

Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research

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Abstract

In this paper, we review past empirical research studies on the use of three-dimensional immersive virtual worlds in education settings such as K-12 and higher education. Three questions guided our review: (1) How are virtual worlds (eg, *Active Worlds*, *Second Life*) used by students and teachers? (2) What types of research methods have been applied? (3) What research topics have been conducted on virtual worlds in teaching and learning, as well as their related findings? Overall, we found that virtual worlds may be utilised for the following uses: (1) communication spaces, (2) simulation of space (spatial), and (3) experiential spaces ('acting' on the world). Most of the studies reviewed were descriptive and conducted in polytechnic and university settings, and past virtual world research had been most frequently carried out in the media arts and health and environment disciplines. Three main research topics were found: participants' affective domain, learning outcomes and social interaction. We conclude by summarising some major findings and discussing three limitations of previous empirical studies. Several recommendations for future research related to virtual worlds in education settings are also provided.

Introduction

Three-dimensional (3-D) immersive virtual worlds are an emerging medium currently being used in both traditional classrooms and distance education (Dickey, 2005a). 3-D virtual worlds are 'richly immersive and highly scalable 3-D environments; where people enter these worlds via an avatar which is their representation in that space, moving their avatar through the spaces as if they were physically walking—or in some cases, flying' (New Media Consortium and EDUCAUSE Learning Initiative, 2007, p. 18). Virtual

worlds are open-ended environments in which people design and create the world, its objects and their behaviours (Delwiche, 2006). Consequently, virtual worlds can be applied to any context (New Media Consortium and EDUCAUSE Learning Initiative, 2007). Examples of 3-D virtual world applications include *Active Worlds* (Activeworlds Inc., Las Vegas, Nevada), *Second Life* (Linden Lab, San Francisco, California), *OnLive! Traveler* (Digital Space Corp., Santa Cruz, California), *Croquet* (Croquet Consortium Inc., Durham, North Carolina) and *There* (There Inc., San Mateo, California). The metaphors behind the design of virtual worlds are quite diverse, ranging from replication of real universities to other planets (Prasolova-Förland, 2008).

According to Dickey (2005a), 3-D virtual worlds typically share three important features: the illusion of 3-D space, avatars that serve as visual representations of users and an interactive chat tool for users to communicate with one another. An avatar is the user's on-screen persona, what Gerhard, Moore and Hobbs (2004, p. 5) described as 'user embodiment' in a virtual environment, and has various actions such as walk, run, wave and jump that the user can control using the keyboard and mouse (Bailey & Moar, 2001). The use of avatars helps enable direct visual interaction with the 3-D environment and with other avatars in the virtual world (Bailey & Moar, 2001). To these three features of virtual worlds, we add a fourth—that is, the ability for a user to 'act' on the world. Objects have properties that allow them to be taken, dropped and so on, which makes it possible for students to learn by doing rather than simply learning by listening to the instructor or reading text.

3-D virtual worlds can offer an incomparable environment for creating spaces where teachers and learners, who are separated by distance, can engage in social activity of learning (Bronack, Riedl & Tashner, 2006). For example, the use of avatars in virtual worlds can overcome the limitations of text-based, computer-mediated communication by giving users the means to display in real-time, nonverbal communication cues such as gesture and emotional states (eg, happiness) that facilitate communication (Peterson, 2006).

Purpose of this review

The purpose of this paper is to review past empirical research studies on the use of 3-D virtual worlds in education settings (K-12 and higher education). Specifically, our review was guided by the following questions:

1. How are virtual worlds used by students and teachers?
2. What types of research methods have been applied using virtual worlds in K-12 and higher education settings?
3. What research topics have been conducted so far, and what are their related findings?

Method

Searching and selection procedures

The search for relevant literature was completed in two stages. First, we examined empirical, peer-reviewed papers that we found in electronic databases using the

keyword search *virtual world*. We used the following databases: (1) *Academic Search Premier*, (2) *Education Research Complete*, (3) *ERIC* and (4) *PsycARTICLES*. As of February 27, 2008, our database searches revealed 414 hits. We believe our choices of the four databases were reasonable and sufficient because together these databases cover more than 10 430 journals. Moreover, the first database, *Academic Search Premier*, is considered one of the most prominent databases in academic institutions (Blessinger & Olle, 2004). Furthermore, some of these databases were frequently used by other scholars in their search for empirical papers (eg, Hew & Brush, 2007; Luppini, 2007; Rinke, 2008; Wang, Odell & Schwille, 2008).

In the second stage, we used the 'snowball' method by searching for journal papers that are cited in some of the papers that we had read. In addition, we searched the *EditLib Digital Library for Information Technology and Education* that includes paper proceedings from four international conferences: *International Conference on Mathematics/Science Education and Technology*, *Society for Information Technology and Teacher Education International Conference*, *World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education* and *World Conference on Educational Multimedia, Hypermedia and Telecommunications*. These yielded an additional 35 papers. Finally, we searched through a *Second Life* education workshop convention ($n = 21$ papers), which was held in Chicago on August 24–26, 2007.

Altogether, as at March 24, 2008, we had a total of 470 papers. Of these 470 papers, 455 were discarded because they were opinion papers, conceptual papers, non-empirical descriptions of programme implementations, literature reviews or non-K-12 and higher education related. Appendix A lists the remaining papers ($n = 15$) that we included in our review of research. These papers are listed according to the authors, year of publication, purpose, research method, data collection method and context.

Data analysis

The basic unit of analysis was each individual empirical paper. To answer the first question—How are virtual worlds used by students and teachers?—we used the following features of virtual worlds to guide our initial analysis and coding: illusion of 3-D space, avatars that serve as visual representations of users and the ability to 'act' on the world. Although these features were used a priori, we did not forcefully impose any of the coding categories onto the data corpus. During the course of our analysis, we also allowed for new categories of virtual world uses, if any, to emerge inductively during the coding process.

To answer the second and third questions—What types of research methods have been applied using virtual worlds in K-12 and higher education settings? What research topics have been conducted so far, and what are their related findings?—we used the constant comparative method or grounded approach by Lincoln and Guba (1985). This method is similar to the iterative-pattern coding approach (Miles & Huberman, 1994). Using the constant-comparative method, the coding scheme was not predetermined prior to our analysis but emerged inductively from the data. Specifically, the constant-

comparative method involves the following steps: examining each individual paper, forming various categories (ie, research methods and research topics), comparing categories and achieving category saturation. For instance, we began by selecting the first paper, read it and noted its content to form a tentative *research topic* category. This first paper represented the first entry in the first tentative category of research topic. We then selected the next paper, read it and again noted its content to determine whether its content was similar to the first paper. If so, we put the second content into the first category and proceeded to the third paper. If not, the second content represented the first entry in a new second tentative category of research topic. As we read each unit, we compared it with the existing categories until each category was saturated—meaning, new paper began to confirm the existing categories rather than create new ones. Please see the following results section for a fuller description of the various research methods and research topic categories.

Results and discussion

Categories of virtual world uses

At the end of our analysis of previous research studies, we found that virtual worlds may be utilised for the following uses: (1) communication spaces, (2) simulation of space (spatial) and (3) experiential spaces ('acting' on the world). One or more representative examples from previous studies are presented to illustrate the various uses.

Communication spaces

This refers to employing the virtual worlds to communicate information from one person to another. Communication in virtual worlds can take both verbal and nonverbal forms (Robbins, 2007). Verbal communication is typically established synchronously with the text-based chat function, which is usually available in the virtual world environments. Nonverbal communication can be established through avatar appearance, avatar posturing and gestures (Robbins, 2007).

An illustrative example is the study by Peterson (2006) which explored the interaction of English-as-a-foreign-language students during task-based, computer-mediated communication in *Active Worlds*. A majority of students were Japanese. Students were asked to self-select a partner after they had entered the virtual world. Using their avatars and the chat feature, students engaged in three task types such as jigsaw, decision making and opinion exchange. For example, in the jigsaw task, six pictures depicting a series of events were mixed up and divided into two task sheets each containing three pictures. Students were required to uncover the correct story sequence by describing the pictures to each other through the chat function. Besides using the synchronous text-based chat function, 15 of 24 students also made use of the communication features of their avatars, mainly waving to attract the attention of potential task partners. Of the 15, 13 made use of emotional responses such as joy to be displayed on their avatars.

Simulation of space (spatial)

One fundamental attribute of a virtual world is its ability to project a simulation of 3-D space or spatial aspect. This spatial aspect affords users the opportunity to be immersed

or embodied in the 3-D environment through an avatar. For example, Sourin, Sourina and Prasolova-Førland (2006) described a virtual campus of the Nanyang Technological University in Singapore. The virtual campus could be seen as a place of not merely displaying general information about the campus organisation but also helping international students acclimate to the real campus through the virtual world, something that other information applications could not do. Utilising the spatial aspect, international students could wander around the virtual campus and visit the various schools, residential hostels, libraries and lecture theatres. Anecdotal evidence revealed that students got a feeling of really being on the campus. This helped them to familiarise themselves with the real campus and its facilities before coming to Singapore.

In another example, Dickey (2005b) described a 3-D world, created by using *Active Worlds*, which consisted of a spacious rectangle plaza surrounded by a backdrop image of mountains that frame Boulder, Colorado, USA. Stone-lined roads extend on all four sides of the plaza, leading to nearby buildings. By moving east or west along one of the roads aptly named after each of the applications (eg, Microsoft Word Lane), students encounter a series of one-room buildings. Each building represents a software application and an assignment that students must complete with that application within the particular undergraduate Business Computing Skills course. Students move from building to building to submit the assignments, review grades and receive information such as instructor feedback. Many students during the informal interviews reported that the simulation of space made them feel like they were 'in school', or 'actually there' embodied in the environment (p. 445).

Experiential spaces ('acting' on the world)

Besides employing virtual worlds as communication and/or spatial spaces, some educators utilised them as experiential spaces. Following Kolb's (1984) experiential learning cycle concept, users in virtual worlds can act on the objects in the 3-D environment, which allows them to learn by doing, to observe the outcomes of their actions, to test their hypotheses about the world and to reflect further on their own understanding (Chee, 2007). As Chow, Andrews and Trueman (2007) put it, the use of virtual worlds allows users to virtually experience information as opposed to just reading text.

For example, Dickey (2003, 2005b) investigated the use of a virtual world for teaching a 3-D object modelling course, Intro to RenderWare Scripts (RWX) Modeling. The focus of Intro to RWX Modeling is to teach *Active Worlds* users to create original 3-D objects. RenderWare (RW, Criterion Software Limited, Guildford, Surrey, United Kingdom) is a commercially available middleware platform for supporting 3-D virtual environments (Dickey, 2005b). The *Active Worlds* browser uses RW to display 3-D environments by relying on RWX to define objects in the 3-D space. During each class, the instructor presented a concept of 3-D object modelling and then provided examples of how the concept was actualised by building and exhibiting a sample 3-D object in the virtual world. Dickey (2005b) reported that unlike 3-D modelling classes offered in a more traditional setting, the virtual world-based RWX object modelling class was situated in an environment made up of RWX objects, with learners literally represented as RWX

object. Hence, instead of observing actions such as object rotation from a third-person perspective, learners in the virtual world were able to construct an understanding from a first-person perspective.

In another example, students in Sourin *et al.*'s (2006) study had to complete several projects, two of which were the function-based web visualisation and the interactive function-based shape modelling. In the function-based web visualisation project, students defined analytically how one shape articulated by parametric formulas transformed into another one. This morphing was modelled as an animated shape conversion. In the interactive function-based shape-modelling project, students designed sophisticated shapes using implicit functions and made them available in their virtual homes in a virtual campus. Observations by Sourin *et al.* (2006) showed that when students worked on their coursework in the virtual world, which itself was created using computer graphics tools, then gradually and without making any extra effort, students were immersed in many concepts of computer graphics and could feel and touch real-time rendering, visualisation and virtual reality. Sourin *et al.* (2006) posited that this might explain the better learning of computer graphics concepts that had led to a 14% increase in the students' mean examination scores.

It is important to note that not all previous studies shown in Appendix A appeared to be unique to virtual worlds. One of the important questions or issues in analysing virtual world implementations is considering whether a particular study or task could have been carried out in another environment. It appeared that some studies are not really unique to virtual worlds because the activities and procedures described in them could also be implemented using other nonvirtual world applications. We present two examples to illustrate this point.

The first example is the study by Holmes (2007) which investigated the impact of using software agents as learning partners in an *Active Worlds* virtual space where students generated explanations about river ecosystem concepts. Students were randomly assigned to experimental groups from four Grade 5 classes taught by the same teacher. The three conditions used in this study varied by how the explanation resources were presented and whether the learning partner or advisor was another student or a software agent. All students and software agents were represented by avatars in the *Active Worlds* environment. The first two conditions involved pairs of students who worked in collaboration. Pairs in the first group (Group SST, $n = 24$) were provided with text-based resources, while pairs in the second group (Group SSA, $n = 21$) obtained their resources through dialogue with a software agent. The main difference between these two groups was the manner in which the resources were presented (text vs. software agent). Students in the third group (Group SA, $n = 24$) had a software agent (instead of a student) as a partner and obtained their explanations through dialogue with the same agent. Strictly speaking, the idea of using software agents as advisors to students could be implemented by using other applications instead of *Active Worlds*. For example, Baylor and Ryu (2003) investigated the use of software agents that were implemented using Microsoft Agent characters (eg, Merlin the Wizard).

The second example is the study by Cooper (2007) which explored the use of *Second Life* to increase awareness about the health effects of eating fast food and certain traditional ethnic food. Students participated in a nutrition scenario developed inside *Second Life*. The scenario simulated one day of food choices. The players chose what food they wanted to consume for the meal. After three meals had been consumed, the scenario ended. The players were then told how much weight they would gain or lose in 1 week, 1 month and 1 year based on their eating habits for the day. How much of their diet came from fat and how much cholesterol they consumed were also compared with recommended values. Players were also told of likely ailments to expect based on these values. This study did not appear to utilise the spatial aspect. Moreover, 90% of players preferred to use their personal statistics rather than an avatar when playing the game, hence suggesting that the nutrition scenario could be implemented using simple two-dimensional multimedia program.

Although some of the previous studies may not be unique to virtual worlds, we feel that they were nevertheless useful because they, at the very least, can provide information about what researchers are currently attempting to use virtual worlds for, and how. Because 3-D immersive virtual worlds are a relatively new technology, it is possible that many researchers are just beginning to explore them and, hence, are not very familiar with their fundamental affordances and the pedagogy of using them. It is possible that some researchers and educators are using virtual worlds as mere replacement to something they typically do in order to first explore the feasibility of using them, before using virtual worlds as technology for transformation (Hughes, 2005), typically carried out by utilising the technology's unique affordances, to provide innovative educational opportunities.

Types of research methods

In this section, we summarise the various research methods employed in the previous studies that we reviewed. We also summarise the various settings in which research on virtual worlds had been conducted. Two main types of research methods were found: descriptive research and experiment. Descriptive research is typically naturalistic, depicts conditions as they exist in a particular setting (Ross & Morrison, 1997) and is mainly concerned with *what is* type of questions that describe events focusing on a particular issue or phenomenon (Knupfer & McLellan, 1996).

As revealed in Appendix A, the majority of the studies are classified as descriptive research (14 of the 15 papers). The finding is consistent with Knupfer and McLellan's (1996) prognosis that there would be more studies employing descriptive research as their research method in succeeding years to explain educational events or issues. A probable reason for this is that important variables and processes pertaining to use of virtual worlds in K-12 and higher education have yet to be fully developed and understood—hence the lack of other research methods, such as experimental research, that involve questions about cause and effect. The use of descriptive research can provide information that can help isolate the variables that will eventually be used to measure cause and effect and, at the least, can help furnish surrounding information

that will aid logical interpretations of research questions within the context of a specific situation (Knupfer & McLellan, 1996).

A variety of data collection methods were used in the descriptive research papers that we reviewed. These methods included the questionnaire (eight studies), interviews (five studies), observations (seven studies), online log files (eg, chat transcripts) (three studies) and exam scores (one study). The questionnaire typically included both closed-ended items and open-ended questions to collect data on participants' satisfaction, or attitudes about a specific issue (eg, students' satisfaction of using virtual worlds). Although there are a variety of data collection methods, the use of questionnaires seems to be the main method of gathering research data in virtual world research.

As an illustration of a descriptive research, we may consider the study by Chow *et al.* (2007) that involved 18 participants in the USA, including four faculty members, one *Second Life* instructor, nine graduate students and four students who attended a series of virtual seminars in *Second Life*. *Second Life* was used in conjunction with a blend of face-to-face, television and course website. One graduate course used *Second Life* to provide its 'face-to-face' lecture in a virtual, private 'sky box' that brought students from three campuses together into one 'classroom'. Faculty members also held virtual office hours in *Second Life* for distance students to drop in to talk to them. Duration of study was 10 months. Data collection methods included observations, interviews, questionnaire and online logs. Analysis of data was carried out to explore how usable *Second Life* is in terms of utility and general ease of use for students and faculty.

Another type of research method that we reviewed was the experimental research. Experimental research typically involves an experimental group and a control group to test hypotheses regarding certain treatments or interventions (Ross & Morrison, 2004). Furthermore, in experimental research, the participants are randomly assigned to either group (Fraenkel & Wallen, 2006). So far in our review, only one paper (Holmes, 2007) utilised this research method. As previously mentioned, Holmes investigated the impact of using software agents as learning partners or advisors in an *Active Worlds* virtual space where students generated explanations about river ecosystem concepts. Participants of the study were 80 fifth graders in the USA. Data sources in the study included pretest, posttest, chat transcripts and student interviews. The pretest and posttest had multiple-choice and short-answer type questions based on ecosystem contents.

We also summarised the various settings in which past research on virtual worlds had been conducted. On the whole, a majority of previous studies were carried out in polytechnics and university settings (69%), followed by secondary schools (19%) and primary schools (12%). In addition, results suggest that past research on virtual worlds had been carried out in eight different disciplines of study. These included media arts (eg, 3-D modelling), education (eg, leadership and education studies, instructional technology), health and environment (eg, nutrition), commerce (eg, electronic commerce), language (eg, English as a foreign language), computing (eg, information tech-

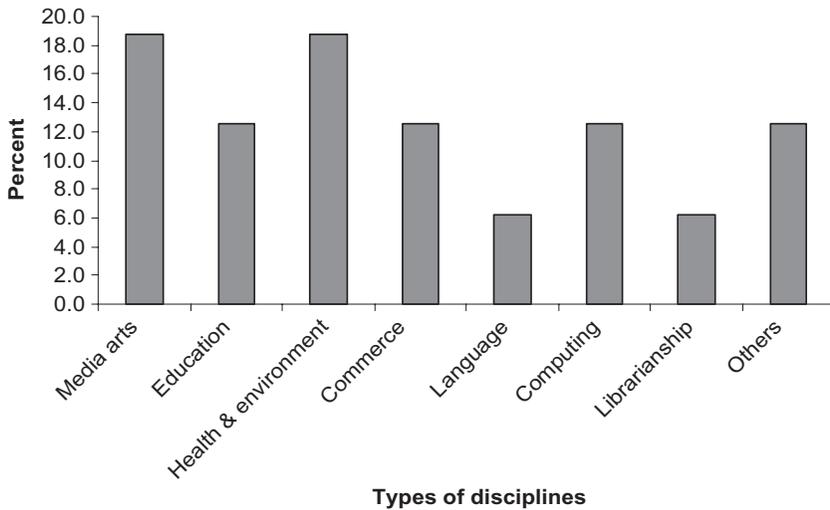


Figure 1: Types of discipline of study in which research on virtual worlds had been conducted

Table 1: Frequency count of types of research topics

Topic	Frequency count
Affective domain	11
Learning outcome	5
Social interaction	4

nology, computer engineering), librarianship and others (eg, study of terrorism, multidisciplinary subjects). Results revealed that past virtual world research had been most frequently conducted in media arts (18.8%), as well as in health and environment (18.8%). This was followed by education (12.5%), commerce (12.5%), computing (12.5%), others (12.5%), language (6.3%) and librarianship (6.3%) (see Figure 1).

Research topics and their related findings

Although many papers discussed only one research topic, there were still other papers that covered two or more topics. Table 1 shows the frequency counts for each research topic. From Table 1, it can be seen that three main types of research topics were found: participants' affective domain, participants' learning outcomes and participants' social interaction.

Affective domain

This research topic investigated outcomes in the participants' affective domain such as their attitudes and satisfaction (eg, likes and dislikes, benefits and limitations) of using virtual world. Eleven studies covered this research topic either singularly or as one of the

topics (Bailey & Moar, 2001; Chow *et al.*, 2007; Cooper, 2007; Dickey, 2003, 2005b; Gonzalez, 2007; Ligorio & van Veen, 2006; Martinez, Martinez & Warkentin, 2007; Michailidou & Economides, 2003; Riedl, 2004; Sanders, Gilmore & Drake, 2007). Researchers mainly used descriptive research methods to report students' experiences in using virtual worlds. Data collection methods included student questionnaire, student observation, student and teacher interview and online logs (eg, chat transcripts).

With regard to students' satisfaction, research overall seems to suggest that students liked using the virtual worlds because of the following reasons: the ability to fly and move around freely in a 3-D space, to socialise and meet new people and to experience virtual field trips and simulated experiences (ie, learners, in a sense, were embodied in the learning content and context (Dickey, 2005b), as opposed to the traditional flat, one-dimensional, text-driven digital displays.

On the other hand, some of the reported dislikes about using virtual worlds include: inability to access the virtual world environment through older computers, technical requirements involving the need for robust computing and Internet connectivity, general prohibition of the use of such virtual world software in public computers, having to instantaneously formulate answers and responses and needing fast typing skills in order to communicate textually through the chat tool, no provision of turn-taking or threaded discussion because of the chat function and unfamiliarity with the virtual world software.

Learning outcomes

One question that people who use virtual worlds for teaching and learning want to answer is whether virtual worlds can help improve or enhance students' learning. In our review of the research, we found five studies that covered this research topic either singularly or as one of the topics being investigated (Cooper, 2007; Holmes, 2007; Ligorio & van Veen, 2006; Sourin *et al.*, 2006; Ye, Fang, Liu, Chang & Dinh, 2007). Of these five studies, four utilised the descriptive research method, while one employed the experimental research. Three of the four descriptive research studies relied primarily upon student self-report data, such as student survey and student interview, to determine if the use of virtual worlds helped them learn (Cooper, 2007; Ligorio & van Veen, 2006; Ye *et al.*, 2007). One descriptive study relied upon student examination scores (Sourin *et al.*, 2006).

Results from the student self-report studies, on the whole, appeared to suggest that the use of virtual worlds could help students learn. For example, when asked how much was learned from a *Second Life*-based virtual environment about nutrition, on a scale of 1 (lowest) to 5 (highest), 65% of students reported a 4 or 5, and 94% answered with a 3, 4 or 5. When asked the open-ended question, 'What have you learned from using the *Second Life* environment?', one student explained, 'I learned how different types of food compare to one another in the context of calories, sodium intake, etc. Some foods were more damaging than I expected while others were not as bad as I would have thought. It was an eye opening experience (Cooper, 2007).

Similarly, 93.3% of students who participated in another *Second Life*-based environment on environmental education thought that the 3-D virtual world was very instructive as a tool for environmental education, hence suggesting that 3-D virtual world like the *Appalachian Tycoon* (Ohio University, Athens, Ohio, USA) game would be effective in increasing environmental awareness or teaching environmental knowledge (Ye *et al.*, 2007). In another study, Ligorio and van Veen (2006) reported that students indicated that they learned about the culture of another country when they collaborated with other students from that particular country and that the virtual world project improved their use of English as a second language.

Instead of relying on student self-report data, Sourin *et al.* (2006) used students' examination scores and student observations by the instructor. As previously mentioned, in this descriptive research study, students had to complete several projects, two of which were the function-based web visualisation and the interactive function-based shape modelling. The use of the virtual world in a one-semester course of computer graphics had resulted in a 14% increase of the mean examination mark.

The final study that explored student learning outcome was the experimental investigation by Holmes (2007) on the use of software agents as learning partners or advisors in a virtual world. Although results suggested that students working alone with the agents (the third experiment group) generated deeper explanations than students who did not interact with agents, a post hoc Tukey test failed to find a significant difference between the three groups in terms of their test scores with regard to the learning of ecological concepts.

Social interaction

In addition to outcomes in the affective and learning domains, researchers were also interested in examining students' social interaction in the virtual worlds. Some of the research questions that were addressed within this particular topic included the following: 'Do the use of avatar-based virtual worlds facilitate interaction among students?' 'Do learners make use of the communicative features of their avatars to talk to other learners?' 'What are some of these communicative features?' Four descriptive studies covered this research topic either singularly or as one of the topics being investigated (Bailey & Moar, 2001; Dickey, 2005b; Peterson, 2006; Riedl, 2004). Data sources included student observations, student interviews, student questionnaire and online logs such as student chat transcripts.

One UK study (Bailey & Moar, 2001) found that avatars appeared to be very successful as a means to facilitate interaction among primary school children. All the children expressed an interest in making their own avatars, and ultimately, most children wanted to make their avatars look like themselves. Avatars appeared to be the main means for children to initiate contact and conversation with others. Primary school pupils spent most of their time searching for other people. They looked forward far more to sessions when they knew they would meet up with other people, most especially with pupils from other schools.

Dickey (2005b), in her study of US undergraduates in a business computing skills course, found the combination of text chat tool, unique names and avatars provided a sense of anonymity. On the whole, students appeared to take great liberties in their interactions (eg, 'hey babes') prior to learning each student's actual identities than might be usually encountered in a typical American undergraduate classroom. This could be due to the selection of avatars that consisted primarily of representing young, fit and shapely Caucasians. This finding is at variance with that of Riedl (2004), who found that some graduate students in the USA had difficulty trying to interact with the avatars of those they did not know.

The study by Peterson (2006), which drew upon data from English-as-a-foreign-language students in Japan, revealed that the use of a personal avatars contributed to the creation of a sense of telepresence and copresence within a virtual world environment. Telepresence is the sense of feeling present in a virtual world of 'being there', while copresence is a 'sense of being together' (Schroeder, 2002, pp. 3 and 4). Moreover, the use of an avatar appeared to enhance these aspects of the interaction to a greater degree than was reported for other chat environments. A majority of students (15 of 24) made use of the communication features of their avatars, mainly waving to attract the attention of potential task partners. Of the 15, 13 made use of emotional responses such as joy to be displayed. In addition, 14 students claimed that using avatars to communicate was an enjoyable experience and wanted to participate in future avatar-based virtual worlds.

It is important to note that there are several limitations concerning previous empirical studies. Firstly, although a majority of previous studies appear to suggest that students' learning is enhanced through the use of virtual world, such finding should be viewed with caution. Four of five studies that dealt with this topic were descriptive research that relied primarily on participants' retrospective self-report data such as interviews and questionnaires. A general problem of studies based on self-reported data is that participants usually have correct notions about socially desirable answers, which can be referred to as the tendency to provide answers that cause the respondent to look good (Hakkarainen *et al.*, 2001; Rosenfeld, Both-Kewley, Edwards & Thomas, 1996). Social desirability responding has long been viewed as a potential source of error variance in self-report measures (Hancock & Flowers, 2001). Moreover, many of the studies that examined the question of whether virtual worlds can enhance students' learning did not utilise a control group. Without a control group, improvements in students' learning might not necessarily be attributable to the use of virtual worlds per se. Improvements to the students' learning could be a result of other uncontrolled variables such as the instructional strategy used. For example, in the nutrition scenario study, the researcher focused mainly on asking participants about the instructional strategy (ie, scenario), instead of *Second Life* itself. A deeper analysis of the findings suggested that the positive results obtained were attributed more to the scenario (instructional strategy) rather than to the virtual world.

Secondly, more than half of the studies (53%) were limited in their duration, ranging from less than one semester to 1 year. (Five of the 15 studies did not indicate the study

duration.) Studies that are short term may suffer from a novelty effect, where it is possible that students and teachers are more likely to use and enjoy virtual worlds because the technology is new to them compared with participants who used them for a longer period of time. This may introduce a significant bias with respect to some of the obtained results.

Thirdly, many descriptive research studies lacked details defined in the historical traditions of qualitative research designs. For example, none of the studies that employed interviews as a means to collect data reported measures of authenticity such as member checking. In addition, studies that employed observations as a means to collect data did not report any interobserver or intraobserver agreement reliability. Knupfer and McLellan (1996) argued that because human observers may have biasing expectations, and their recording methods may change over time because of fatigue or practice, it is important that an assessment of both interobserver and intraobserver reliability be conducted for observational research.

Conclusion

Significance of this review

In this paper, we undertook a review of previous empirical studies that were published in journals and conference proceedings with open-ended search period until March 24, 2008 in order to summarise the current research regarding the use of 3-D virtual worlds in both K-12 and higher education settings. The findings of this review provide insights for educators and researchers into: (1) the different ways by which virtual worlds were used by students and teachers, (2) the types of research methods employed by previous virtual world studies, and (3) the kinds of research topics conducted on virtual worlds, and their related findings.

Overall, we found that virtual worlds may be utilised for the following uses: (1) communication spaces, (2) simulation of space (spatial), and (3) experiential spaces ('acting' on the world). Most of the studies reviewed were descriptive and conducted in polytechnic and university settings, and past virtual world research had been most frequently carried out in the media arts and health and environment disciplines.

We also found that past virtual world research focused mainly on three research topics: participants' affective domain, learning outcomes and social interaction. In general, students like using virtual worlds because they enjoy the ability to move around freely in a 3-D space, to meet new people, and experience virtual field trips and simulated experiences. Students, however, dislike the inability to access the virtual world environment through older computers, the general prohibition of the use of such virtual world software in public computers, having to instantaneously formulate responses and type fast in order to communicate textually through the chat tool, the lack of provision of turn-taking or threaded discussion because of the chat function, and unfamiliarity with the virtual world software. Studies also suggest that the use of virtual worlds could help foster social interaction among participants through the use of avatars.

Suggestions for future research

Future research should be carried out to explore improvements to previous studies as mentioned above. For example, future research should provide a rich, thick description of the methodology, including the duration of the study, interobserver and intra-observer agreement reliability and effect sizes so that findings can be adequately interpreted. The APA Task Force stressed that researchers should provide some effect-size estimate such as Cohen's *d* when reporting a *p*-value because reporting and interpreting effect sizes are essential to good research (Wilkinson & APA Task Force on Statistical Inference, 1999). Kotrlik and Williams (2003) argued that reporting effect size allows a researcher to judge the magnitude of the differences present between groups, thus increasing the capability of the researcher to judge the practical significance of the results derived.

Future studies should also be longitudinal in nature, extending the duration to perhaps more than 1 year. Doing longitudinal studies provides researchers with the opportunity to examine 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, which hitherto has not been investigated at all. In addition to longer term studies, future studies with either experienced students, or started a few years after the initial virtual world projects are initiated would also mitigate novelty effects.

Another area for further exploration would be the use of avatars. In an interesting study, Nowak and Rauh (2006) evaluated a series of avatars in a static context in terms of their androgyny, anthropomorphism, credibility, homophily and users' likelihood of choosing them during an interaction. Results from 255 participants of communication courses at a large northwestern American public university showed that anthropomorphic avatars were perceived to be more attractive and credible, and people were more likely to choose to be represented by them. Participants further reported that masculine avatars were less attractive than feminine avatars. It should be noted that static images of avatars were employed in the study. Future research could replicate this study in a virtual world environment using 3-D avatars to verify the findings. Other possible areas for further exploration could be the investigation of how, or if, people's responses to avatars would actually influence their responses to a person who chose to be represented by the particular avatar, as well as how avatars might influence the perception of a message sent by a person being represented by that avatar (Nowak & Rauh, 2006).

There is also a need for more research examining the unique attributes or affordances of virtual worlds. One particular interesting affordance of virtual world is the opportunity for students to be immersed in the 3-D learning content and context and to interact with the objects in the environment. As previously mentioned, observations by Sourin *et al.* (2006) showed that when students worked on their coursework in the virtual world, which itself was created using computer graphics tools, then, gradually and without making any extra effort, were got immersed in many concepts of computer graphics and could feel and touch real-time rendering, visualisation and virtual reality.

Sourin *et al.* (2006) suggested that such immersion might explain the better learning of computer graphics concepts that led to a 14% increase in the mean examination scores. Future research should be carried out to test this claim.

We also urge future research to examine sociocultural factors influencing the use of virtual worlds. For example, some students may approach learning from a cultural tradition where different teaching and learning approaches are predominant (eg, teacher-centred vs. student-centred) (Luppardini, 2007). Future research may best contribute by investigating different ways of utilising virtual worlds within various cultural contexts. In addition to examining cultural differences, other areas for exploration could be individual differences, such as facility in social learning versus solo learning. Finally, future research can also examine the influence of country contexts on the use of virtual worlds. So far in our review, a majority of the studies (87%) involved participants from countries in North America and Europe, compared with other countries. There is a continual need to study participants in other countries in order to better understand how different geographical contexts might influence the use of virtual worlds differently.

The use of 3-D virtual worlds is an emerging trend. We hope that this review would be useful to researchers as they study and continue to build knowledge about the use of virtual worlds in K-12 and higher education settings.

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Appendix A

Summary of reviewed virtual world empirical studies

Author(s) and year	Research aim	Research method	Data collection	Context
Bailey and Moar (2001)	Explore the potential of virtual worlds as creative learning tools for children	Descriptive research	Observations	Three primary schools in the UK. Duration was one year. Virtual world used <i>Active Worlds</i> . Virtual world used as a medium for art/creativity tool. For example, pupils created 3-D virtual clip art such as piecing together ready-made walls, floors, doors, roofs, trees and flowers. A major achievement was the construction of an interactive maze that was built collaboratively by eight children working together across the network.
Chow <i>et al.</i> (2007)	Examine how the use of <i>Second Life</i> can be used to increase the overall quality of learning and instruction in a graduate distance learning programme	Descriptive research	Observation Interview Survey Online logs (eg, discussion transcripts)	Eighteen participants in the USA. Duration of study was 10 months. <i>Second Life</i> used in conjunction with a blend of face-to-face, television and course web site. One graduate course used <i>Second Life</i> to provide its 'face-to-face' lecture in a virtual, private 'sky box' that brought students from three campuses together into one 'classroom'. Faculty members also held virtual office hours in <i>Second Life</i> for distance students to drop in to talk to them.
Cooper (2007)	Describe the use of <i>Second Life</i> to increase awareness about the health effects of eating fast food and certain traditional ethnic food	Descriptive research	Student survey	N = 20 respondents from undergraduate and graduate students. Students came from computer science and minority health departments. Duration of study was 5 months. Students participated in a nutrition game developed inside <i>Second Life</i> . The game simulated one day of food choices. The player chose what food they wanted to consume for the meal. After three meals had been consumed, the game ended. They were told how much weight they would gain or lose in 1 week, 1 month and 1 year based on their eating habits for the day. How much of their diet came from fat and how much cholesterol they consumed would be compared with recommended values. They were also told of likely ailments to expect based on these values.

Dickey (2005b)	Investigate how <i>Active Worlds</i> is being used for distance learning and determine the type of learning experiences afforded by the virtual environment	Descriptive research	Observations Interviews (face to face and online)	Study—undergraduate business computing skills course, duration 2 years. <i>Active Worlds</i> used to create a 3-D world consisted of a spacious rectangle plaza surrounded by a backdrop image of mountains that frame Boulder, Colorado. Students moved from building to building to submit assignments, review grades and send/receive feedback. Students also collaborated on group projects by meeting in arranged meeting areas (patios) and by using the chat tool for communication.
Dickey (2003)	Describe an evaluative case study of the pedagogical implications of using one 3-D virtual world, <i>Active Worlds</i> , for synchronous distance education.	Descriptive research	Observation Class logs Instructor interview	One instructor of a course Intro to RWX Modeling. The focus of Intro to RWX Modeling is to teach <i>Active Worlds</i> users to create original 3-D objects. The course consisted of four weekly 90-minute meetings. Initial data were gathered during the fall of 1998 and winter of 1999. Subsequent observations were conducted during the winter and spring of 2000. Concluding interviews with the instructor were conducted during the winter and spring of 2001.
Gonzalez (2007)	Describe how <i>Second Life</i> was used in a digital entertainment technology education course	Descriptive research	Student survey	N = 13 diploma students enrolled in a digital entertainment technology course at Nanyang Polytechnic, Singapore. Duration of study was one semester. <i>Second Life</i> was used for conducting lessons and as a platform for assignments.
Holmes (2007)	Investigate the use of software agents as learning partners in an <i>Active Worlds</i> virtual space	Experiment	Pretest Posttest Chat transcripts Interview	N = 80 fifth graders in the USA. Duration of study was not mentioned. The learning activity was situated within an <i>Active Worlds</i> environment that simulated important aspects of a river ecosystem. Students were randomly assigned to three experimental groups. The three conditions used in this study varied by how the explanation resources were presented and whether the learning partner was another student or software agent.

Appendix A Continued

Author(s) and year	Research aim	Research method	Data collection	Context
Ligorio and van Veen (2006)	Describe a virtual environment where four Italian and three Dutch primary and secondary schools collaborated on multidisciplinary content.	Descriptive research	Teacher interview Student interview	Seven schools (four Italian and three Dutch primary and secondary schools) participated in the study. Duration of study was 8 months. Virtual world used was <i>Active Worlds</i> . Participants had to build 3-D 'cultural' houses containing objects and information connected to certain curricula (music, art, history, geography). Italian classes built Dutch cultural houses, and Dutch classes built Italian cultural houses. In addition, each of the classrooms was required to search for information, answer questions, give help and provide comments on all of the 3-D buildings, even when other classes were responsible for them.
Martínez <i>et al.</i> (2007)	Explore the possibilities and challenges of using <i>Second Life</i> as a lecturing synchronous environment	Descriptive research	Observation Student focus group	N = 1 lecturer in a course on technology, human and transcendence at a university in Mexico City. The lecture theme was a study of terrorism. Number of students was not indicated. Students were undergraduates in diverse fields: engineering, design, law, political science and architecture. Most of them were third-year students. The main objective of the lecture was to identify convergence and divergence of technology, faith and philosophy in recent terrorist events. The delivery strategy was to present significant facts and information regarding each event, then to discuss this information and finally, through a brainstorm exercise, identify the convergence/divergence as described above. The lecture room design included benches for seating the attendees, a lectern, a projection screen for slides (Metatlab) and another for video projection (TV projector). A number of posters with relevant information were hung (actually suspended) on the room periphery.

Michailidou and Economides (2003)	Describe the use of a virtual world for teaching electronic commerce	Descriptive research	Student survey	Twenty undergraduate students in electronic commerce in Greece. Virtual world used was <i>Elearn</i> (University of Macedonia, Thessaloniki, Greece) which was built by using Active Worlds. There were six spaces in <i>Elearn</i> : reception room, selection room, lessons room, library, lecture room and electronic store.
Peterson (2006)	Investigate the interaction of EFL students during task-based Computer Mediated Communication (CMC) in <i>Active Worlds</i>	Descriptive research	Chat transcripts Field notes Student questionnaire	N = 24 undergraduates in English as a foreign language. Majority of students were Japanese. Duration was 5 weeks. Students were asked to self-select a partner after they had entered the virtual world. Using their avatars and the chat feature, students engaged in three task types: jigsaw, decision-making and opinion exchange. In the jigsaw task, six pictures depicting a series of events were mixed up and divided into two task sheets each containing three pictures. Students were required to uncover the correct story sequence by describing the pictures to each other. In the decision-making task, students were asked to discuss a variety of possible options in the selection of a gift. In the opinion-exchange task, students discussed the qualities of an ideal marriage partner.
Riedl (2004)	Describe the development of an instructional technology programme offered through a virtual world	Descriptive research	Student survey	Duration of study was one semester. Students from two cohorts in the USA participated. <i>AppEdTech</i> (Appalachian State University, USA) is the name of the virtual world that is running on an <i>Active Worlds</i> Galaxy Server at Appalachian State University. Currently, there is an entry plaza that has three buildings around it. To the left of the user, upon entry, was a student services building that houses space for general information (such as information on how to forward Appalachian State email to personal email accounts). There were currently six courses that have been constructed in <i>AppEdTech</i> .

Appendix A *Continued*

<i>Author(s) and year</i>	<i>Research aim</i>	<i>Research method</i>	<i>Data collection</i>	<i>Context</i>
Sanders <i>et al.</i> (2007)	Describe two graduate students' reactions to and comments about their involvement in a project conducted predominantly through their use of Active Worlds	Descriptive research	Student survey	N = 2 graduate students in the USA from the department of leadership and education studies. Duration of study was not reported. Utilising core learning episodes, reflective journals and learning sets, each student developed an action learning plan to systematically explore, plan, act and reflect regarding their chosen topic or issue. The Commons in the virtual world provided the space in which students could meet together, interact with students and faculty, access course and project resources and contribute to discussions and blogs.
Sourin <i>et al.</i> (2006)	Describe three cases of using cyberworlds for teaching computer graphics	Descriptive research	Exam score Observation	Duration of study was one semester. Number of participants was not reported. Virtual world used for a computer graphics course at the Nanyang Technological University (NTU) in Singapore. Three projects were made: virtual campus of NTU, function-based web visualisation and interactive function-based shape modelling. The virtual campus could be seen as a place displaying general information about the campus organisation, probably for new students. In interactive function-based shape modelling project, students designed sophisticated shapes using implicit functions, and made them available in their virtual homes in the virtual campus. In the function-based Web visualisation project, students had to define analytically how one shape defined by parametric formulas transformed into another one. This morphing was modelled as an animated shape conversion.

Ye <i>et al.</i> (2007)	Describe the use of <i>Second Life</i> in an environmental education course	Descriptive research	Student survey	<p>N = 15 high school students. Duration of study was not indicated. The game was designed to specifically simulate stream pollution. The Appalachian Tycoon game was a single-player game in which the player served as the user of the stream bank, which was initially grassland. Initially, the player was given 1000 points (representing money). The player played the game by investing the money in developing the stream bank. The time to play the game was limited, ie, 200 time units. The goal of the player was to maximise both economic and environmental benefits from the investment, ie, to gain a score as high as possible, in the limited time. The player currently had six land use options: surface mining, power plant, commercial farm, organic farm, residential land and planting trees. Because the game emphasised environmental awareness, those environment friendly options such as organic farming tended to bring in a higher score than other options.</p>
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