Educational Visualizations in 3D Collaborative Virtual Environments: a Methodology

Mikhail Fominykh and Ekaterina Prasolova-Førland
Program for learning with ICT
Norwegian University of Science and Technology
Trondheim
Norway

Acknowledgments:

The research presented in this paper is financed by Program for Learning with ICT and Department of Computer and Information Science, Norwegian University of Science and Technology (NTNU). Additional support is provided by EU projects CoCreat and TARGET. This publication reflects the views only of the authors, and the European Commission cannot be held responsible for any use which may be made of the information contained therein.

Biographical Details:

Mikhail Fominykh graduated from the Computer Science department of Mari State Technical University, Yoshkar-Ola, Russia in 2006. Since 2007, he is a PhD candidate at the Program for learning with ICT, Norwegian University of Science and Technology. The topic of his study is "Three-dimensional virtual environments in education: collaborative work, design of tools, and community support".

Ekaterina Prasolova-Førland is an associate professor and project coordinator at the Program for learning with ICT, Norwegian University of Science and Technology (NTNU). She holds a M.Sc. in Technical Cybernetics and a PhD in Computer Science from the same university. Her research interests include educational and social aspects of 3D Collaborative Virtual Environments and augmented environments as well as virtual universities, mobile learning and serious games. She is author and co-author of more than 50 publications on the topic. She is currently involved in two EU-financed projects focusing on creativity and serious games in 3D virtual worlds. Recently, she started working for the Norwegian Armed Forces, developing educational simulations for training cultural awareness in military operations.

Structured Abstract:

Collaborative Virtual Environments (CVEs) have become increasingly popular in educational settings and the role of 3D content is becoming more and more important. Still, there are many challenges in this area, such as lack of empirical studies that provide design for educational activities in 3D CVEs and lack of norms of how to support and assess learning in with such technology. The major purpose of this paper is to address these challenges, by discussing the use of a 3D CVE in a university course for three years and suggesting practical guidelines based on the data from observations.

The main research question of the discussion in this paper is: How to facilitate learning by means of educational visualizations in 3D CVEs? We discuss data from several explorative case studies conducted within the Cooperation Technology course at the Norwegian University of Science and Technology. In these case studies, we focused on a particular type of collaborative work with 3D content – educational visualizations. Groups of students were asked to build creative visualizations of a certain topic (e.g. a research project or a curriculum topic) and present the construction to the public. The data were collected from the direct observation of students' activities online, virtual artefacts, such as chat log and 3D constructions, and users' feedback in a form of group essays or blogs.

Following the analysis of these data, we introduce an original methodology for facilitating collaborative work with 3D content in an educational context. In addition, we provide a characterization framework – Typology of 3D Content and Visualization Means, which can be used together with the methodology for analysing constructions in 3D CVEs. We used constructionism and social constructivism as a theoretical grounding.

Although the research method applied has certain limitations related to the settings of the conducted studies, such as observing the same course each year and impossibility of having a control group, this research still provides important insights as it identifies overall tendencies in conducting educational activities in 3D CVEs.

Suggested methodology was developed for teachers, instructors, and technicians. It can be used as a guideline for organizing educational activities using collaborative work with 3D content.

Results of our research indicate that the methodology suggested in the paper benefits structuring and planning of educational visualizations in 3D CVEs. It can be considered as a contribution to the field, as it helps to fill the gap in practical guidelines for the advanced use of 3D CVEs in educational settings.

Keywords:

3D Collaborative Virtual Environments, 3D content, educational visualizations, Second Life

1. Introduction

The use of 3D Collaborative Virtual Environments (CVEs) such as Second Life for educational purposes has been constantly increasing during the recent years (de Freitas et al., 2009). One of the reasons is the potential and capability of such environments to support collaborative work with various types of content, as discussed in several studies (Atkins, 2009, Hwang et al., 2008, van Nederveen, 2007, Arreguin, 2007). Most CVEs allow advanced content manipulation, uploading, creating and sharing 3D objects and other media, such as text, graphics, sound and video. The term 'content' can be understood more widely than media objects, as we previously discussed (Prasolova-Førland et al., 2010b). Content can be 'objects, places, activities' or any valuable information or experience (Bessière et al., 2009).

Another important reason is the opportunity for participants to interact and communicate in a way that conveys a sense of presence lacking in other media (Park et al., 2009, Kelton, 2007). Wide opportunities for simulating environments make CVEs suitable for conducting meetings, performances and role playing (Sant, 2009).

A growing number of education- and research-intensive institutions have started using CVEs for presentations and promotions, conferencing, sketching, training and other purposes. Second Life is one of the most successful CVEs (www.secondlife.com). It remains one of the most stable, developed and used, though there are certain limitations. In this paper, we present an original methodology for using collaborative work with 3D content in education. The methodology was developed based on data from several explorative case studies in Second Life.

2. Collaborative visualization exercises

2.1 Background

During autumn semesters, we conduct regular practical exercises within the Cooperation Technology course at the Norwegian University of Science and Technology (NTNU). In several earlier exercises, we were exploring various aspects of collaborative work and learning in 3D CVEs. Since 2009, we have been using a virtual campus of NTNU in Second Life for these exercises.

In order to identify common success factors and challenges, we analysed our case studies, conducted earlier in Active Worlds, including *Collaborative Creation of Common Information Space* (Prasolova-Førland and Divitini, 2005), *Creative Curriculum Visualization* (Prasolova-Førland, 2007), and *Constructing a Virtual Tower of Babel* (Prasolova-Førland et al., 2008). Based on the analysis, we proposed a characterization framework *Typology of 3D Content and Visualization Means* that can be used for analysing and evaluating constructions in 3D CVEs (Prasolova-Førland et al., 2010b).

In this paper, we particularly focus on developing an approach for the use of collaborative educational visualizations in 3D CVEs. We analyse data from three exploratory case studies conducted in 2009, 2010, and 2011. In all these studies, Cooperation Technology students were working in groups (2–4 students in each) and asked to build creative visualizations of various scientific topics. In 2009, the students visualized research areas or courses taught at NTNU (Prasolova-Førland et al., 2010a). In 2010, the next generation of students worked on visualizations of research projects (Fominykh and Prasolova-Førland, 2011a). In 2011, new students created visualizations of major curriculum concepts. Each year, the resultant constructions were presented to an international audience at the joint sessions and seminars. Analysing the results of each study, we identified challenges related to the learning approach and the work in a 3D environment.

In all three studies, we used the same environment and gave a similar task to the students. However, each time we improved both the environment and the learning approach, based on the student feedback. Besides that, in 2010 the study was conducted in conjunction with the first International Summer School on Collaborative Technologies, Serious Games and Educational Visualizations, organized by the EU TARGET project (http://www.reachyourtarget.org/). Student constructions were available in the Virtual Campus during the Norwegian Science Week festival and demonstrated at the virtual science fair (Fominykh and Prasolova-Førland, 2011b). In 2011, the study was conducted in conjunction with a preparatory study of the Designing Technology Enhanced Learning course, developed by the EU CoCreat project (http://www.cocreat.eu/) and with the second TARGET summer school.

2.2 Settings of the case studies and student constructions

In the 2009 study, six groups of students (3–4 students in each) were asked to build a visualization representing one of the research areas or a course taught at NTNU. Resulted constructions were presented to the international audience at a joint session (Figure 1). Afterwards, the students had two weeks for reflecting on their activities in group essays.

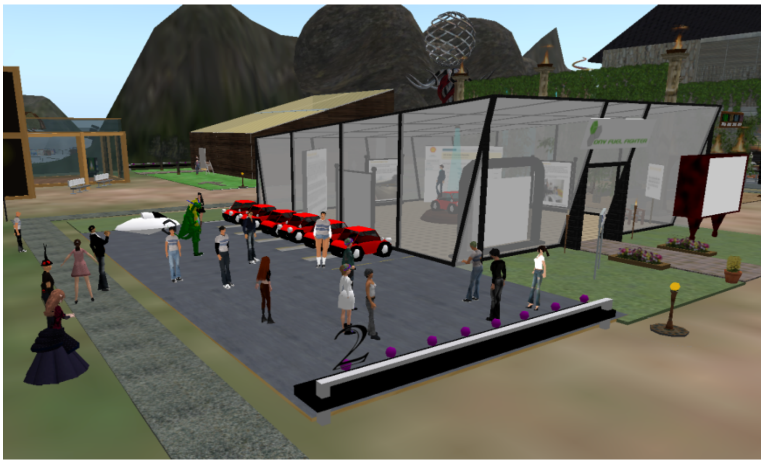

Figure 1. Student visualization project Fuel Fighter, 2009

The study in 2010 was conducted with 25 students in seven groups, 2–4 students in each. None of the students had previous experience with Second Life. However, most of them were familiar with 3D virtual environments from gaming. The students were asked to build a visualization representing any research project and present it at a joint session by role playing (Figure 2). After the joint sessions, the students had two weeks for reflecting on their activities in group essays. We provided a guideline for this task in the form of a set of questions to discuss and aspects to consider. In the essays, the students discussed their collaborative process, design choices, role playing and reflected on the learning method.

Figure 2. Student visualization project Solar Skin, 2010

In 2011, the study was conducted with 37 students in 10 groups, 3–4 students in each. The students were asked to build an educational module representing a major curriculum topic and present it at a joint session by role playing (Figures 3 and 4). Before the students started to work in Second Life, we suggested they should answer a questionnaire. We identified their previous experience in cooperation technologies and 3D virtual environments as well as their expectations of the forthcoming exercise. Each group was supposed to create and keep a blog during the exercise. The group blogs were used for sharing and discussing proposals, reflecting and documenting the progress, and for the final discussion after the constructions were completed and presented. In addition, each student was required to create and keep an individual blog for weekly reflection. After the role-play session, each group evaluated two other constructions following instructions based on the Typology of 3D Content and Visualization Means, which is presented later in the paper. Upon completion of the exercise, we suggested that students answer another questionnaire to identify how their experience matched their expectations.

Figure 3. Student visualization project Communication Maze, 2011

Figure 4. Student visualization project Awareness Lab, 2011

3. Summary of the results

In this section, we summarise the results of all three case studies, however, without looking deeply into details. Instead, we look at the results as a whole, analysing how the students worked with 3D content and how they cooperated in groups. In addition, we observe how student experience and resultant constructions changed from one study to another. The results of the studies are presented in more detail in our early publications (Fominykh and Prasolova-Førland, 2011b, Fominykh and Prasolova-Førland, 2011a, Prasolova-Førland et al., 2010a).

3.1 Collaborative process

In all three studies, most of the groups noticed that the project was interesting and their knowledge in the area of cooperation technologies has increased. Describing the collaborative process, some of the groups reported that they had worked mostly asynchronously due to the different time schedules or communication problems. Other groups preferred the synchronous mode exploiting the advantage of increased workspace awareness as they could follow the development of the group construction in real-time. All the groups used many other communication and cooperation tools at different stages of the project work, including email, instant messaging, file-sharing, and video conferencing. Real-life meetings were also used by most of the groups to a varying degree and for different purposes. Reflecting on their experience, most of the students reported that this allowed them to learn more about cooperation methods and identify which of them are suitable for work in CVEs, for their group and for their task.

3.2 Inspiration

In the second and third Second Life studies, we explored how the students were inspired by other constructions available in the virtual campus. The students expressed very different opinions when reflecting on their inspiration sources. The feedback varied from stressing the importance of studying previous students' constructions to mentioning a minor effect of this kind of studying for inexperienced users.

> *The other constructions on the island were useful to get an idea of what was possible and a sense of how things were done, especially in the first stages and on interactive objects.*

For us, the other projects on NTNU Island only had a minor effect on our inspiration. Because we didn't know Second Life from before, we had no clue about how hard it would be to make something equally cool/fancy.

The most common feedback was stressing the importance of observing different visualization means in a 3D environment and how they can be realized in Second Life.

Buildings from previous years … show the variety of possibilities … and it also gives stimulation and inspiration for creating our own ideas. When we first saw the last years' buildings we were impressed, but as soon as we got the hang of the building, we found out that we could build almost anything from our imagination.

3.3 Design choices

In order to mediate their understanding of the presented projects, the students used various design choices. The groups exploited different place metaphors from a very simple room to museums, galleries, and convention halls. According to the student feedback, choosing metaphors was in many cases related to the nature of project presented, for example, using a virtual 'exhibition' to present results of a project (Figure 1). In other constructions, this choice was defined by the reality, for example, recreating a part of a building with a solar panel for the solar energy project (Figure 2). Creating impressive authentic atmosphere and graphical effects were the key factors, for example, in a project representing Awareness in two remote laboratories (Figure 4).

The students used various means for presenting information. In the first and second studies, the most common tools were slide shows and posters. In half of the constructions, slides and posters played the role of the main sources of information. In the rest of the constructions, they were complementing information presented by visual symbols and interactive elements or simulations, which is a more appropriate use. In the third study, we explicitly introduced different types of content and visualization means, and the students were able to observe constructions from two previous years. This resulted in the appropriate use of slides and posters by most of the groups.

Interactive simulations were used by two groups in the second study and by five groups in the third one, attracting interest and evoking most of the positive feedback. In the third study, three groups out of ten developed interactive tools as parts of their constructions. The use of visual symbols made constructions highly appealing, intensively exploiting advantages of the technology.

Decorations are beautification elements and usually do not comprise meaning, unless they are used as visual symbols for creating authentic atmosphere. Such elements were also used in the constructions to a different degree.

3.4 Presentations

Constructions in all the studies were presented at the joint sessions to the peer students and international visitors. Although in the second and the third studies, the students were given a task to prepare presentations as role plays, most of the groups cut them to simply describing constructions. Nevertheless, those groups who actually performed role plays made a better impression on the audience, according to the feedback. Role playing had another advantage in terms of explaining the details of the projects, since the audience was to a different degree involved in the play. Interactive simulations were also attractive to the audience by the possibility to try or test presented topic or system. Few groups or individual students prepared authentic avatars that were appealing to the audience and contributed to the overall atmosphere.

3.5 Visualization and increased understanding

In the second study, the students provided feedback on how their understanding of the group's own research topic improved during the visualization effort. All the groups except one claimed that they became more aware of the presented topic and their understanding (subjectively) increased. In the same study, three groups described the pre-phase to the actual construction as the most 'learning-intensive', since during this phase they had to discuss how to present their topics in the best possible way, e.g. "how to implement the concept into something concrete".

During the research each of the group members learned much. In order to visualize the construction we arrange a series of field trips took pictures and made sketches which also provided a better understanding of the construction.

Some team member never built a piece in real life. But they also reported that they became more aware of the construction method while building in SL.

Reflecting on the understanding of the projects presented by other groups in the second and the third studies, the students emphasized the importance of interactive elements as experience-enhancing and giving a practical idea of the topic presented. Some additional comments (both positive and negative) were related to exploiting the unique advantages of the technology, stressing the value of creating something that is impossible (or expensive) in the real world. Engaging the audience in presentations and role plays were considered important factors for increasing understanding of the topic. Using voice chat or both voice and text chats was recommended to make presentations appealing and easy to follow. Authentic avatars and the overall atmosphere of a construction as well as recreating real-life buildings were also considered important for enhancing the learning experience.

> *The winner means of presentation must be the constructions with their functionality. To be able to interact with "something" in a presentation makes the crowd feel excited, focused and eager to learn. The use of [authentic] avatars also helped clarify who gave the presentation and was writing or talking.*
>
> *Using a 3D representation of a real object (the solar panels) was interesting. Engaging the audience in a concurrent design process was an interesting idea and a good choice given the subject.*

3.6 Challenges

Exploring and adopting this way of learning in 3D CVEs, we faced a number of challenges. In order to find solutions to them, we used data and feedback collected in the studies presented. In this paper, we focus on two particular challenges: first – how to describe, analyse and evaluate educational visualizations in 3D CVEs, and second – how to utilize learning theories and advantages of the technology for this learning approach.

4. Discussion

In this section, we summarize our experience of conducting exploratory studies on educational visualizations and present a methodology that we developed to structure this activity.

4.1 Typology of 3D Content and Visualization Means

Elaborating the results of the first study, we realized that we needed a framework for analysing educational visualizations in 3D CVEs. We revised some of our previous related studies and proposed such a framework (Prasolova-Førland et al., 2010b).

In the second study, we used the initial version of the framework for two purposes: first – for structuring guidelines given to the students before the exercise and second – for analysing resultant constructions and presentations (Fominykh and Prasolova-Førland, 2011a). As a result, the students had a wider understanding of the technological possibilities of 3D CVEs, while observing constructions built by other students and working on their own. In addition, we had a clearer picture of the resultant constructions. We could analyse how elaborating different aspects of the constructions influenced learning, cooperation, and the overall result.

In the third study, we extended the use of Typology of 3D Content and Visualization Means. We used the framework for self and peer evaluations. The students were required to analyse constructions and role plays in detail. They explained the ideas behind the use of different types of content and visualization means in their own constructions. Each group was also required to evaluate constructions and role plays of two other groups. A group of students from College of Education, University of Hawaii visited the virtual campus of NTNU and evaluated each construction using the framework.

The Typology of 3D Content and Visualization Means is a characterization framework. It suggests describing a 3D construction along two dimensions: virtual exhibits (types of content) and visual shell (content presentation form).

Virtual exhibits have three main categories: text, 2D graphics and multimedia, and 3D visual symbols. An additional dynamic category considers how the virtual exhibits are presented by the authors, for example, by role playing. 3D CVEs allow presenting information in different modes, which also include complex installations and 'dioramas'. Virtual exhibits can have different degrees of interactivity, including playing sound or video, animating avatars, modifying 3D objects or triggering other events in the environment. It is necessary to consider the duality and, in some cases, antagonism between different types of content. Text is straightforward, while the meaning of 2D graphics and especially 3D symbols might often be unclear and ambiguous without proper explanation. At the same time, 3D is often more vivid and appealing than text, while graphics is somewhere in between. For example, visualizing 'communication' as a two-player maze game, the students used text explaining the rules of the game, posters were used for displaying examples, and the maze itself was a 3D visual symbol (Figure 3).

By *visual shell* in a 3D CVE, we mean a way of organizing, presenting and structuring content, for example using a certain metaphor. Although the content itself often has higher priority than its presented form (a shell in this context), these two concepts are interdependent and complement each other (being a duality). The role of the shell is complex and not limited to mere instrument. Visual shells are especially important in 3D virtual environments, considering their plentiful visualization opportunities. A visual shell can be described using three dimensions: aesthetics, functionality, and expressed meaning.

Aesthetics of a shell plays an important role in enhancing students' motivation and triggering their creativity, especially when competition was involved (as was the case in most of the cases studied). In all the studies, constructions with elaborated aesthetics were rated highly, when it was used appropriately (such as a pub for social interaction or a Chinese temple for a Kung-Fu training project). However, these elaborate constructions can have little or nothing in common with the topic presented (such as a medieval castle hosting an exhibition dedicated to the 'awareness' concept).

Functionality is the ability of a construction (or a part of it) to perform a certain task or function. It was often in conflict with the aesthetics of student constructions. This included elements such as furniture, doors, stairs, lighting, sound and various 'fancy' items being obstacles, complicating navigation and diverting attention from the actual content being displayed. In the earlier studies, constructions with simple structure (such as separate virtual houses for different subtopics) were rated highly by the peer students. Such simplicity was often achieved at the expense of less elaborated aesthetics. Another category appreciated by the audience was following well-known metaphors, such as the 'museum', with clearly structured exhibitions and navigational paths through them. However, examples in the two latest studies demonstrate that functionality can be elaborated in harmony with the other aspects. In these constructions, the students designed tools (such as awareness displays connecting two laboratories) or interactive visual symbols (such as a part of wall with a solar panel).

Expressed meaning is the symbolism contained in the overall design of a construction and in the details. Apart from aesthetics and functionality, the appearance of the constructions symbolizes a certain idea. For example, 'communication' was visualized as a two-player maze game, where communication between the players helps to overcome the challenge. The aspect of meaning might also be in conflict with aesthetics and functionality. Creating realistic and meaningful constructions often requires a significant amount of effort and planning. Meaningful constructions often had a rigid structure. However, the expressed meaning contributed to a better understanding of the content that was inside (for example, by creating associations).

Choosing a suitable presentation form for educational content is about finding a balance between aesthetics, meaning, and functionality of the *visual shell* as well as different ways of displaying the virtual exhibits. It is necessary to produce harmony between the visual shell and the virtual exhibits, something that is not often obtained in practice. Generally, one of the major problems in the creative construction process can be summarized as the 'content-presentation' conflict, i.e. bringing the meaning of the visual shell in conformance with the displayed content. One of the student groups described their experience in this way: "It is impossible … to separate the design from the content. So, if one wants to make a design change, this cannot be one by itself, but the content needs to be adjusted as well".

4.2 Methodology for learning with educational visualizations in 3D CVEs

Our approach to using educational visualizations in 3D CVEs for learning has been evolving over time. We have been exploring affordances of 3D CVEs for learning and socializing. Our main research question was: How to facilitate learning by means of educational visualizations in 3D CVEs? The methodology is based on *constructionism* (Papert and Harel, 1991) – an educational philosophy which implies that learning is more effective through the design and building of personally meaningful artefacts than consuming information alone (Bessière et al., 2009, Papert and Harel, 1991, Papert, 1986). Constructionism is related to the *social constructivist* approach (Vygotsky, 1978), where the main idea is that learners co-construct their environment and understanding together with their peers. We also applied *role playing*, which is a widely used and effective learning and teaching method. It implies an active behaviour in accordance with a specific role (McSharry and Jones, 2000, Craciun, 2010).

In order to present the methodology more clearly, we divide it into phases.

Phase 1 – Preparation and planning. During this phase, the environment should be constructed and the task elaborated. The environment should have a specific design, including virtual places to support planned activities. The task should explain what the participants have to do and the learning goals they are expected to achieve. Phase 1 of our latest study is in the focus of another paper (Fominykh et al., 2011).

Phase 2 – Lecture on the use of 3D CVEs. The lecture should contain the basic information on the technology and present its affordances in a specific learning area. A live demonstration of the tools and features to be used in the exercise and a tutorial are beneficial. In addition, the task should be elaborated and discussed during the lecture. The participants should be divided into groups of 3-4 and given the first assignment – a proposal of the 3D visualization described using the Typology of 3D Content and Visualization Means. In our studies, we used a face-to-face mode for the lecture, but other modes can also be used. We also give the students a week or two to get to know each other and develop the proposal.

Phase 3 – Virtual welcome meeting. This phase aims at familiarising the participants with their working environment and clarifying the task. The meeting should be conducted in the 3D CVE that is to be used for the exercise. At the welcome meeting, the environment should be demonstrated to the participants, and their proposals should be discussed. A questions-and-answers session is usually productive at this stage.

Phase 4 – Collaborative construction in a 3D CVE. During this phase, the participants implement their proposals in a 3D environment, discuss them with each other, and reflect on their activities. Collaborative work on 3D content and active discussions allow participants to deepen their understanding of the topic visualized. Constant on-demand assistance should be provided to keep the participants focused on their task and not on the technical issues. Individual and group reflection should be organized during this phase. It helps to keep the participants focused and reminds them of the expected progress. In our studies, we devote about 5 weeks to this phase.

Phase 5 – Presentations of the resultant constructions. This phase includes preparing scenarios and presentation of constructions at a session in front of an audience. Such an event allows receiving feedback. It creates a competition and motivates the participants to elaborate their constructions. In addition, public presentations triggers additional exploration of the topic presented as it should be explained to other people. We used the role-playing method for presentations in two of our studies, and it proved to be suitable.

Phase 6 – Final reflection and discussion. When the constructions are presented, the participants should be given the final assignment – to discuss and reflect on their experience. The task may include analysis of their own construction structured according to the Typology of 3D Content and Visualization Means. In addition, it may include analysis of the collaborative process and questions related to the topic studied. In our studies, we devote about two weeks for this phase.

5. Conclusions and future work

In this paper, we focus on the use of educational visualizations in 3D CVEs and present our approach. In particular, we provide a characterization framework – Typology of 3D Content and Visualization Means, which can be used for analysing educational visualizations in 3D CVEs. In addition, we describe the Methodology for learning with educational visualizations in 3D CVEs, which can be used as a guideline. The main contributions of the paper are based on the results of explorative qualitative case studies conducted in the Virtual Campus of NTNU in Second Life and earlier studies in Active Worlds. Our future work will include further research into the use of CVEs in educational settings, further improving our approach and developing the Virtual Campus environment.

References

Arreguin, C. (2007), Reports from the Field: Second Life Community Convention 2007 Education Track Summary. *Global Kids Series on Virtual Worlds.* New York, USA: Global Kids.

Atkins, C. (2009), Virtual Experience: Observations on Second Life. *In:* Purvis, M. and Savarimuthu, B. (eds.) *Computer-Mediated Social Networking.* Berlin / Heidelberg: Springer.

Bessière, K., Ellis, J. B. and Kellogg, W. A. (2009), Acquiring a professional "second life": problems and prospects for the use of virtual worlds in business. *27th CHI International Conference extended abstracts on Human factors in computing systems*, Boston, MA, USA. ACM, 2883–2898.

Craciun, D. (2010), Role – playing as a Creative Method in Science Education. *Journal of Science and Arts,* 1**,** 175–182.

de Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G. and Poulovassilis, A. (2009), Developing an Evaluation Methodology for Immersive Learning Experiences in a Virtual World. *1st International Conference in Games and Virtual Worlds for Serious Applications (VS-GAMES)*, March 23–24, Coventry, UK. IEEE, 43–50.

Fominykh, M. and Prasolova-Førland, E. (2011a), Collaborative Work on 3D Content in Virtual Environments: Methodology and Recommendations. In: Nunes, M. B. and McPherson, M., eds. *5th International Conference e-Learning (EL)*, July 20–23, Rome, Italy. IADIS Press, 227–234.

Fominykh, M. and Prasolova-Førland, E. (2011b), Virtual Research Arena: Presenting Research in 3D Virtual Environments. In: Barton, S.-M., Hedberg, J. and Suzuki, K., eds. *2nd Global Conference on Learning and Technology (Global Learn Asia Pacific)*, March 28–April 1, Melbourne, Australia. Chesapeake, VA: AACE, 1558–1567.

Fominykh, M., Prasolova-Førland, E. and Divitini, M. (2011), Constructing a 3D Collaborative Virtual Environment for Creativity Support. In: Ho, C. P. and Lin, M.-F. G., eds. *16th World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education (E-Learn)*, October 18–21, Honolulu, Hawaii. Chesapeake, VA: AACE, 1919–1928.

Hwang, J., Park, H., Cha, J. and Shin, B. (2008), Effects of Object Building Activities in Second Life on Players' Spatial Reasoning. *2nd International Conference on Digital Game and Intelligent Toy Enhanced Learning*, November 17–19, Banff, Canada. IEEE, 62–69.

Kelton, A. J. (2007), Second Life: Reaching into the Virtual World for Real-World Learning. *ECAR Research Bulletin.* Boulder, CO, USA: EDUCAUSE.

McSharry, G. and Jones, S. (2000), Role-Play in Science Teaching and Learning. *School Science Review,* 82**,** 73–82.

Papert, S. (1986), Constructionism: A new opportunity for elementary science education. Massachusetts Institute of Technology, Media Laboratory, Epistemology and Learning Group.

Papert, S. and Harel, I. (1991), Situating Constructionism. *In:* Papert, S. and Harel, I. (eds.) *Constructionism.* Westport, CT, USA: Ablex Publishing Corporation.

Park, S., Hwang, H. S. and Choi, M. (2009), The Experience of Presence in 3D Web Environment: An Analysis of Korean Second Life. In: Jacko, J. A., ed. *13th International Conference on Human-Computer Interaction. Part IV: Interacting in Various Application Domains*, July 19–24, San Diego, CA, USA. Springer Berlin / Heidelberg, 387–395.

Prasolova-Førland, E. (2007), Creative Curriculum Visualization in a 3D CVE. *Journal of Advanced Technology for Learning,* 4**,** 154–159.

Prasolova-Førland, E. and Divitini, M. (2005), Using 3D CVEs for Collaborative Creation of Common Information Space: Experiences and Future Directions. *5th International Conference on Advanced Learning Technologies (ICALT)*, July 5–8, Kaohsiung, Taiwan. IEEE CS Press, 887–889.

Prasolova-Førland, E., Fominykh, M. and Wyeld, T. G. (2010a), Virtual Campus of NTNU as a place for 3D Educational Visualizations. In: Abas, Z. W., Jung, I. and Luca, J., eds. *1st Global Conference on Learning and Technology (Global Learn Asia Pacific)*, May 17–20, Penang, Malaysia. Chesapeake, VA: AACE, 3593–3600.

Prasolova-Førland, E., Fominykh, M. and Wyeld, T. G. (2010b), Working on Educational Content in 3D Collaborative Virtual Environments: Challenges and Implications. *13th International Conference on Computers and Advanced Technologies in Education (CATE)*, August 23–25, Maui, Hawaii, USA. ACTA Press, 183–190.

Prasolova-Førland, E., Wyeld, T. G. and Chang, T.-W. (2008), Dealing with Cultural Differences in a 3D Virtual Classroom: a Case Study of Collaboratively Constructing a Virtual Tower of Babel *7th International Conference on Web-based Education (WBE)*, Innsbruck, Austria. ACTA Press, 412–417.

Sant, T. (2009), Performance in Second Life: some possibilities for learning and teaching. *In:* Molka-Danielsen, J. and Deutschmann, M. (eds.) *Learning and Teaching in the Virtual World of Second Life.* Trondheim, Norway: Tapir Academic Press.

van Nederveen, S. (2007), Collaborative Design in Second Life. In: de Ridder, H. A. J. and Wamelink, J. W. F., eds. *2nd International Conference World of Construction Project Management (WCPM)*, October 24–25, Delft, The Netherlands. TU-Delft, 1–6.

Vygotsky, L. S. (1978), *Mind in society: the development of higher psychological processes,* Cambridge, MA, USA, Harvard University Press.