6 |
| | Investigating the relationship between users' virtual lives and their real lives, including what role accepted educational institutions play in online interaction and learning. | Virtual life vs. real life, Institutional role | 2<br>5 |
| | Coping with data collection limitations in virtual worlds (e.g., maintaining participant confidentiality). | Qualitative research design, Data collection | 1 |
| | Discovering how strong the influence of social mores, norms and laws are in internet-based virtual realities (e.g., Second Life) with special consideration for ethical demands of practice, including issues of safety, prevention, and mandatory reporting. | Ethical and equity issues | 7 |
| | Understanding social learning and community mentality which can affect a moral attitude change and encourage negative deviant behavior such as computer hacking. | Ethical and equity issues | 7 |
| Duncan et al. (2012) | Improving the way people use virtual worlds with the development of immersion technology like 3D haptic input equipment (e.g., video helmet, gloves, etc.), motion detection and interaction hardware and software (e.g., Kinect), and higher speed broadband and graphics cards which can reduce the lag and downtime in Second Life. | Usability, Technical issues, Haptics, Motion capture, Connectivity, Graphics | 2<br>3 |
| | Understanding in-world behavior can help develop the educational use of virtual worlds. | User behavior | 2 |
| | Performing research to find the most suitable learning theory and applicable strategy for in-world course design and practice. | Learning theories and strategies | 5 |
| | Monitoring student learning with better mechanisms developed to ensure that students have effective learning practices and that they are measured accordingly, given the known research issues of cohort analysis and observational difficulties. | Assessment and evaluation methods, Learning theories and strategies | 5 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Addressing inclusion and accessibility issues since the use of virtual worlds for education should not disadvantage particular social, minority or disabled groups. | Inclusion, Accessibility | 6 |
| | Developing suitable educational activities, learning environments, supporting technologies, revised learning theories, and experimental and verifiable evaluation practices. | Educational models and activities, Learning theories and strategies | 5 |
| | Addressing the need for both finely grained categorical work and holistic approaches to research and practice in virtual education, encompassing multiple taxonomic units. | Assessment and evaluation methods | 1 |
| | Providing fine-grained surveys demonstrating changing trends based on technology availability, speed and cost, the requirement for geographically separated teaching and hopefully a more inclusive approach to all age and social groups and physical abilities. | Qualitative research design, Research surveys | 1 |
| | Addressing contextual information taking into account its amount and display. | Contextual information | 8 |
| | Focusing the delivery of in-world skills (e.g., creating things in the virtual world) applicable to the real world by analyzing how students transfer their knowledge gained in the virtual world to real life. | Skill development, Virtual life vs. real life | 2<br>4 |
| Jäkälä and Pekkola (2007) | Identifying relevant themes and research items in virtual worlds by using qualitative methods (e.g., Grounded Theory), and proposing frameworks for classifying individual users, virtual worlds, collaboration mechanisms, and their relations in a systematic way. | Qualitative research design, Assessment and evaluation methods | 1 |
| Bailenson and Yee (2008) | Using haptic devices to measure implicit attitudes (e.g., attitudes towards different racial groups) by evaluating participants using avatars of different skin tones or ethnicities and studying the effects of being touched in a virtual environment by employing a paradigm where the touch itself is social (e.g., increasing the social status of an avatar). | Technical issues, Haptics, User behavior, Use of avatars, Presence | 2<br>3 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Davis et al. (2009) | Understanding how metaverses are different from traditional virtual collaboration and change team members' perceptions of virtuality and presence, and the relationships to foundational theories relevant for enhancing understanding of behavior, management, and technology phenomena. | Collaboration, User behavior, Virtuality, Presence | 2 |
| | Working on the design and architecture of metaverses (i.e., software and hardware). | Virtual space design | 3 |
| | Developing the ability of people to port their avatars seamlessly among different types of metaverse environments. | Interoperability | 3 |
| | Determining how individuals use specific metaverse technology capabilities to improve participation and interaction (e.g., factors affecting the avatar's appearance). | Attributes/affordances of virtual worlds, User behavior | 2<br>3 |
| | Knowing how the group attitude or group outcome may change or be enhanced in a metaverse and how do metaverse environments impact group attitude and help to build group outcomes that are synergistic. | User behavior | 2 |
| | Coping with the trade-off between scientific control and realism, inability to adequately replicate previous studies, and access to representative sample populations. | Realism, Qualitative research design, Sampling | 1<br>2 |
| | Applying measurement strategies for metaverse environments (e.g., collecting data on team and meeting behaviors) by using surveys, video, built artifacts, images, and chat. | Assessment and evaluation methods | 1 |
| | Reducing the high learning curve associated with metaverse technology by augmenting the ease with which people enter and become comfortable in virtual worlds. | Learning curve | 4 |
| | Overcoming restriction and scheduling difficulties of the synchronous avatar interaction, and exploiting how artifacts might be used for handing-off interim tasks asynchronously. | Synchronicity | 2 |
| | Investigating how teams balance in-world and out-world processes, and what tasks are amenable to metaverse technology capabilities. | User behavior, Virtual life vs. real life | 2 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Understanding the adoption and diffusion of metaverses in everyday use. | User acceptance, Ubiquity | 2 |
| | Filling the lack of instructional design and faculty development programs with distance learning strategies. | Institutional role, Learning theories and strategies | 5 |
| Phillips and Berge (2009) | Overcoming the extensive limitations in the use of teledentistry regarding insurance coverage, licensure, malpractice, and privacy since real patient data may be misdiagnosed due to medical error or lost through transmission of data. | Healthcare, Security | 3<br>6 |
| | Investigating the users' experiences of leisure gaming technology for explicit medical training purposes. | Games, Healthcare | 6<br>9 |
| Creutzfeldt et al. (2010) | Solving technical issues such as bandwidth, hardware, firewalls, downtime and lag, as well as usage problems such as navigation, object creation and avatar manipulation. | Technical issues, Connectivity, Security, Navigation, Use of avatars, Object creation and manipulation | 2<br>3 |
| Warburton (2009) | Addressing the management of virtual identities, including the ways users grapple with the fluidity and playfulness. | Virtual identity | 2 |
| | Improving digital and cultural literacies by coping with cultural issues such as the difficulty of finding, developing a sense of belonging to, and becoming an active participant of an in-world community, as well as the need to become comfortable and familiar with the codes, norms and etiquette rules of the virtual world. | Social and cultural contexts, Ethical and equity issues | 2<br>7 |
| | Understanding the links between immersion, empathy and learning more fully, and developing design skills that can be used productively to exploit virtual spaces. | Immersion, Empathy, Virtual space design, Skill development | 2<br>3<br>4 |
| | Addressing collaboration issues that have to do with the challenges in cooperation and co-construction within a virtual world, and the minimal social networking tools and functions available. | Collaboration, Object creation and manipulation, Social media | 2<br>3<br>9 |
| | Designing and implementing learning activities and resources that make use of the technology in pedagogically sound ways, including time issues and the associated workload impositions on educators. | Educational models and activities, Synchronicity, Workload | 2<br>5 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Considering economic issues, including the cost of purchasing land, uploading images and textures, buying in-world objects/tools, and employing skilled people to perform building and scripting tasks. | Economic models | 10 |
| | Addressing the problem of standardization, specifically the lack of open standards and interoperability between virtual world platforms, which limits educators and institutions to transfer resources. | Standardization, Interoperability | 3 |
| | Scaffolding persistence and social discovery issues. | Persistence, Sociability | 2 |
| Inman et al. (2010) | Developing more safe and secure environments for all students in K-12 through the collaboration between researchers and educators. | Security | 3 |
| | Collecting data from within the virtual worlds since their ethnographic research possibilities are endless. | Qualitative research design, Data collection | 1 |
| Wimpenny et al. (2012) | Realizing conceptualizations within groups of students concerning the mutability of the relationship between digital games, social media and virtual worlds. | Games, Social media | 9 |
| Mikropoulos and Natsis (2011) | Performing studies incorporating intuitive interactivity and settings that use immersive virtual environments reporting positive results on users' attitudes and learning outcomes. | Immersion, User behavior, Learning outcomes | 2<br>5 |
| | Studying characteristics of virtual reality (e.g., immersion) and features such as the sense of presence (e.g., perceptual features, individual factors, content characteristics, and interpersonal, social and cultural contexts). | Immersion, Presence, Social and cultural contexts | 2 |
| Parsons and Cobb (2011) | Developing robust and usable technologies that can really make a difference in real world classrooms and educational contexts, and testing the relevance and applicability of virtual reality for children on the autism spectrum. | Healthcare, Autism spectrum | 6 |
| | Answering questions about the nature of the representation itself. | Use of avatars | 2 |
| Bellani et al. (2011) | Using virtual reality tools for habilitation in autism helping caretakers and educators to enhance the daily life social behaviors of autists. | Healthcare, Autism spectrum, Inclusion, Sociability | 2 |
| | Investigating how newly acquired skills are transferred to real world and whether virtual reality may impact on neural network sustaining social abilities. | Skill development, Virtual life vs. real life, Sociability | 2<br>4 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Dalgarno et al. (2011a) | Taking accurate pictures of the 'state of play', including current, past and planned tools at various institutions, so as to help direct research, development and use, as well as compiling an annotated bibliography of published research into, and evaluations of, 3D immersive virtual worlds in higher education. | Qualitative research design, Research surveys | 1 |
| Wright and Madey (2009) | Refining past surveys of technologies for building virtual environments with different and updated variables. | Qualitative research design, Research surveys | 1 |
| Messinger et al. (2008) | Understanding how standards of social behavior are evolving in virtual worlds comparing with the physical world, evaluating the influence of behaviors and attitudes learned in virtual worlds on real-world settings. | User behavior, Virtual life vs. real life | 2 |
| | Approaching regulation in virtual worlds, including social values and norms implied in the process as well as their influence on aspects such as creativity and productivity. | Regulation, Ethical and equity issues | 3<br>7 |
| | Understanding the influence of factors such as the monetary system in virtual worlds, nature of the platform, and forms of interaction allowed (e.g., synchronous, and asynchronous) on people's behavior, identifying how they differ in meeting people's information needs, stimulating social interaction, or engendering trust. | Economic models, Technical issues, Synchronicity, User behavior, Sociability, Contextual information | 2<br>3<br>8<br>10 |
| | Identifying how the appearance of an avatar instructor be designed. | Use of avatars | 2 |
| | Discovering if different platforms are more or less conducive to self-governance. | Governance | 2 |
| | Studying demographics, psychographics, geographic characteristics, membership sizes, and participation levels of various virtual worlds. | Quantitative research design, Social and cultural contexts | 1<br>2 |
| | Verifying how virtual worlds will support themselves with a single up-front fee, periodic subscription payments, advertising, pay-as-you-go extras, or sales of ancillary products. | Economic models | 10 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Schmeil and Eppler (2008) | Providing additional patterns, classification approaches, and well-grounded guidelines in virtual environments. | Assessment and evaluation methods | 1 |
| | Performing on-going revisions of the current classification models, and developing scientific proof to help researchers, designers and practitioners to assess a 3D collaboration and learning scenario in terms of its scope and benefits. | Assessment and evaluation methods, Collaboration | 1<br>2 |
| | Executing experimental comparisons of collaboration tasks in 3D3C worlds against corresponding tasks in text-based virtual worlds and real life collaboration settings. | Collaboration, Virtual life vs. real life | 2 |
| | Investigating the question of which theories (e.g., the actor-network theory, Gibson's theory of affordances, and the cognitive scaffolding theory) help to explain 3D interaction for collaboration and learning. | Learning theories and strategies, Collaboration | 2<br>5 |
| | Identifying enhancements needed to make a 3D virtual world a really useful environment for serious distributed collaborations. | Attributes/affordances of virtual worlds, Collaboration | 2<br>3 |
| Schmeil and Eppler (2010) | Proposing more frameworks to provide indications about the possible value added by collaboration patterns in virtual environments. | Qualitative research design, Collaboration | 1<br>2 |
| | Using controlled online experiments and in-situ participatory observation in institutions. | Qualitative research design | 1 |
| Otto et al. (2006) | Addressing effective haptic implementations for immersive projection technology, as well as studying the role of gaze, facial expressions and body postures during concurrent object interaction. | Technical issues, Haptics, Motion capture, Immersion | 2<br>3 |
| De Freitas (2008) | Analyzing how the license-fee based worlds will survive against the open source ones. | Economic models | 10 |
| | Providing a framework for ongoing work concerning the tension between participation, learner control, educational standards and quality assurance, and accurate benchmarking metrics for evaluation and validation. | Educational models and activities, Assessment and evaluation methods | 1<br>5 |
| | Testing the real learning opportunities of multiplayer role play games and mirror worlds. | Games | 9 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Creating more engaging, personalized and student-centered learning experiences, especially for hard-to-reach and unmotivated learner groups and those studying at a distance. | Educational models and activities | 5 |
| | Empowering learners to construct their own spaces, content and activities, facilitating cross-disciplinary collaborative research and learning initiatives as well as mixing or 'blending' virtual and real spaces and experiences by using tools such as SketchUp and 3ds Max. | Virtual space design, Object creation and manipulation, Collaboration, Virtual life vs. real life | 2<br>3 |
| | Providing support for learners with disabilities or mobility issues. | Accessibility | 6 |
| | Considering access control and the need for broadband connectivity, the development of open standards, and the provision of support for practitioners in the form of guidelines, case studies and implementation models. | Technical issues, Connectivity, Standardization, Access control | 3 |
| Salmon (2009) | Retrieving teachers' visions about the potential of virtual worlds (especially in the teaching of history and science). | Qualitative research design | 1 |
| | Integrating learning technologies as a prospect to create effective and customized 3D virtual classrooms, and understanding how to transfer pedagogical concepts from other electronic environments to frame group development and group working. | Interoperability, Educational models and activities, Virtual space design | 3<br>5 |
| Brown et al. (2011) | Testing the emergent themes of intuitiveness, ease of application, soundness, usefulness, user acceptance, and enhanced knowledge sharing ability in further, more controlled, empirical research. | Qualitative research design, User acceptance | 1<br>2 |
| | Enhancing computer-supported networked collaborative process modeling. | Collaboration | 2 |
| | Ensuring scalability to larger and more complex collaboration process scenarios. | Scalability, Collaboration | 2<br>3 |
| | Applying usability analysis in modeling interactions in order to improve their affordance for collaborative process tasks. | Usability, Collaboration | 2<br>3 |
| Prasolova-Førland (2008) | Exploiting the influence of virtual place design and other factors on the suitability of 3D virtual worlds in educational settings, and discovering how they could be analyzed in a systematic way, place metaphors typically used, and beneficial design features. | Virtual space design | 3 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Hasler et al. (2009) | Studying the physical environment from which team members access the environment. | Virtual life vs. real life | 2 |
| | Creating a research agenda focused on behavioral indicators of high- and low-performing teams, sociability factors, and usability toward a theoretical foundation on collaboration in 3D virtual worlds. | Qualitative research design, Research surveys, User behavior, Sociability, Usability, Collaboration | 1<br>2<br>3 |
| | Proposing an automated behavioral tracking approach towards the systematic analysis of group interaction processes. | User behavior, Assessment and evaluation methods | 1<br>2 |
| Pinkwart and Olivier (2009) | Exploring possible classes of group work and project-based learning that can be enhanced through 3D3C worlds' technology by investigating the risks and chances of new options for collaborative work and learning contexts. | Collaboration, Educational models and activities, Learning theories and strategies | 2<br>5 |
| | Advancing the recognition of gestures and facial expressions of the user and projecting them into the virtual world through the avatar, and exploiting the full potential of this interaction technique through ongoing research on collaboration dynamics. | Motion capture, Use of avatars, Collaboration | 2<br>3 |
| | Investigating the adoption of 3D3C worlds in organizations (e.g., training staff). | Organizational contexts | 9 |
| | Exploring requirements for 3D virtual worlds to make inroads into the everyday work practices of users, probably one of the most crucial aspects to deal with it is privacy. | Security | 3 |
| Montoya et al. (2011) | Examining the content of communications and the relationship with performance given the social relational affordances offered by 3D virtual worlds (e.g., team transcripts could be content coded to reveal the proportion of communications devoted to task-related interactions conveying ideas, decision-making and social/relational exchanges). | Qualitative research design | 1 |
| | Considering inter- and intra-organizational uses including collaborative virtual teamwork. | Collaboration, Organizational contexts | 2<br>9 |
| | Performing systematic and foundational research that examines the impact of 3D virtual worlds on team behaviors and ultimately performance-related outcomes. | Qualitative research design, User behavior | 1<br>2 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Understanding the relative importance of affordances on both team processes and outcomes, particularly as they may vary by 3D platform. | Attributes/affordances of virtual worlds | 3 |
| | Examining how communication technology use is related with aspects of mediated team collaboration. | Collaboration | 2 |
| | Exploring the learning curve associated with virtual worlds, which can help managers to understand start-up costs needed to support a virtual team into a 3D platform. | Learning curve | 4 |
| | Performing longitudinal research engaging real teams in the context of real projects. | Qualitative research design, Long term studies | 1 |
| Wallace et al. (2009) | Focusing on affiliativeness and sociability as an interesting step in the investigation of collaboration in virtual worlds for education, and examining other personality traits related with collaboration in virtual worlds between avatars of different ethnicities, species and other forms, where further studies could examine such facets of personality as emotional empathy, arousal and sensation seeking, affect and emotions. | Collaboration, Sociability, Virtual identity | 2 |
| | Developing frameworks considering positive social attitudes of participants in distance learning environments hold toward their classmates' avatars. | Sociability, Use of avatars | 2 |
| Hansen (2008) | Using virtual simulations to teach healthcare students may be questionable until more research is conducted and educational outcomes are realized. | Healthcare, Learning outcomes | 5<br>6 |
| | Considering the time and cost involved in creating learning spaces within a virtual environment. | Virtual space design | 3 |
| | Assessing the efficiency associated with sharing text, images, and videos via an avatar versus a standard format on a computer's desktop. | Use of avatars | 2 |
| | Evaluating learning outcomes by overcoming challenges facing developers of virtual worlds and serious gaming for educational purposes (e.g., ownership of collaborative work, and certification of authorship). | Learning outcomes | 5 |
| | Determining students' satisfaction, competency, and knowledge acquisition. | Learning outcomes | 5 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Weinberg et al. (2009) | Providing evidence regarding the benefit of simulation as measured by actual patient outcomes, with the exception of resuscitation and central line placement studies. | Healthcare | 6 |
| | Filling the limitations of current simulation studies including small sample size and lack of validated instruments to measure performance. | Qualitative research design, Sampling | 1 |
| | Incorporating a scenario-based curriculum in many institutions which are unable to afford the high cost of advanced patient simulators can successfully increase provider skills and performance. | Institutional role, Skill development, Healthcare | 4<br>5<br>6 |
| Ghanbarzadeh et al. (2014) | Studying the impact of 3D virtual worlds in the education of surgeons. | Healthcare | 6 |
| | Creating specific rooms and environments in virtual worlds so students can remotely access their course materials (e.g., files, e-books, lecture captures, and presentation slides). | Virtual space design, Educational models and activities | 3<br>5 |
| | Training students and the public in first aid with 3D virtual worlds. | Learning curve | 4 |
| | Analyzing the impact of 3D virtual worlds on people's health and lifestyle, and investigating the advantages and disadvantages of applying this technology in improving healthy behaviors and extending the health culture. | Healthcare | 6 |
| | Filling the lack of research on some application areas of 3D virtual worlds in treatment in healthcare and medicine (e.g., social isolation, care of the elderly, and phobias). | Healthcare, Inclusion | 6 |
| | Applying of 3D virtual worlds in modeling, and simulating health scenarios (e.g., investigating the impact of simulated sophisticated hospital equipment on the skill-building of hospital staff). | Healthcare, Skill development | 4<br>6 |
| | Examining the impact of 3D virtual worlds on various healthcare contexts through the replication of earlier studies with larger sample sizes. | Healthcare, Qualitative research design, Sampling | 1<br>6 |
| De Freitas and Oliver (2006) | Designing frameworks that consider explicitly the use of simulations in education and guide and support the evaluation of educational software, including the context, learning theory and practice and the attributes of the learner and learner group. | Assessment and evaluation methods, Educational models and activities, Learning theories and strategies | 1<br>5 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Barbour and Reeves (2009) | Researching the factors that account for K-12 student success in distance education and virtual school environments, and performing more design research approaches than traditional comparisons of student achievement in traditional and virtual schools. | Learning outcomes, Educational models and activities | 5 |
| | Coping with high start-up costs associated with virtual schools, access issues surrounding the digital divide, approval or accreditation of virtual schools, and student readiness issues and retention issues. | Economic models, Universal access, Institutional role, Learning outcomes | 5<br>6<br>10 |
| Savin-Baden (2010) | Working on haptics, motion capture, simulation and deconstruction, merging real life and immersive virtual worlds, using photorealism in order to use one's real life face on one's avatar, and using voice and own name/identity so that the interaction between real life and avatar identity was closer. | Haptics, Motion capture, Realism, Use of avatars, Virtual identity, Virtual life vs. real life | 2<br>3 |
| Savin-Baden et al. (2010) | Allowing guidance and pedagogic structuring, and filling the lack of understanding of the location and roles of staff when teaching in immersive virtual worlds in higher education, particularly since most research is focused on how students perceive learning in such educational contexts. | Educational models and activities, Institutional role | 5 |
| | Exploiting the other dimension of the kinetic 3D nature of immersive virtual worlds, including identity work, meaning-making, and self-representation by means of a complex set of interlocking modes of communication. | Motion capture, Virtual identity | 2<br>3 |
| Dionisio and Gilbert (2013) | Developing psychological realism (e.g., sound, touch, and gestures and expressions), ubiquity of access and identity (availability of virtual worlds, and manifest persona and presence), interoperability of content and experience across virtual environments, and scalability as essential features of virtual world technology. | Realism, Ubiquity, Virtual identity, Presence, Universal access, Interoperability, Scalability | 2<br>3<br>6 |
| | Moving from a set of sophisticated but completely independent immersive environments to a massive integrated network of 3D virtual worlds or metaverse, thus establishing a parallel context for human interaction and culture. | Interoperability | 3 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Dalgarno and Lee (2010) | Documenting enhanced post-test knowledge and/or skills of students using desktop-based 3D environments over those using equivalent 2D technologies, testing if the facilitation of embodied actions and communication within a 3D MUVE lead to a greater sense of co-presence and afford learning tasks that encourage richer and/or more effective collaborative learning than is possible with 2D alternatives. | Skill development, Presence, Collaboration | 2<br>4 |
| | Studying how realistic display, smooth view changes and embodied actions contribute independently or together to spatial knowledge development, when compared to alternative static or animated images. | Realism, Spatial knowledge | 2<br>8 |
| | Identifying how the various aspects of the environment fidelity (e.g., visual realism, and refresh rate) lead to the achievement of a sense of presence, engagement, intrinsic motivation, and improved contextualization of learning (manifested through greater transfer to a corresponding real environment) in a 3D virtual learning environment. | Realism, Presence, Virtual life vs. real life | 2 |
| | Testing if spatial audio and tactile feedback leads to the achievement of a greater sense of presence and the learner's development of spatial knowledge representations in a 3D virtual learning environment. | Presence, Spatial knowledge | 2 |
| | Identifying changes to accepted design principles from established theories (e.g., cognitive load theory, dual coding theory, cognitive theory of multimedia learning) when instructional elements are presented within a 3D virtual learning environment. | Learning theories and strategies | 5 |
| | Designing learning tasks to be carried out within a 3D virtual learning environment to meet specific, desired educational outcomes (e.g., content knowledge in particular subject domains, and generic skills such as teamwork and problem solving). | Educational models and activities, Learning outcomes, Skill development | 4<br>5 |
| | Identifying characteristics of learning tasks within a 3D virtual learning environment that will make them intrinsically motivating, and result in a high sense of presence. | Educational models and activities, Presence | 2<br>5 |
| | Discovering how important is suspension of disbelief to the achievement of both cognitive and affective learning goals. | Learning theories and strategies | 5 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Boulos et al. (2007) | Overcoming caveats and workarounds of 3D virtual worlds, including Internet addiction, gambling, violence, pornography, trust, identity and privacy issues, copyright issues, health information quality and quackery issues, vandalism, and the need to master new skills depending on user role (e.g., ordinary resident, learner, educator, and builder). | Ethical and equity issues, Security, Contextual information, Skill development | 3<br>4<br>7<br>8 |
| | Supporting older people and people with physical disabilities, and helping them combat social isolation and loneliness with 3D virtual worlds may pose potential user interface, 3D navigation/accessibility issues. | Inclusion, Accessibility, Navigation | 3<br>6 |
| | Using 3D virtual worlds for supporting medical and health education. | Healthcare | 6 |
| | Identifying educational and library-related possibilities explored in various settings/scenarios and carefully researched, refined and evaluated to document best practices, as well as characterizing the pitfalls that are to be avoided before they can be extensively used in daily teaching and learning activities. | Educational models and activities, Learning theories and strategies | 5 |
| De Freitas et al. (2010) | Exploiting interactivity and immersion as relatively under-researched areas, designing experiments in the representational dimension. | Interactivity, Immersion | 2 |
| | Engaging more learners on structuring learning activities, and providing greater support in advance of trialing. | Learning theories and strategies | 5 |
| | Providing more rigorous frameworks and metrics for supporting future efficacy studies. | Assessment and evaluation methods | 1 |
| Dalgarno et al. (2011b) | Addressing technological problems, limitations and success factors such as bandwidth, firewalls and other IT policy issues, hardware requirements, and audio. | Technical issues, Connectivity, Ethical and equity issues | 3<br>7 |
| | Solving problems related with support, funding and time (e.g., time commitment, cost and funding, management support, and resources). | Economic models, Management | 10 |
| | Coping with usability and familiarity concerns, including student user familiarity and learning curve, academic user familiarity and learning curve, and general user familiarity and usability of software. | Usability, Learning curve | 3<br>4 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| | Solving equity related and ethical problems, limitations and success factors. | Ethical and equity issues | 7 |
| | Analyzing student acceptance, academic staff acceptance, and general acceptance concerning the use of virtual worlds. | User acceptance | 2 |
| | Approaching management and planning issues, including planning for learning (e.g., content, outcomes, and timelines), design and development of the environment, people synchronization issues, continuity as subject is revised and/or teaching staff changed, need for workshops, meetings, training, and need to collaborate with others. | Management, Learning theories and strategies, Learning outcomes, Virtual space design, Synchronicity, Institutional role, Collaboration | 2<br>3<br>5<br>10 |
| Allison et al. (2012) | Filling the lack of features provided by OpenSimulator and Second Life by coping with non-exhaustive challenges such as management guidance for educators (e.g., training for virtual world management), network infrastructure, 3D Web, and programmability. | Management, Technical issues, Connectivity | 3<br>10 |
| Callaghan et al. (2009) | Integrating virtual learning environments and virtual worlds to harness relative strengths of each platform (e.g., the course management features of virtual learning environments and the immersive/highly interactive nature of virtual worlds) can create engaging learning experiences for students, overcoming overheads in setting up, configuring and maintaining an own server and the final decision about which platform to use would be down to individual choice and requirements. | Interoperability | 3 |
| Konstantinidis et al. (2010) | Integrating Sloodle and OpenSimulator platforms for supporting collaborative learning scenarios in a broad and simplified sense, overcoming scientific challenges (e.g., the ability of assessing or validating learning in formal contexts), pedagogical interoperability challenges (e.g., identifying and combining complementary and compatible pedagogies), and technical challenges (e.g., integration of 2D and 3D educational tools, resulting in an efficient, accessible and accomplished system, and bridging the different systems, defining standards, and envisaging innovative interfaces). | Interoperability, Collaboration, Technical issues | 2<br>3 |
| Allison et al. (2011) | Broadening virtual worlds in terms of business models and programmability to support open learning. | Economic models, Technical issues | 3<br>10 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Allison, Miller, Sturgeon, Nicoll, and Perera (2010) | Exploiting the validity of online identity, privacy of personal work from other students, easy accessibility to coursework for markers, provenance of authorship, and a reliable submission mechanism which constitute security issues associated with the management of a credit-bearing coursework. | Virtual identity, Security, Access control, Universal access | 2<br>3<br>6 |
| | Creating innovative, interactive learning environments, and engaging students in coursework assignments for overcoming social and technical drawbacks such as (1) annual recurrent funding to rent land, (2) land cost divided into parcels for individual students coursework, (3) distant servers with poor Quality of Service unblocked by institutional firewalls, (4) presence of "adult content" and an age barrier at 18, (5) inability to make copies of content outside of Second Life, and (6) permissions model making submission of coursework unreliable. | Virtual space design, Technical issues, Economic models, Access control | 3<br>10 |
| Dede (2009) | Discovering to what extent does good instructional design for immersive environments vary depending on the subject matter taught or on the characteristics of the learner, and for what types of curricular material is full sensory immersion important. | Educational models and activities, Immersion | 2<br>5 |
| | Exploring the ability of the successes of one's virtual identity in immersive environments to induce greater self-efficacy and educational progress in the real world. | Virtual identity, Learning outcomes, Virtual life vs. real life | 2<br>5 |
| | Discovering optimal blend of situated learning in real, augmented, and virtual settings, and identifying which insights about bicentric frames of reference can generalize from immersive environments to pedagogical strategies in face-to-face settings. | Learning theories and strategies | 5 |
| Hendaoui et al. (2008) | Simulating and integrating components of a real-world classroom (teachers' and students' physical presence, classroom, and video and voice capabilities, among other things) which leads to research issues related with a possible transition from e-learning to v-learning, virtual space design, lecturers' roles, assessment of learning outcomes, instructor's avatar design and appearance, and adoption and use of social virtual worlds as teaching environments. | Virtual life vs. real life, Presence, Virtual space design, Learning outcomes, Use of avatars, User acceptance, Assessment and evaluation methods | 1<br>2<br>3<br>5 |

(continued)

**Table 1** (continued)

| References | Condensed meaning unit | Topic/category | Theme |
|---|---|---|---|
| Anstadt et al. (2013) | Investigating (1) technological infrastructures for supporting the future metaverse, (2) standards and/or 3D protocols (e.g., OpenGL, Direct 3D) for social virtual worlds, (3) evolution of clients (e.g., by integrating head-mounted displays for enhanced 3D experiences), (4) connection of mobile devices and Web sites with social virtual worlds, (5) development of easy-to-use and powerful applications to build content for social virtual worlds, (6) interoperability between heterogeneous social virtual worlds, (7) communication protocols and standards, (8) ability to run the own social virtual world servers and interaction with other servers, (9) security problems and tools such as antispam, antivirus, and antispyware into social virtual worlds, (10) dynamics of the virtual worlds, and (11) emergent behavior. | User behavior, Technical issues, Standardization, Connectivity, Interoperability, Security | 2<br>3 |

Legend:

| Theme | Description | Topic/category |
|---|---|---|
| #1 | Research methods, theories and models, and user studies | Qualitative research design (Sampling, Long term studies, Data collection, Research surveys), Assessment and evaluation methods |
| #2 | Sociological concerns | Social and cultural contexts, Virtual life vs. real life, User behavior (Use of avatars, Virtual identity), Presence, Collaboration, Synchronicity, Virtuality, Realism, User acceptance, Ubiquity, Immersion, Workload, Persistence, Sociability, Governance, Interactivity |
| #3 | Technical characteristics and attributes | Usability, Attributes/affordances of virtual worlds, Technical issues (Haptics, Motion capture, Connectivity, Graphics), Virtual space design, Interoperability, Security, Regulation, Access control, Navigation, Object creation and manipulation, Standardization, Scalability |
| #4 | User familiarity and expertise | Learning curve, Skill development |
| #5 | Educational settings | Educational models and activities, Learning theories and strategies, Learning outcomes, Institutional role |
| #6 | Healthcare and universal design | Healthcare (Autism spectrum), Accessibility, Inclusion, Universal access |
| #7 | Ethics | Ethical and equity issues |
| #8 | Context and awareness | Contextual information, Spatial knowledge |
| #9 | Application areas | Games, Social media, Organizational contexts |
| #10 | Monetary and management issues | Economic models, Management |

virtual environments). Complementarily, they also suggested the creation of more safe and secure environments for students in K-12, and the use of ethnography to collect and analyze data. Hence, a review undertaken by Savin-Baden et al. (2010) emphasized pedagogy, staff role, and digital literacies. The authors described issues concerned with identity work, meaning-making, self-representation, and location and roles of staff when teaching.

Savin-Baden's (2010) study on staff experiences of learning and teaching in immersive worlds "introduced issues relating to identity play, the relationship between pedagogy and play and the ways in which learning, play and fun were managed (or not)". The interaction between virtual world and real life was also addressed with challenges in haptics, motion capture, simulation and deconstruction, photorealism, and identity. Nevertheless, socio-political impacts of virtual world learning on higher education were exploited by Wimpenny et al. (2012), and three dominant frames of reference have appeared: institutional space and ownership, disciplinary learning, and games and gaming media. Moreover, a scoping guide for serious virtual worlds (De Freitas, 2008) discussed challenges related with the survivability of license-fee based worlds against open source platforms, the co-construction of virtual spaces, activities and content, the support for learners with disabilities or mobility limitations, and the creation of accurate benchmarking metrics for assessment and validation.

The use of virtual worlds in education was also studied from an OpenSimulator perspective (Allison et al., 2012), introducing challenges concerned with network infrastructure, management guidance, 3D Web, and programmability. Although 3D virtual learning environments are able to support teaching and learning in educational contexts, their presentation layer are highly restrictive (Callaghan et al., 2009), and more alternatives integrating virtual worlds with virtual learning environments (e.g., Sloodle) are required to create engaging learning experiences for students (Konstantinidis et al., 2010). Nonetheless, simulating and integrating the components of real-world classrooms, as well as adopting and using social virtual worlds as teaching environments were indicated as research goals (Hendaoui et al., 2008). The abilities of virtual worlds for engaging students in open learning were tested by Allison et al. (2011), despite their restrictiveness in terms of business models and programmability, while land cost, quality of server providers, age filter, authorship and privacy were also considered as challenges that must be addressed (Allison et al., 2010). As technology evolve to support learning specificities, more studies are needed regarding the abilities, strengths and preferences of immersive media, as well as the suitability of instructional designs to varied types of immersive mediums (Dede, 2009).

### *3.3 Sociological Perspectives on 3D3C Worlds in Learning*

The seminal ethnographic work presented by Castronova (2001) dawned the interest on the use of qualitative data collection methods for virtual worlds research, considering interactivity, physicality, and persistence as distinguishing features. Subsequently, Castronova and Falk (2008) approached virtual worlds as Petri dishes for the social and behavioral sciences. A typology of virtual worlds was presented by Messinger et al. (2008), including the purpose, place, platform, population, and profit model. According to the authors, emergent features may become worth incorporating into such kinds of classification schemes. Furthermore, more research is needed on understanding standards of social behavior, attitudes learned in virtual worlds, influence of factors such as the nature of platform on people's behavior, regulation (e.g., social values and norms), avatar appearance, self-governance, etc. Nonetheless, economic concerns (e.g., periodic subscription payments), guidelines and demographics might also be studied. Anstadt et al. (2011) recognized a need for considering users with developmental and physical disabilities, the relationship between virtual and real life contexts, institutional roles, and ethical demands of practice (e.g., safety, and prevention). In addition, Bailenson and Yee (2008) mentioned the use of haptic devices as possible instruments to measure implicit attitudes towards aspects such as ethnicities or skin tones, while immersive 3D virtual worlds were addressed by Otto et al. (2006) taking into account their suitability for supporting closely coupled collaboration.

Davis et al. (2009) characterized the use of virtual worlds for virtual team collaboration, considering the virtual world itself, people/avatars, technology capabilities (communication, rendering, interaction, and team process), behaviors (coordination, trust, role clarity, and shared understanding), and outcomes (perceived quality, member support, self-image, cultural synchronicity, intent to immerse, deception, and reconnect anxiety) as elements of a conceptual model for virtual worlds research. The transition of newly acquired skills from virtual to real world and the impact of virtual reality on the neural network sustaining social abilities were indicated as current challenges. Some scholars believe that there is a need to cope with virtual identities, digital and cultural literacies, immersion, empathy and learning, design skills, collaboration, economic concerns (e.g., cost of purchasing land), social presence and social networks, standardization, and scaffolding persistence and social discovery (Warburton, 2009). Similarly, interactivity and immersion were also considered under-researched areas in the representational dimension (De Freitas et al., 2010).

A systematic description structure of collaboration patterns in 3D virtual environments was proposed by Schmeil and Eppler (2008), including usage situations, objective, number of participants, interaction intensity, typical duration, required artifacts, avatar actions, risks, and design effort. The authors advocate the promotion of new frameworks and on-going revisions in classification models, experimental comparisons of collaboration tasks in 3D virtual worlds, text-based virtual worlds, and real life collaboration settings, as well as theories explaining 3D interaction in collaboration and learning scenarios. Complementarily, Schmeil and Eppler (2010) suggested a systematic framework which "organizes the necessary elements for the design and implementation of collaboration patterns in virtual worlds", claiming for contributions on the use of controlled on-line experiments and in-situ participatory observation within organizations. Computer-supported networked collaborative process modeling was considered by Brown et al. (2011) as a challenge for researchers in terms of testing emergent themes (e.g., intuitiveness, user acceptance, and ease of application), ensuring scalability to larger and more complex collaboration process scenarios while applying usability analysis in modeling interactions.

Place metaphors used in 3D virtual learning environments were previously addressed (Prasolova-Førland, 2008). Hasler et al.'s (2009) conceptual framework and research agenda focused on behavioral indicators of virtual teamwork (i.e., form and content of team interaction, individual level effects, and intra- and inter-group effects), sociability factors (perceived presence, social conventions, emerging roles, and relationship formation), and usability factors (perceived usability, collaboration tools, communication mode, and support facilities). The link between spatial and visual characteristics, collaborative behaviors, and virtual teamwork in 3D3C worlds was explored by Montoya et al. (2011), while Wallace et al. (2009) studied the self-representation with human and non-human avatars concerning the willingness to collaborate in virtual worlds.

## *3.4 Immersive Virtual 3D Healthcare Learning Environments*

Considering the application of 3D virtual worlds in healthcare, Phillips and Berge (2009) reported the use of teledentistry regarding insurance coverage, licensure, malpractice, and privacy. Creutzfeldt et al. (2010) claimed for solving technical troubles (e.g., bandwidth, downtime, and lag) and usage problems such as navigation, object creation and handling, and avatar manipulation. A literature review on three-dimensional healthcare learning environments (Hansen, 2008) suggested a need for empirical research about the pedagogical outcomes and advantages of this technology taking into account the time and cost involved in creating appropriate learning spaces within a 3D virtual environment. The use of simulation as a training and assessment tool in medical education (e.g., lethal events in pediatrics such as trauma and respiratory arrest) was approached by Weinberg et al. (2009) in the form of challenges and features for human patient simulators, including but not limited to monitoring blood pressure and programmable clinical scenarios.

An analysis on the use of 3D virtual environments in healthcare (Ghanbarzadeh et al., 2014) provided insights about the need for studying the impact of this technology in the education of surgeons, improving healthy behaviors and filling the lack of research on application areas such as social isolation, care of the elderly, and phobias. In addition, Boulos et al. (2007) also indicated challenges in medical and health education, including Internet addiction, gambling, violence, identity, privacy, copyright, trust, and pornography. Parsons and Cobb (2011) presented some advantages and benefits of virtual reality in social and life skills training for children on the autism spectrum, providing evidence on the nature of representation and the lack of robust and usable technologies that can enhance real world educational contexts. Moreover, Bellani et al. (2011) also analyzed the use of virtual reality for habilitation in autism, helping caretakers and educators to enhance the daily life social behaviors of autists.

### *3.5 Technical Barriers and Empirical Research on 3D Learning Ecosystems*

A comprehensive survey performed by Dionisio and Gilbert (2013) identified psychological realism, scalability, interoperability, identity, and ubiquity of access across virtual environments as central features of virtual world technology. A vast number of limitations related with technology (e.g., bandwidth, audio, and IT policies), time commitment, cost and funding, usability, learning curve, ethics, management support and user acceptance were discussed by Dalgarno et al. (2011a, 2011b) Finally, technological infrastructures for metaverses, standards and 3D protocols, connection of mobile devices and websites with social virtual worlds, security, and interoperability were considered by Anstadt et al. (2013). Ubiquitous tracking and augmented reality have been arising as lines of further examination, while platforms such as Xj3D can be used to build and deploy 3D3C worlds. This breadth reinforces the view that an integration with collaboration tools allows increasing user's self-awareness, facilitating interaction and coordination while improving social bonds.

Qualitative methods such as ethnography and Grounded Theory are indicated as means of informing the creation of frameworks for classifying users, virtual worlds, collaboration mechanisms, and their relations in a systematic way (Jäkälä & Pekkola, 2007). In addition, more research is needed about the past, current, and planned tools at various institutions by means of surveys and annotated bibliographies considering the use of 3D immersive virtual worlds in higher education (Wright & Madey, 2009; Dalgarno et al., 2011a, 2011b). A lack of dedicated frameworks evaluating educational games and simulations in learning contexts and subject areas was mentioned as a limitation by De Freitas & Oliver (2006). In addition, Pinkwart and Olivier (2009) indicated that "a cohesive body of research is still missing" taking into account the lack of empirical research on the risks and chances of 3D virtual worlds technology within collaborative settings, the system requirements, the connection between physical and virtual objects enabling new forms of cooperation trough 'mixed reality', and the adoption of 3D3C worlds in organizations.

## 4 Discussion

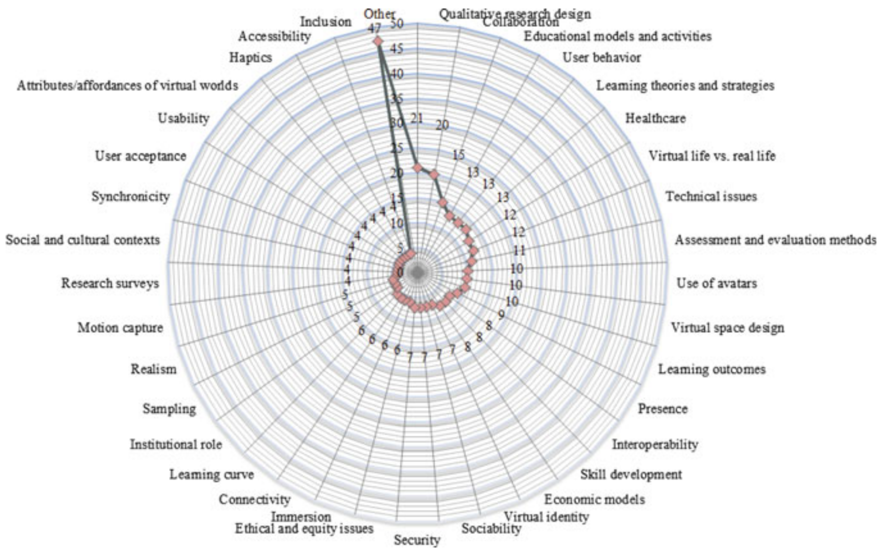
In spite of the larger number of studies, some indicators can be interpreted from a qualitative point of view. A prevalence of challenges and possibilities concerned with research study design is clearly noted, including a lack of details about the methodology, a common absence of control groups, a short length and coverage of current studies, and a need for fine-grained surveys. A second level of challenges includes the relationship between users' virtual and real lives, technical issues (e.g., bandwidth, downtime and lag, and haptics), and educational models and activities. Furthermore, collaboration is also a topic of intensive research, including issues such as object co-creation within a virtual world. Other relevant aspects include but are not limited to assessment and evaluation methods (e.g., classification models), virtual space design, user behaviors (e.g., use of avatars), interoperability, skill development, learning theories and strategies, learning outcomes, and healthcare (e.g., autism spectrum). A distinct level of abstraction comprises issues related with sociability (e.g., daily life social behaviors of autists), security, familiarity with virtual worlds, institutional role, ethics and equity, economics, accessibility, inclusion, and synchronicity. Figure 2 represents a scheme for synthesizing research challenges and opportunities in learning through the use of 3D3C worlds.

The selection criterion used for naming the categories/topics is adopted from Dalgarno et al. (2011a, 2011b), including the number of mentions as a limitation, barrier or opportunity for research. A total of 36 main categories and 23 complementary topics (with less than four mentions) were identified. As previously mentioned, earlier studies have also proposed conceptual models and research agendas in different forms. For example, Davis et al. (2009) presented a scheme for virtual worlds research comprising technology capabilities, people/avatars, behaviors, and outcomes. Relationships between categories are not comprised in this scheme.

Each category/topic has its own constituent attributes. For instance, synchronicity can be represented by synchronous or asynchronous interaction, and such sub-categories constitute the temporal dimension of a time-space matrix (Johansen, 1988). Other examples include user behavior (which can be represented by the study of emotions, attitudes, virtual identity, use of avatars, etc.) and collaboration (e.g., environment, process, support, and functions). Furthermore, sub-functions of topics such as collaboration (e.g., instant messaging, and actor presence monitoring) can arise from a new level of abstraction. However, such abstraction requires a lot of work distilling units of analysis from large amounts of text.

### *4.1 Research Methods, Theories and Models*

There is a lack of studies examining students' and teachers' perceptions using 3D virtual worlds (including detrimental effects) over a long period of time




| **Complementary categories** | | Scalability | 2 |
|---|---|---|---|
| Long term studies | 3 | Autism spectrum | 2 |
| Access control | 3 | Spatial knowledge | 2 |
| Object creation and manipulation | 3 | Social media | 2 |
| Standardization | 3 | Organizational contexts | 2 |
| Universal access | 3 | Virtuality | 1 |
| Contextual information | 3 | Workload | 1 |
| Games | 3 | Persistence | 1 |
| Management | 3 | Governance | 1 |
| Data collection | 2 | Interactivity | 1 |
| Ubiquity | 2 | Graphics | 1 |
| Navigation | 2 | Regulation | 1 |

**Fig. 2** Research challenges and possibilities on the use of 3D3C worlds in learning and training

(Hew & Cheung, 2010). Furthermore, classification systems are required for characterizing new scenarios. Research agendas, annotated bibliographies, and surveys of published research are also required concerning the use and acceptance of 3D immersive virtual worlds in education settings (Wright & Madey, 2009; Dalgarno et al., 2011a, 2011b). Data collection in 3D3C worlds is a current problem that can be addressed by using qualitative methods such as Grounded Theory (Jäkälä & Pekkola, 2007) and virtual ethnography (Inman et al., 2010). Some experiments have been conducted "to evaluate the use of embodied survey bots (i.e., software-controlled avatars) as a novel method for automated data collection in 3D virtual worlds" (Hasler et al., 2013). Replacing human interviewers by automated, survey bots in a virtual world involves ethical implications and needs the understanding of relations where humans might co-exist with automated entities.

## 4.2 Sociological Concerns

While exploring the influence of self-representation on online perceptions using human and non-human 3D avatars is very important, including aspects such as androgyny, anthropomorphism, credibility, and skin tones (Bailenson & Yee, 2008; Hew & Cheung, 2010), more emphasis is needed on studying aspects such as in-world behavior, implicit attitudes and motivations, sociocultural factors affecting the use of 3D3C worlds, transitions between virtual life vs. real life, collaborative learning and cooperative work endeavors, and links between immersion, empathy, and learning. Researchers have recognized the importance of understanding and evaluating concepts such as presence, virtual identity and virtuality, realism (e.g., psychological), sociability, self-governance, and interactivity.

## 4.3 Technical Characteristics and Attributes

Issues related with interoperability between different virtual world platforms and other educational tools must be further addressed (Konstantinidis et al., 2010). As noted by Kelton (2008), there is a "lack of tools for facilitating truly collaborative interactions between users in real-time". Filling the lack of features provided by OpenSimulator and Second Life can be realized by coping with challenges such as programmability and network infrastructure (Allison et al., 2012), scalability (Dionisio & Gilbert, 2013), and virtual space design (Hansen, 2008). Furthermore, working on 3D haptic implementations (e.g., video helmets), motion capture (e.g., Kinect), photorealism, simulation, and deconstruction (Otto et al., 2006; Savin-Baden, 2010; Duncan et al., 2012) can allow a closer interaction between real-life and avatar identity.

## 4.4 Educational Contexts

The challenges related with 3D virtual learning environments include the perspective that "the only students typically successful in online learning environments are those who have independent orientations towards learning, highly motivated by intrinsic sources, and have strong time management, literacy, and technology skills" (Barbour & Reeves, 2009). Learning analytics is another road of ongoing research (Duncan et al., 2012) for measuring the entire learning process and outcomes (Mikropoulos & Natsis, 2011). Furthermore, there is a need for institutional support such as faculty development programs (Davis et al., 2009). Understanding the roles educational institutions play in online interaction and learning is also critical (Anstadt et al., 2011). Suitable learning theories and strategies for in-world course practice and design must be revised and examined more carefully (Duncan et al., 2012). Simulating and integrating components of real-world classrooms such as teachers' and students' physical presence (Hendaoui et al., 2008), identifying types of curricular material for which full sensory immersion is relevant (Dede, 2009), as well as characterizing the pitfalls that are to be avoided before they can be extensively used in daily teaching and learning activities (Boulos et al., 2007) must be also addressed by researchers interested in 3D virtual worlds.

### *4.5 Healthcare and Accessibility*

The design of access technology for disabled people has presented several challenges concerned with solving real accessibility problems. Moreover, frameworks to evaluate, compare and classify such technology remain necessary since it is difficult to identify contributions, connections and gaps in this space (Bigham et al., 2011). Another set of significant contributions regards the study of virtual world education as an area of further development "for the physically and socially disadvantaged, which is lagging behind other areas of research" (Duncan et al., 2012). For example, 3D virtual spaces such as the virtual store of a supermarket can be constructed for allowing users navigate by products and ask for help using human computation features. Virtual worlds for education "should not disadvantage particular social, minority or disabled groups" and must be inclusive (Duncan et al., 2012). Social isolation is a current problem and elderly people can be engaged through several activities (e.g., physical exercise) using 3D virtual worlds and motion capture technology (Paredes et al., 2014). Digital divide is a reality in certain contexts and 3D virtual learning environments should be available to all students for getting easy access to coursework materials and submission of contributions (Allison et al., 2010). Nevertheless, autism spectrum (Bellani et al., 2011; Parsons & Cobb, 2011), recovery treatments for traumas (e.g., military), and phobias (Ghanbarzadeh et al., 2014) are some application areas of 3D virtual worlds in healthcare and medicine.

### *4.6 Additional Themes Concerned with 3D3C Worlds in Learning and Training*

Complementary categories covered in this study include user familiarity and expertise, ethics, context and awareness, monetary and management issues, and application areas. From a multidisciplinary point of view, investigating the users' experiences of leisure and serious gaming technology for explicit medical training intents (Phillips & Berge, 2009), social networking tools and functions

(Warburton, 2009), and inter-and intra-organizational contexts (Montoya et al., 2011) are some application areas of virtual worlds. The learning curve related with the perceived utility and natural use of virtual world technology is also a topic of further improvement. Ethical concerns associated with gambling, copyright, violence and privacy deserve attention (Boulos et al., 2007), context, and awareness remain topics of interesting research (Dalgarno & Lee, 2010). Broadening virtual worlds in terms of economic models (considering issues such as land cost) must be also taken seriously to support open learning using three-dimensional spaces.

## 5 Final Thoughts

This chapter presents several challenges and possibilities for research in 3D virtual worlds in learning within an open, meta-theoretic research framework. The study carried on allowed identifying healthcare contexts, K-12 research, entertainment, security, cultural influence and immersion, economic concerns, mobile and multiplayer technologies, open source platforms, gestures recognition, social behaviors, and physical interaction. By updating work in the application areas of 3D virtual worlds, this study also attempts to help a wide variety of individuals and organizations, such as practitioners, nurses, managers, hospitals, healthcare agencies, private groups, business health companies and corporations, and universities (Ghanbarzadeh et al., 2014). Such insights can be particularly useful for researchers interested in this topic to better understand the field and previous studies, helping them classify research, identify gaps in the literature, and shape the future trends.

The results of this meta-analysis show that 3D3C worlds find their place as alternative ecosystems to enhance learning and collaboration abilities between humans and computerized residents and objects. Heuristics, methods and interpretations of literature-based evidences are error prone and there is a need to reinforce the creation of research agendas and theoretical frameworks aware of the social-technical requirements of virtual worlds. In addition, this analysis needs future revisions and different perspectives on the current status of research in 3D3C worlds to reinforce an updated research basis focused on different disciplines.

**Acknowledgments** This work is funded (or part-funded) by the ERDF—European Regional Development Fund through the COMPETE Programme (operational programme for competitiveness) and by National Funds through the FCT—Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) within project «FCOMP—01-0124-FEDER-022701». The analysis and results presented in this study are entirely the authors' responsibility. Special acknowledgments are addressed to Tzafnat Shpak and Yesha Sivan for inviting the authors to submit this extended chapter as part of an ongoing research agenda on 3D virtual worlds for collaborative learning and cooperative work.

## References


Allison, C., Campbell, A., Davies, C. J., Dow, L., Kennedy, S., & McCaffery, J. P., et al. (2012). Growing the use of virtual worlds in education: An OpenSim perspective. In *Proceedings of the Second European Immersive Education Summit*.

Allison, C., Miller, A., Sturgeon, T., Nicoll, J. R., & Perera, I. (2010). Educationally enhanced virtual worlds. In *IEEE frontiers in education conference* (pp. T4F-1–T4F-6).

Allison, C., Miller, A., Sturgeon, T., Perera, I., & McCaffrey, J. (2011). The third dimension in open learning. In *Proceedings of the IEEE Frontiers in Education Conference* (pp. T2E-1–T2E-6).

Anstadt, S. P., Bradley, S., Burnette, A., & Medley, L. L. (2013). Virtual worlds: Relationship between real life and experience in Second Life. *The International Review of Research in Open and Distance Learning, 14*(4), 160–190.

Anstadt, S. P., Burnette, A., & Bradley, S. (2011). Towards a research agenda for social work practice in virtual worlds. *Advances in Social Work, 12*(2), 289–300.

Bailenson, J. N., & Yee, N. (2008). Virtual interpersonal touch: Haptic interaction and copresence in collaborative virtual environments. *Multimedia Tools and Applications, 37*(1), 5–14.

Barbour, M. K., & Reeves, T. C. (2009). The reality of virtual schools: A review of the literature. *Computers and Education, 52*(2), 402–416.

Bartle, R. A. (2010). From MUDs to MMORPGs: The history of virtual worlds. In J. Hunsinger et al. (Eds.), *International handbook of internet research* (pp. 23–39). Netherlands: Springer.

Bellani, M., Fornasari, L., Chittaro, L., & Brambilla, P. (2011). Virtual reality in autism: State of the art. *Epidemiology and Psychiatric Sciences, 20*(3), 235–238.

Benford, S., Greenhalgh, C., Rodden, T., & Pycock, J. (2001). Collaborative virtual environments. *Communications of the ACM, 44*(7), 79–85.

Bentley, R., Hughes, J. A., Randall, D., Rodden, T., Sawyer, P., & Shapiro, D., et al. (1992). Ethnographically-informed systems design for air traffic control. In *Proceedings of the ACM Conference on Computer-Supported Cooperative Work* (pp. 123–129).

Bigham, J. P., Ladner, R. E., & Borodin, Y. (2011). The design of human-powered access technology. In *Proceedings of the International ACM SIGACCESS Conference on Computers and Accessibility* (pp. 3–10).

Boulos, M. N. K., Hetherington, L., & Wheeler, S. (2007). Second Life: An overview of the potential of 3-D virtual worlds in medical and health education. *Health Information and Libraries Journal, 24*(4), 233–245.

Brown, R., Recker, J., & West, S. (2011). Using virtual worlds for collaborative business process modeling. *Business Process Management Journal, 17*(3), 546–564.

Callaghan, M. J., McCusker, K., Losada, J. L., Harkin, J., & Wilson, S. (2009). Integrating virtual worlds & virtual learning environments for online education. In *Proceedings of the International IEEE Consumer Electronics Society's Games Innovations Conference* (pp. 54–63).

Castronova, E. (2001). *Virtual worlds: A first-hand account of market and society on the cyberian frontier* (CESifo Working Paper No. 618).

Castronova, E., & Falk, M. (2008). *Virtual worlds as petri dishes for the social and behavioral sciences* (German Council for Social and Economic Data No. 47).

Correia, A., Cassola, F., Azevedo, D., Pinheiro, A., Morgado, L., Martins, P., et al. (2014). Metatheoretic assumptions and bibliometric evidence assessment on 3-D virtual worlds as collaborative learning ecosystems. *Journal of Virtual Worlds Research, 7*(3), 1–18.

Crabtree, A., & Rodden, T. (2008). Hybrid ecologies: Understanding cooperative interaction in emerging physical-digital environments. *Personal and Ubiquitous Computing, 12*(7), 481–493.

Creutzfeldt, J., Hedman, L., Medin, C., Heinrichs, W. L., & Felländer-Tsai, L. (2010). Exploring virtual worlds for scenario-based repeated team training of cardiopulmonary resuscitation in medical students. *Journal of Medical Internet Research, 12*(3), e38.

Dalgarno, B., & Lee, M. J. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology, 41*(1), 10–32.

Dalgarno, B., Lee, M. J., Carlson, L., Gregory, S., & Tynan, B. (2011a). An Australian and New Zealand scoping study on the use of 3D immersive virtual worlds in higher education. *Australasian Journal of Educational Technology, 27*(1), 1–15.

Dalgarno, B., Lee, M. J., Carlson, L., Gregory, S., & Tynan, B. (2011b). Institutional support for and barriers to the use of 3D immersive virtual worlds in higher education. In *Proceedings of the 28th ASCILITE Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education: Changing Demands, Changing Directions* (pp. 316–330).

Damer, B. (2008). Meeting in the ether: A brief history of virtual worlds as a medium for user-created events. *Artifact, 2*(2), 94–107.

Davis, A., Murphy, J., Owens, D., Khazanchi, D., & Zigurs, I. (2009). Avatars, people, and virtual worlds: Foundations for research in metaverses. *Journal of the Association for Information Systems, 10*(2), 90–117.

De Freitas, S. (2008). *Serious virtual worlds. A scoping guide. JISC e-Learning Programme*. London: The Joint Information Systems Committee (JISC).

De Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? *Computers and Education, 46*(3), 249–264.

De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology, 41*(1), 69–85.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323*(5910), 66–69.

Dionisio, J. D. N., & Gilbert, R. (2013). 3D virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys (CSUR), 45*(3), 34.

Dodgson, M., Gann, D. M., & Phillips, N. (2013). Organizational learning and the technology of foolishness: The case of virtual worlds at IBM. *Organization Science, 24*(5), 1358–1376.

Duncan, I., Miller, A., & Jiang, S. (2012). A taxonomy of virtual worlds usage in education. *British Journal of Educational Technology, 43*(6), 949–964.

Fonseca, B., Paredes, H., Lt. Rafael, J., Morgado, L., & Martins, P. (2011). A software architecture for collaborative training in virtual worlds: F-16 airplane engine maintenance collaboration and technology. In *Proceedings of the 17th CRIWG Conference on Collaboration and Technology* (pp. 102–109). Berlin, Heidelberg: Springer.

Ghanbarzadeh, R., Ghapanchi, A. H., Blumenstein, M., & Talaei-Khoei, A. (2014). A decade of research on the use of three-dimensional virtual worlds in health care: A systematic literature review. *Journal of Medical Internet Research, 16*(2), e47.

Grady, S. M. (1998). *Virtual reality: Computers mimic the physical world*. New York, NY: Universities Press.

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today, 24*(2), 105–112.

Grimstead, I. J., Walker, D. W., & Avis, N. J. (2005). Collaborative visualization: A review and taxonomy. In *Proceedings of the Ninth IEEE International Symposium on Distributed Simulation and Real-Time Applications* (pp. 61–69).

Hansen, M. M. (2008). Versatile, immersive, creative and dynamic virtual 3-D healthcare learning environments: A review of the literature. *Journal of Medical Internet Research, 10*(3), e26.

Hasler, B. S., Buecheler, T., & Pfeifer, R. (2009). Collaborative work in 3D virtual environments: A research agenda and operational framework. In A. A. Ozok & P. Zaphiris (Eds.), *Online communities and social computing* (pp. 23–32). Berlin, Heidelberg: Springer.

Hasler, B. S., Tuchman, P., & Friedman, D. (2013). Virtual research assistants: Replacing human interviewers by automated avatars in virtual worlds. *Computers in Human Behavior, 29*(4), 1608–1616.

Haynes, C., & Holmevik, J. R. (1998). *High wired: On the design, use, and theory of educational MOOs*. Ann Arbor: University of Michigan Press.
Hendaoui, A., Limayem, M., & Thompson, C. W. (2008). 3D social virtual worlds: research issues and challenges. *IEEE Internet Computing, 12*(1), 88–92.
Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33–55.
Inman, C., Wright, V. H., & Hartman, J. A. (2010). Use of Second Life in K-12 and higher education: A review of research. *Journal of Interactive Online Learning, 9*(1), 44–63.
Jacovi, M., Soroka, V., Gilboa-Freedman, G., Ur, S., Shahar, E., & Marmasse, N. (2006). The chasms of CSCW: A citation graph analysis of the CSCW conference. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work* (pp. 289–298).
Jäkälä, M., & Pekkola, S. (2007). From technology engineering to social engineering: 15 years of research on virtual worlds. *ACM SIGMIS Database, 38*(4), 11–16.
Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers and Education, 53*(1), 169–182.
Johansen, R. (1988). *Groupware: Computer support for business teams*. New York, London: The Free Press.
Jonassen, D. H. (2004). *Handbook of research on educational communications and technology*. New York, NY: Taylor & Francis.
Joslin, C., Di Giacomo, T., & Magnenat-Thalmann, N. (2004). Collaborative virtual environments: From birth to standardization. *IEEE Communications Magazine, 42*(4), 28–33.
Kelton, A. J. (2008). Virtual worlds? "outlook good". *EDUCAUSE Review, 43*(5), 15–22.
Kitchenham, B., Brereton, O. P., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2009). Systematic literature reviews in software engineering—a systematic literature review. *Information and Software Technology, 51*, 7–15.
Konstantinidis, A., Tsiatsos, T., Demetriadis, S., & Pomportsis, A. (2010). Collaborative learning in OpenSim by utilizing Sloodle. In *Proceedings of the Sixth IEEE Advanced International Conference on Telecommunications* (pp. 90–95).
Krippendorff, K. (1980). *Content analysis: An introduction to its methodology* (The Sage Commtext Series). London: Sage Publications.
Mak, W. K., & Palia, A. P. (2014). Educational perspective of collaborative virtual communication and multi-user virtual environments for business simulations. *Developments in Business Simulation and Experiential Learning, 32*, 200–207.
Messinger, P. R., Stroulia, E., & Lyons, K. (2008). A typology of virtual worlds: Historical overview and future directions. *Journal of Virtual Worlds Research, 1*(1), 1–18.
Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers and Education, 56*(3), 769–780.
Montoya, M. M., Massey, A. P., & Lockwood, N. S. (2011). 3D collaborative virtual environments: Exploring the link between collaborative behaviors and team performance. *Decision Sciences, 42*(2), 451–476.
Morgado, L. (2013). Technology challenges of virtual worlds in education and training—research directions. In *Proceedings of the IEEE International Conference on Games and Virtual Worlds for Serious Applications* (pp. 1–5).
Morgado, L., Varajao, J., Coelho, D., Rodrigues, C., Sancin, C., & Castello, V. (2010). The attributes and advantages of virtual worlds for real world training. *The Journal of Virtual Worlds and Education, 1*(1), 15–35.
Moscato, D. R., & Boekman, D. M. (2014). Using 3-D virtual worlds as a platform for an experiential case study in information systems auditing. *Communications of the IIMA, 10*(1), 3.
Okutsu, M., DeLaurentis, D., Brophy, S., & Lambert, J. (2013). Teaching an aerospace engineering design course via virtual worlds: a comparative assessment of learning outcomes. *Computers and Education, 60*(1), 288–298.

Onwuegbuzie, A. J., Leech, N. L., & Collins, K. M. (2012). Qualitative analysis techniques for the review of the literature. *Qualitative Report, 17*, 56.
Otto, O., Roberts, D., & Wolff, R. (2006). A review on effective closely-coupled collaboration using immersive CVE's. In *Proceedings of the ACM International Conference on Virtual Reality Continuum and Its Applications* (pp. 145–154).
Paredes, H., Cassola, F., Morgado, L., Carvalho, F., Ala, S., & Cardoso, F., et al. (2014). Exploring the usage of 3-D virtual worlds and kinect interaction in exergames with elderly. In *Proceedings of the International Conference on Computers Helping People with Special Needs* (pp. 297–300).
Parsons, S., & Cobb, S. (2011). State-of-the-art of virtual reality technologies for children on the autism spectrum. *European Journal of Special Needs Education, 26*(3), 355–366.
Phillips, J., & Berge, Z. L. (2009). Second life for dental education. *Journal of Dental Education, 73*(11), 1260–1264.
Pierzchała, D., Dyk, M., & Szydłowski, A. (2011). Distributed military simulation augmented by computational collective intelligence. In P. Jędrzejowicz, N. T. Nguyen, & K. Hoang (Eds.), *Computational collective intelligence. Technologies and applications* (pp. 399–408). Berlin, Heidelberg: Springer.
Pinkwart, N., & Olivier, H. (2009). Cooperative virtual worlds—a viable eCollaboration pathway or merely a gaming trend? *Electronic Markets, 19*(4), 233–236.
Prasolova-Førland, E. (2008). Analyzing place metaphors in 3D educational collaborative virtual environments. *Computers in Human Behavior, 24*(2), 185–204.
Reeves, B., Malone, T. W., & O'Driscoll, T. (2008). Leadership's online labs. *Harvard Business Review, 86*(5), 58.
Salmon, G. (2009). The future for (second) life and learning. *British Journal of Educational Technology, 40*(3), 526–538.
Savin-Baden, M. (2010). Changelings and shape shifters? Identity play and pedagogical positioning of staff in immersive virtual worlds. *London Review of Education, 8*(1), 25–38.
Savin-Baden, M., Gourlay, L., Tombs, C., Steils, N., Tombs, G., & Mawer, M. (2010). Situating pedagogies, positions and practices in immersive virtual worlds. *Educational Research, 52*(2), 123–133.
Schmeil, A., & Eppler, M. J. (2008). Knowledge sharing and collaborative learning in Second Life: A classification of virtual 3D group interaction scripts. *Journal of Universal Computer Science, 14*(3), 665–677.
Schmeil, A., & Eppler, M. J. (2010). Formalizing and promoting collaboration in 3D virtual environments—a blueprint for the creation of group interaction patterns. In *Proceedings of the International ICST Conference on Facets of Virtual Conference* (pp. 121–134). Berlin, Heidelberg: Springer.
Schneider, D., Moraes, K., Moreira de Souza, J., & Esteves, M. G. P. (2012). CSCWD: Five characters in search of crowds. In *Proceedings of the IEEE 16th International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 634–641).
Schroeder, R., Heldal, I., & Tromp, J. (2006). The usability of collaborative virtual environments and methods for the analysis of interaction. *Presence, 15*(6), 655–667.
Sequeira, L. M., Morgado, L., & Pires, E. J. (2014). Simplifying crowd automation in the virtual laboratory of archaeology. *Procedia Technology, 13*, 56–65.
Serino, S., Triberti, S., Villani, D., Cipresso, P., Gaggioli, A., & Riva, G. (2014). Toward a validation of cyber-interventions for stress disorders based on stress inoculation training: a systematic review. *Virtual Reality, 18*(1), 73–87.
Siriaraya, P., Ang, C. S., & Bobrowicz, A. (2014). Exploring the potential of virtual worlds in engaging older people and supporting healthy aging. *Behaviour and Information Technology, 33*(3), 283–294.
Stangl, B., Kastner, M., & Polsterer, F. (2012). Social virtual worlds' success factors: Four studies' insights for the tourism supply and demand side. In *Forty-Fifth IEEE Hawaii International Conference on System Science (HICSS)* (pp. 993–1002).

Stapić, Z., López, E. G., Cabot, A. G., & Ortega, L. M. (2012). Performing systematic literature review in software engineering. In *Proceedings of the Central European Conference on Information and Intelligent Systems* (pp. 441–447).

Sung, H. Y., & Hwang, G. J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers and Education, 63*, 43–51.

Wallace, P., Presley, A. B., Adrian, A. M., Belden-Adams, K., Caton-Rosser, M., Sleep, D., et al. (2009). Avoidance and attraction in virtual worlds: The impact of affiliative tendency on collaboration. *The International Journal of Technology, Knowledge and Society, 5*(3), 119–126.

Warburton, S. (2009). Second Life in higher education: assessing the potential for and the barriers to deploying virtual worlds in learning and teaching. *British Journal of Educational Technology, 40*(3), 414–426.

Weinberg, E. R., Auerbach, M. A., & Shah, N. B. (2009). The use of simulation for pediatric training and assessment. *Current Opinion in Pediatrics, 21*(3), 282–287.

Wiecha, J., Heyden, R., Sternthal, E., & Merialdi, M. (2010). Learning in a virtual world: Experience with using second life for medical education. *Journal of Medical Internet Research, 12*(1), e1.

Wimpenny, K., Savin-Baden, M., Mawer, M., Steils, N., & Tombs, G. (2012). Unpacking frames of reference to inform the design of virtual world learning in higher education. *Australasian Journal of Educational Technology, 28*(3), 522–545.

Wright, T. E., & Madey, G. (2009). A survey of technologies for building collaborative virtual environments. *The International Journal of Virtual Reality, 8*(1), 53–66.