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# Collaborative Work on 3D Educational Content

Thesis for the degree of Philosophiae Doctor

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Norwegian University of
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Department of Computer and Information Science

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# Abstract

The use of three-dimensional Collaborative Virtual Environments (3D CVEs) for educational purposes has been constantly increasing during the recent years. One of the reasons is the potential of such environments and the possibility they offer for supporting collaborative work with various types of content. Another important reason is an opportunity for participants to interact in a way that conveys a sense of presence lacking in other media. These opportunities result in a number of benefits for establishing and supporting learning communities, simulating various contexts and conducting educational activities. Nevertheless, this area is in the early stage of development and needs both theoretical concepts and empirical results.

The research work presented in the thesis has three main objectives. The first is to provide recommendations and guidelines for supporting collaborative work on 3D educational content. The second is to provide frameworks for designing tools and environments in 3D CVEs to benefit educational activities. The third is to provide frameworks for technological and instructional support of learning communities in 3D CVEs.

Within this research work, four empirical studies were conducted. The data were extracted from a number of sources, including direct observation, digital artefacts created by the participants and recorded interaction, reflection and feedback. Analysed data were applied to each next empirical study and, in addition, used for developing theoretical frameworks.

The research work presented in the thesis resulted in six main contributions. Two of them are related to the use of collaborative work on 3D content for learning: C1 – Typology of 3D Content and Visualization Means; and C2 – a methodology for learning with educational visualizations in 3D CVEs. Other two contributions are related to the design of tools and environments for supporting educational activities in 3D CVEs: C3 – a framework for designing tools in 3D CVEs called Creative Virtual Workshop; and C4 – guidelines for designing environments based on a virtual campus and virtual city metaphors. The two final contributions are related to the support of learning communities in 3D CVEs: C5 – a framework called Virtual Research Arena for creating awareness about educational and research activities, promoting cross-fertilization between different environments, and engaging the general public; and C6 – a framework called 'Universcity' for integrating the cultural, social, educational, and entertainment aspects of a city community life in a single 3D CVE.

The findings presented in the thesis can be applied by developers for creating educational 3D CVEs and by educators for conducting educational activities in 3D CVEs. All the findings can also be used for further research.

# Preface

This thesis is submitted to the Norwegian University of Science and Technology (NTNU) for partial fulfilment of the requirements for the degree of philosophiae doctor.

This doctoral work has been conducted at the Department of Computer and Information Science, NTNU, Trondheim, with Associate Professor Ekaterina Prasolova-Førland at the Program for Learning with ICT, NTNU as the main supervisor. The work was co-supervised by Associate Professor Alf Inge Wang at the Department of Computer and Information Science, NTNU, Associate Professor Mikhail Morozov at the Mari State Technical University, and Assistant Professor Torbjørn Hallgren at the Department of Computer and Information Science, NTNU.

The doctoral work is financed by the Program for Learning with ICT (LIKT), NTNU. Additional funding was received from the Department of Computer and Informational Science (IDI), NTNU.

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In addition, I would like to thank *Vera Byzova* for editing Part I of this thesis and some of the research papers.

Finally, I wish to thank my *friends* and *family* who supported me during the research work presented in this thesis.

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**Part I**

# Summary

# 1 Introduction

## 1.1 Motivation

Three-dimensional Collaborative Virtual Environments (3D CVEs) have a number of unique advantages in supporting a variety of activities and their use has been continuously increasing in recent years (de Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2009). 3D CVEs have also become more widespread as a technology for learning despite many challenges. A number of studies have been done in this area outlining advantages and limitations of 3D CVEs as learning environments. As stated in recent surveys (Duncan, Miller, & Jiang, 2012) and (Hew & Cheung, 2010), the use of 3D CVEs as learning environments is a new emerging trend and still under development. This fact motivates further research in the area.

There are many cases in which 3D CVEs can benefit educational process. Most of them are considered to exploit advantages of the technology, such as low cost and high safety, three-dimensional representation of learners and objects, interaction in simulated contexts with a sense of presence (Dalgarno & Lee, 2010; Warburton, 2009).

3D CVEs have the possibility for supporting collaborative work with various types of content, as discussed in several studies (Arreguin, 2007; Atkins, 2009; Hwang, Park, Cha, & Shin, 2008; Perera, Allison, Nicoll, Sturgeon, & Miller, 2010; van Nederveen, 2007). Content can be “objects, places, activities” or any valuable information or experience, which is well supported by the technology (Bessière, Ellis, & Kellogg, 2009). 3D CVEs can be well used as information visualization environments, immersing users and providing them with rich sensory experience (Bowman et al., 2003; Chen & Börner, 2005). In addition, 3D CVEs are used for educational simulations (Falconer & Frutos-Perez, 2009) and demonstrating complex concepts (Dekker, Moreland, & van der Veen, 2011; Youngblut, 1998).

Visualization possibilities of 3D CVEs can be applied together with collaborative learning and active learning approaches. Applying *social constructivism* (Vygotsky, 1978) in 3D CVEs allows learners to co-construct their environment and understanding together with their peers (Bryceson, 2007). Another suitable approach is *constructionism* (Papert & Harel, 1991) – an educational philosophy, which implies that learning is more effective if done through the design and building of personally meaningful artefacts than consuming information alone (Bessière, et al., 2009; Papert & Harel, 1991).

Despite the demand and interest from educators, in most cases, 3D CVEs are adopted for educational purposes, but not specially created (Kluge & Riley, 2008). Cooperation and co-construction in 3D CVEs need to be supported and require additional tools (Warburton, 2009). The design of environments or 'learning spaces' within 3D CVEs is considered to be important, however, there are no strong guidelines (Minocha & Reeves, 2010). Together with the novelty of the area, this is the motivation for developing design principles and frameworks for tools and environments that can help support educational activities in 3D CVEs.

Educational environments are often created based on metaphors, and *virtual campus* is one of the most used in this context. Still, a significant part of virtual campuses is designed using different technics, principles, and theoretical groundings (De Lucia, Francese, Passero, & Tortora, 2009; Grieu, Lecroq, Person, Galinho, & Boukachour, 2010; Prasolova-Førland, Sourin, & Sourina, 2006). There is a lack of theoretical and empirical studies in this area (Bijnens et al., 2008; Grieu, et al., 2010).

Virtual campuses can be used not only as educational tools but also for supporting learning communities. University campuses are vital socializing places. They become even more important in cities with a high number of students and strong positions of education and research. In such cities society, culture, entertainment, and education are all interconnected. *Virtual city* metaphor is widely used for designing CVEs. Many virtual cities have functionality for socializing, entertainment, cultural development, and learning. However, very few of them succeeded in integrating those functions.

On the practical level, the possibilities of 3D CVEs for simulating environments and supporting complex interaction result in a number of benefits for establishing and supporting learning communities (Bronack et al., 2008). 3D CVEs allow learning communities to create content and leave traces of their activities, which may become part of the shared repertoire of the community through the process of reification (Wenger, 1998). Considering that establishing and nurturing vibrant learning communities is seen as a highly complex process (Wenger, McDermott, & Snyder, 2002; Wenger, White, & Smith, 2009), these possibilities of 3D CVEs can be exploited.

## 1.2 Research goal

Given the challenges presented above, the main goal of the research work is to *explore collaborative work on 3D content, including its use in educational context, design of tools and environments, and support of communities.*

The research goal requires specification. In this thesis, collaborative work on 3D content is studied in a university context, using educational visualizations as a major activity. Virtual campus of NTNU was used as a place for conducting this activity. The data collected in the studies were used for developing a learning approach for the use of educational visualizations in 3D CVEs.

In addition, the data were used for exploring the design of tools and environments for conducting educational visualizations and for collaborative work on 3D content in general. The design of environments was also studied exploring virtual city environments. In these studies, cities with strong positions of education and research were considered as possible use cases.

Support of communities was studied in the context of presented virtual environments. The major emphasis was on the technological and instructional support of learning communities in a university and its connections to the other communities in the city.

The main question that this research work aims to answer is:

**MRQ:** How to provide learning communities with an adequate support for collaborative work on 3D educational content in a virtual campus and virtual city context?

The main research question can be decomposed into three following topics:

**Topic 1**: Collaborative work on 3D educational content

**Topic 2**: Design of tools and environments within 3D CVEs

**Topic 3**: Support for learning communities in 3D CVEs

This decomposition leads to the definition of the following sub-questions determining the development of the work:

**RQ1:** How can *collaborative work on 3D content* benefit educational activities?

RQ1a: How to characterise 3D content and educational visualizations in CVEs?

RQ1b: How to facilitate learning by means of educational visualizations in 3D CVEs?

**RQ2:** How to design *tools and environments* in 3D CVEs to benefit educational activities?

RQ2a: How to design tools for a virtual campus and a virtual city?

RQ2b: How to design environments of a virtual campus and a virtual city?

**RQ3:** How to support *learning communities* in 3D CVEs?

RQ3a: How to support learning communities by means of collaborative work on 3D content?

RQ3b: How to support learning communities in an educational virtual city?

Propositions to these research questions are described in section 3.

## 1.3 Research Context

The research work presented in this thesis is financed by the Program for learning with ICT (LIKT) and the Faculty of Social Sciences and Technology Management (SVT). However, the work is partly conducted at the Department of Computer and Information Science (IDI) at the Faculty of Information Technology, Mathematics and Electrical Engineering (IME).

The research work was partly financed by and contributed to the following projects:

- Virtual City of Yoshkar-Ola (VCYO) – a research project led by the Multimedia Laboratory at Mari State Technical University, Russia.
- Travel in Europe (TiE) – a joint European project led by ELIOS Research Group, University of Genova, Italy in cooperation with Program for learning with ICT (LIKT), Norwegian University of Science and Technology (NTNU) and other organizations.
- Virtual Campus of NTNU in Second Life –a project led by the program for learning with ICT.
- Transformative, Adaptive, Responsive and enGaging EnvironmenT (TARGET) – a collaborative project partially funded by the European Community under the Seventh Framework Programme.
- Enabling Creative Collaboration through Supportive Technologies (CoCreat) – a project supported by the European Commission under the Life Long Learning programme.

## 1.4 Contributions

The research work presented in this thesis (research questions presented above) resulted in the following contributions.

**Contributions towards collaborative work on 3D content (Topic 1)**

The following contributions are intended to increase understanding and provide practical instructions for collaborative work on 3D content.

**C1:** Typology of 3D Content and Visualization Means

This characterization framework 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 to the viewer, for example by role-playing. Visual shell can be described using three dimensions: aesthetics, functionality, and expressed meaning. The typology was developed based on the results of three exploratory studies conducted within this PhD work in the virtual campus of NTNU. Other relevant studies previously conducted at NTNU were used to a minor degree.

**C2:** Methodology for learning with educational visualizations in 3D CVEs

The methodology provides guidance on the use of collaborative 3D visualizations in educational context. It consists of six phases, which are given with descriptions of their goals, how much time they usually take, what virtual places and tools are required, and what assistance students need. Suggested guidance helps to structure and plan the educational activity. The methodology was developed based on the results of three exploratory studies conducted within this PhD work in the virtual campus of NTNU.

**Contributions towards tools and environments (Topic 2)**

The following contributions provide practical guidelines for designing tools and environments within 3D CVEs.

**C3:** Creative Virtual Workshop framework (CVW)

The framework describes how to design tools for virtual environments, including virtual campus and virtual city. The main feature of the framework is the integration of four virtual places and corresponding functions: virtual workplace to support manipulating 3D content, virtual library of resources to provide building blocks, virtual stage to support presenting projects and virtual gallery to store and exhibit constructions. The first version of this framework was described in the research proposal for this PhD work. It had been improved based on the results of three exploratory studies conducted in the virtual campus of NTNU. A CVW prototype was developed and further elaborated based on the results of each study.

**C4:** Guidelines for designing virtual campuses and educational virtual cities

A concept of a virtual campus integrated into a virtual city is suggested in the thesis. City context extends the possibilities of a virtual campus to support learning and socializing. At the same time, a campus enriches a virtual city with social meaning and educational content. Together, the integration of a virtual city and a campus connects local and distributed learning communities. The guidelines include the following dimensions: appearance, informational resources, community resources and tools, navigation facilities, and atmosphere. The guidelines are developed based on the results of the exploratory study conducted in the VCYO and first two exploratory studies on educational visualizations. Other relevant studies previously conducted at NTNU were used to a minor degree.

**Contributions to learning communities (Topic 3)**

The following contributions are intended to increase understanding and provide practical instructions for supporting learning communities in 3D CVEs.

**C5:** Virtual Research Arena framework (VRA)

Virtual Research Arena at the Virtual Campus of NTNU is a meeting place for researchers, students, and the general public. It is a place for visualizing and promoting research projects. We proposed it as a framework for creating awareness about educational and research activities, promoting cross-fertilization between different environments, and engaging the general public. This framework was developed based on the results of the exploratory study conducted within this PhD work in the virtual campus of NTNU in 2009. CVW framework was also used as grounding for the VRA framework.

**C6:** 'Universcity' framework

Applying a holistic approach to a virtual city design, we integrate different aspects of city life, such as culture, society, education, and entertainment. 'Universcity' is a virtual city for students, researchers, and other stakeholders with education as the main purpose, a university campus as the main feature and all other features serving for learning support. This framework is a result of a theoretical study conducted within this PhD work.

## 1.5 Thesis Structure

The thesis consists of two parts. The details of the research, results, and contributions are described in a set of papers.

The rest of **Part I** is organized as follows.

**Chapter 2** outlines the background on the use of 3D CVEs in educational settings.

**Chapter 3** describes the research context and research design of the PhD work.

**Chapter 4** presents the results of the research work.

**Chapter 5** provides evaluation and discussion of results.

**Chapter 6** concludes the thesis and outlines directions for future research.

**Part II** contains the primary research papers which are numbered in the order of conducted research activities that they present. The relations between the topics, research questions, contributions, and papers are presented in Table 1. Papers marked with bold answer the corresponding research questions and provide the main contributions.

**Paper 1** provides guidelines for designing an educational virtual city.

**Paper 2** provides guidelines for integrating a virtual campus and a virtual city.

**Paper 3** provides implications for designing the virtual campus of NTNU.

**Paper 4** provides an overview and implications for the use of collaborative work on 3D content in educational settings.

**Paper 5** provides a proposal for the integration of cultural, social, educational, and entertainment aspects of learning communities with the 'Universcity' framework.

**Paper 6** provides a proposal and an evaluation of the Virtual Research Arena framework.

**Paper 7** provides a proposal and evaluation of the Typology of 3D Content and Visualization Means. In addition, the paper contains a methodology for learning with educational visualizations in 3D CVEs.

**Paper 8** provides implications for supporting learning communities in 3D CVEs.

**Paper 9** provides requirements for creativity support in an educational 3D CVE.

Table 1: Relations of topics, research questions, contributions, and papers

| Research topics | Research questions | | Contributions | Related papers |
|---|---|---|---|---|
| Collaborative work on 3D content | RQ1 | RQ1a | C1: Typology | P4, **P7** |
| | | RQ1b | C2: Methodology | P3, **P7**, P9 |
| Design of tools and environments | RQ2 | RQ2a | C3: Tools / CVW | **P3**, P6 |
| | | RQ2b | C4: Environments | P1, **P2**, P5, P9 |
| Support of learning communities | RQ3 | RQ3a | C5: VRA | P5, **P6**, P8, P9 |
| | | RQ3b | C6: 'Universcity' | P1, P2, **P5** |

# 2 Background

This chapter provides an overview of the state-of-the-art on the 3D CVE technology, its use in education, design of environments, and support of learning communities.

## 2.1 Computer-supported cooperative work and learning

Computer-supported cooperative work is a well-established and wide research field that includes understanding of cooperative work and the design of computer-based technologies for it (Fitzpatrick, 2003; Schmidt & Bannon, 1992). This field adopted a number of theories, frameworks, and methods to deal with existing challenges, including its application to different domains.

Collaboration by means of technology is an essential part of present-day education. The community of teachers and learners puts into practice more and more innovative tools and methods but still computer-supported cooperative learning is a relatively new trend carrying both abundant opportunities and serious challenges (Stahl, Koschmann, & Suthers, 2006).

Each particular technology that is applied in education has its own specifics. The research work presented in this thesis is focused on one of such technologies – 3D collaborative virtual environments.

## 2.2 3D collaborative virtual environments

This section provides an overview of the 3D CVE technology and its educational use. A particular activity – collaborative work with 3D content is presented in more detail, since it is the focus of this thesis.

3D CVEs need to be distinguished from the other virtual reality technologies. There exist fully immersive, augmented or mixed, and desktop virtual realities, which are different in their interfaces, types of immersion, required resources, and possibilities (Pana, Cheokb, Yanga, Zhua, & Shia, 2006). Although, all these technologies are used for educational purposes (Hai-Jew, 2010), the research work presented in this thesis is focused on exploring one particular type of virtual reality technologies – desktop virtual reality (Ausburn & Ausburn, 2004; Tait, 1992).

### 2.2.1 Overview of 3D collaborative virtual environments

Formal definitions are rare in the area of 3D CVEs, since it is relatively new and complex (Bell, 2008; Schmeil & Eppler, 2009). The technology appeared on the interception between virtual reality and networked computers. There exist few terms to call the technology itself. These terms have overlapping meanings and are often used to describe the same phenomenon. Most commonly used terms include 3D collaborative virtual environments (CVEs), Multi-user Virtual Environments (MUVEs), and Virtual Worlds (VW). Collaborative work on 3D content is one of the major activities explored in this thesis, and therefore, I use the most suitable term – 3D Collaborative Virtual Environments or 3D CVEs.

Based on several sources, 3D Collaborative Virtual Environments can be defined as three dimensional, multiuser, synchronous, persistent environments, facilitated by networked computers (Bell, 2008; de Freitas, 2008b; Schmeil & Eppler, 2009). In such environments, users are represented by animated avatars and can interact using text-based chat, voice chat, and gestures. In addition, 3D CVEs allow interaction with various types of objects, including 3D objects and other media, such as text, graphics, sound, and video.

There are many application domains of 3D CVEs, and their use has been growing rapidly in the first decade of the 21st century. Although entertainment remains one of the most successful application domains, many other CVEs are created to be used for 'serious' purposes (de Freitas, 2008a; Messinger, Stroulia, & Lyons, 2008; Wrzesien & Raya, 2010). Education is often considered to be the main serious use of 3D CVEs (de Freitas, 2008b). However, there are many others, such as training, research, commerce, and socialization. Developing quality specialized 3D CVEs is expensive, but there are examples in the military and health care training. More often, regions of large social virtual worlds are adapted for serious purposes (Hendaoui, Limayem, & Thompson, 2008).

In this research work, I have been deriving platform-independent implications. However, two social virtual worlds (Active Worlds and Second Life) can be briefly presented here as examples. Many theoretical propositions in this research work have been made based on the results of several related studies, conducted in Active Worlds. Another platform – Second Life – has been used for conducting three explorative studies, included in this thesis.

Active Worlds[1] (AW) offers "a comprehensive platform for efficiently delivering real-time interactive 3D content over the web". Active Worlds includes a predefined library of building blocks that can be extended by objects designed with third party tools and added to the 'object path' by the administrator (after conversion into the AW-compatible format). The platform provides a list of standard avatars and a list of gestures. Users can communicate by a text chat and instant messages. Active Worlds platform had been widely used for experimental learning in the beginning of the first decade of the 21st century (Prasolova-Førland, 2007).

Second Life[2] (SL) is defined by its developers as "a free online virtual world imagined and created by its residents". The platform has an "open-ended architecture and collaborative, user-driven character" (Helmer, 2007). Second Life supports various types of content and media, such as text in a form of 'notecards', graphics, primitive and mesh-based 3D objects, streaming sound, video and web. Moreover, it allows creating constructions combining different types of content, programming animations and behaviour through scripts written in Linden Scripting Language and performing complex interactions using avatars. Users can communicate by text and voice chat, as well as custom animations and gestures. This platform has become the most popular 3D CVE for educational projects, however, the interest has been reducing in the second decade of the XXI century (Salmon, 2009).

### 2.2.2 Educational use of 3D collaborative virtual environments

Virtual environments have been attracting attention of educators and researchers since their appearance. This technology provides a unique set of features that can be used for educational purposes, such as low cost and high safety, three-dimensional representation of learners and objects, interaction in simulated contexts with high immersion (Cram, 2011) and a sense of presence (Dede, 2009; Mckerlich, Riis, Anderson, & Eastman, 2011).

Possibilities for synchronous communication and interaction allow using 3D CVEs by various collaborative learning approaches (Lee, 2009). In addition, possibilities for simulating environments on demand and for active collaborative work on the content allow applying situated learning (Hayes, 2006) and project-based learning (Jarmon, Traphagan, & Mayrath, 2008) approaches.

Constructivist approaches, such as problem-based learning, are also popular among the adopters of 3D CVEs (Bignell & Parson, 2010). Social constructivism is often called an ideal approach for learning in a 3D virtual environment, as the technology also allows learners to construct their understanding collaboratively (Coffman & Klinger, 2007; Huang, Rauch, & Liaw, 2010; Molka-Danielsen, 2009).

[1] http://activeworlds.com/
[2] http://secondlife.com/

Exploiting advantages of the content manipulation, 3D CVEs can be used as cost-effective prototyping platforms to build and evaluate models or realistic simulations of existing or planned spaces (Minocha & Reeves, 2010). CVEs can be well used as information visualization environments, immersing users and providing them with rich sensory experience (Bowman, et al., 2003; Chen & Börner, 2005). In addition, CVEs are used for educational simulations (Falconer & Frutos-Perez, 2009) and demonstrating complex concepts (Dekker, et al., 2011; Youngblut, 1998).

Despite the repeated positive conclusions, researches often report that their studies have experimental nature. At the same time, many learning approaches are already used in 3D CVEs, and even a new phenomenon "Virtual world pedagogy" is being discussed (Dawley, 2009).

### 2.2.3 Collaborative work with 3D content

Considering the background presented above, 3D CVEs can be widely used in educational settings. The technology supports many learning approaches. This research work is focused on collaborative work with 3D content, an activity that is both a promising learning approach and well supported by the technology.

3D CVEs have the possibility for supporting collaborative work with various types of content, as discussed in several studies (Arreguin, 2007; Atkins, 2009; Hwang, et al., 2008; Perera, et al., 2010; van Nederveen, 2007). Most 3D 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. It can be "objects, places, activities" or any valuable information or experience (Bessière, et al., 2009).

Besides the possibilities for active and collaborative manipulation on the content, the technology allows storing, sharing, and exhibiting the content in a community repository as well as live presentation, discussion, and experience. Wide possibilities for conducting meetings, events, and performances extend the use cases for collaborative work on 3D content (Sant, 2009). 3D CVEs support creating and sharing content – the key features of social networking and connection to a community (Owen, Grant, Sayers, & Facer, 2006; Smith, Oblinger, Johnson, & Lomas, 2007).

## 2.3 Design of educational 3D collaborative virtual environments

This section provides a background on the design of educational 3D CVEs. Two particular examples: virtual campus and virtual city are presented in more detail, since these metaphors are the focus of this thesis.

### 2.3.1 Use of metaphors in educational 3D collaborative virtual environments

The design of environments for conducting educational activities in 3D CVEs has long been and remains an important issue recognized by researchers, educators, and developers (Dede, 1996; Minocha & Reeves, 2010; Molka-Danielsen, Deutschmann, & Panichi, 2009).

Using place metaphors in the design of educational 3D CVEs is a common practice (Gu, Williams, & Gül, 2007; Li & Maher, 2000; Prasolova-Førland, 2005). Virtual campus metaphor might be seen as one of the most appropriate for an educational CVE. However, there are many other metaphors that are used in different contexts, such as virtual museums, galleries and theatres (Sant, 2009), virtual laboratories and workshops (Dalgarno, Bishop, Adlong, & Bedgood, 2009), virtual libraries (Hill & Lee, 2009), and virtual hospitals (Boulos, Hetherington, & Wheeler, 2007).

The choice of the metaphor and its design is usually based on particular learning goals and on the role of the CVE. In most cases, the design focuses not only on the appearance of the 3D environment, but on the functionality, tools and features (Prasolova-Førland, 2005). Educational 3D CVEs are often created within bigger virtual worlds using their advantages but also being restricted by their limitations (de Freitas, 2008b).

### 2.3.2 Virtual campuses

Many different educational environments that define themselves as 'Virtual Universities' or 'Virtual Campuses' have been developed. Such environments started as online multimedia services for distance learning in the early 90s of the 20th century (Carswell, 1998). The technology of 3D CVEs was among the first to be adopted by educators (Jermann, Dillenbourg, & Brouze, 1999; Maher, Skow, & Cicognani, 1999).

In the first decade of the 21st century, providing online educational services for time- and space-separated users has become one of the most important roles of virtual campuses, representing both traditional and fully online educational institutions. Modern virtual campuses adopt different technologies to provide users with different sets of possibilities, often going far beyond distance learning. These technologies are ranging from web-based systems to immersive 3D virtual environments.

In this thesis, a *virtual campus* is understood as a 3D collaborative virtual environment that uses the university metaphor and provides users with a range of tools for educational activities.

Other possible roles of the virtual campuses include dissemination and sharing of educational content, support for educational simulations and demonstrations (Antonacci & Modaress, 2008; Callaghan, McCusker, Lopez Losada, Harkin, & Wilson, 2009) as well as support for collaborative learning (Abbattista, Calefato, De Lucia, Francese, & Tortora, 2009; Andreas, Tsiatsos, Terzidou, & Pomportsis, 2010). Virtual campuses can facilitate the development of learning communities, provide perception of awareness, and a sense of presence (De Lucia, et al., 2009; Minocha & Reeves, 2010). In addition, virtual campuses support informal learning and provide a platform for open, distributed, and lifelong education (Dickey, 2005; Dondera et al., 2008; Elger & Russell, 2003).

Existing virtual campuses are diverse in their appearance, possibilities, and purposes. Many of them attempt to create a familiar atmosphere for the students. Often, virtual campuses provide a clear association with the real educational institutions they represent, conveying their 'spirit' and atmosphere by different means. These means may include a realistic outlook, informational resources, and possibilities to contact the representatives of the educational institutions (Prasolova-Førland, et al., 2006).

Virtual campuses have been created based on different types of platforms and technological solutions, for example OpenSimulator[1] (Che, Lin, & Hu, 2011), Unity[2], Active Worlds[3], and Bluxxun (Prasolova-Førland, et al., 2006). The most widely used platform at the moment is Second Life, despite the decrease of popularity and certain limitations as a learning environment (Helmer, 2007; Ku & Mahabaleshwarkar, 2011). Over 500 universities and colleges have or had a presence in Second Life (Jennings & Collins, 2008b).

Educational activities in Second Life virtual campuses vary broadly, from full-scale, highly realistic campuses, less realistic 'digital interpretations' to individual classes taught in common areas. For example, Northern Illinois University is supplementing courses with Second Life classes in art, computer science, education, and communication (Kelton, 2007). In Ohio State University's virtual campus visitors can take several courses, get access to learning materials, visit art installation, music centre and other places (Jennings & Collins, 2008a).

### 2.3.3 Virtual cities

The 'city' metaphor is used in a wide range of 3D CVEs (de Freitas, 2008b; Dodge, Doyle, Smith, & Fleetwood, 1998). In the virtual city design the quality of environment and the level of detail are often of high importance (Dokonal, Martens, & Plösch, 2004). Still, it is not only an issue of creating a realistic 3D model, but a place that is invested with social meaning.

[1] http://opensimulator.org
[2] http://unity3d.com
[3] http://www.activeworlds.com

In this thesis, a *virtual city* is defined as an environment representing a real or fictional city and supporting a range of different activities for the purposes of education, cultural development, entertainment, and socializing for local communities and virtual tourists. Other possible roles of a virtual city include attracting potential tourists and visitors and providing them with information about the city, and the local educational institutions.

The most known virtual cities (both collaborative and single-user environments) are made for geographical navigation, such as in Google Earth[1], heritage preservation, such as Rome Reborn[2] and Forbidden City[3], others for gaming and socializing, for example Cybertown[4] and Citypixel[5]. There are examples of virtual cities for advertisement and shopping, such as Near[6]. Some other virtual cities are multifunctional, such as GeoSim Cities[7].

It is also popular to build virtual cities within large virtual worlds that represent the physical world in a very direct and realistic way and known as 'mirror worlds' (de Freitas, 2008b; Hudson-Smith, Milton, Dearden, & Batty, 2009).

In general, while educational 3D CVEs focus on collaboration among learners that are geographically distributed, the metaphor of 'virtual city' brings local issues back into the distributed virtual environment, recognizing the critical role of place and local communities in learning (Rheingold, 2003). Therefore, virtual cities have potential to support what Thackara calls new geographies of learning, "configurations of space, place, and network that respect the social and collaborative nature of learning" (Thackara, 2005).

## 2.4 Learning communities in 3D collaborative virtual environments

This section provides a background on the use of 3D CVEs for the support of learning communities. It is known that constructing meaningful artefacts and collaborative work on meaningful projects is closely related to learning communities (Meyers, Lamarche, & Eisenberg, 2010). Community support is called one of the main reasons for conducting technology-enhanced constructionist learning activities (Bruckman, 1998).

The section provides information on the theoretical framework Communities of Interest, which is used in this research work for describing learning communities.

[1] http://www.google.com/earth/index.html
[2] http://www.romereborn.virginia.edu
[3] http://www.virtualforbiddencity.org
[4] http://www.cybertown.com
[5] http://www.citypixel.com
[6] http://www.nearglobal.com
[7] http://www.geosim.co.il

### 2.4.1 Learning communities and communities of interest

Establishing and nurturing vibrant learning communities is seen as a highly complex process (Wenger, et al., 2002; Wenger, et al., 2009). Yet, at the same time, such communities are seen as highly important in developing and spreading new skills, insight and innovation (Johnson, 2010). Traditionally, Communities of Practice (CoP) have been the most common form of community. Hence, the notion of a Community of Interest (CoI), as introduced by Fischer et al., seems to incorporate the variety and dynamism that is a typical feature of modern society (Fischer, Rohde, & Wulf, 2007).

CoIs can be thought of as "communities of communities" (Brown & Duguid, 1991) or a community of representatives of communities. CoIs are also defined by their shared interest in framing and resolution of a (design) problem, are more temporary than CoPs, come together in the context of a specific project and dissolve after the project has ended. According to (Fischer, 2005; Fischer, et al., 2007), CoIs have potential to be more innovative and transforming than a single CoP if they can exploit the 'symmetry of ignorance' for social creativity.

Stakeholders within CoIs are considered as informed participants (Brown, Duguid, & Haviland, 1994; Fischer, et al., 2007), being neither experts nor novices, but both. They are experts in their own domains when they communicate their knowledge and understanding to others. At the same time, they are novices and apprentices when they learn from others' areas of expertise. Therefore, the major strength of CoIs is their potential for creativity (Fischer, 2000; Rittel, 1984). CoIs have great potential to be more innovative and more transforming than a single CoP (Fischer, 2001, 2005; Fischer, et al., 2007).

### 2.4.2 Learning communities support in 3D collaborative virtual environments

The technology of 3D CVEs provides a number of benefits for creating and supporting learning communities. 3D CVEs and virtual worlds are often seen as a special type of social media, which are known for their community support. However, 3D CVEs have characteristics which differentiate them from other social media (Molka-Danielsen, 2011).

3D CVEs support synchronous interaction in immersive spaces which provide a sense of presence. This feature of the technology is reported to be of high importance for the development of online communities (Bronack, et al., 2008). Many 3D CVEs support user-generated content, a key principle of social media. This possibility also benefits learning communities allowing to leave traces of their activities, which may become part of the shared repertoire of the community through the process of reification (Wenger, 1998). 3D CVEs distinguish from other social media by supporting three-dimensional content.

The above characteristics of 3D CVEs extend the possibilities of using boundary objects (Star, 1989) and also shared artefacts as catalysts of collaboration (Thompson, 2005; Wenger, 1998), such as 'monuments' (symbols strengthening identity within the community); 'instruments' (an infrastructure supporting interactive communication) and 'points of focus' around which the interaction and collaboration will be structured.

In addition, 3d CVEs allow creating necessary context for interactions, simulating learning environments. Online communities can benefit from such environments being dedicated community spaces (Wenger, et al., 2002).

## 2.5 Conclusions and challenges

3D CVEs provide both opportunities and challenges for education, and many topics in this area need further research (Burkle & Kinshuk, 2009; Kluge & Riley, 2008).

There is a need for learning approaches and methods that exploit advantages of 3D CVEs and overcome limitations:

> *Virtual worlds are unclaimed spaces as far as education is concerned—educators have not yet established norms of how to support learning within them* (Twining, 2009).
>
> *While many reports espouse the potential impact that 3-D virtual worlds are expected to have on teaching and learning in higher education in a few years, there are few empirical studies that inform instructional design and learning assessment in virtual worlds* (Jarmon, Traphagan, Mayrath, & Trivedi, 2009).

There is a need for convenient educational tools and environments that would support educational activities in 3D CVEs:

> *There is little published research on the design and evaluation of learning spaces in 3D VWs. Therefore, when institutions aspire to create learning spaces in SL, there are few studies or guidelines to inform them except for individual case studies* (Minocha & Reeves, 2010).
>
> *Second life and most virtual worlds were not created for educational purposes. Second Life, nonetheless, is being adapted by educators for teaching and learning. […] Many of the features educators take for granted in Learning Management Systems do not exist in Second Life* (Kluge & Riley, 2008).
>
> *What remains to be seen is whether or not educators will progress past 'Phase 1', in which we merely replicate real-world educational structures. Will we be able to take full advantage of the potential that these new unclaimed spaces offer* (Twining, 2009).

There is a need for exploring how 3D CVEs can support learning communities:

> *While a considerable amount of research has been done on the sociology of virtual communities and virtual worlds, the body of knowledge on educational studies in virtual worlds is still at a relatively early stage* (Campbell & Jones, 2008) in (Leong, Joseph, & Boulay, 2010).

There are also many other challenges in using 3D CVEs for learning, such as steep learning curve and demand for computational and network resources, but they are not in the main focus of this thesis. Addressing them was not possible due to the research context constraints or time limitations.

# 3 Research Context and Design

This chapter first discusses how the research questions were formed out of the challenges, presented in the previous section. Then, the chapter describes an extended context of the research work presented in the thesis, including R&D projects and external partners. Next, the general research approach is presented, including information on the studies conducted and methods used. In addition, the chapter discusses relations between the research questions, studies, and contributions. The chapter is concluded by a presentation of the research process.

## 3.1 Extended Research Context

The research work presented in this thesis was conducted in the context of several projects. The work was both influenced by the following projects and contributed to them.

- Virtual City of Yoshkar-Ola (VCYO)

VCYO is a research project led by the Multimedia Laboratory at the Mari State Technical University, Russia. The project has an open prototype – a multiuser 3D virtual environment representing the central part of the real city in exact manner. The project aims at supporting and exploring local social networks based on a virtual city as a natural environment for communication and as a subject of common interest for citizens (http://virtyola.ru/). This PhD work includes a study conducted using VCYO, involving NTNU students and international participants.

- Travel in Europe (TiE)

TiE is a joint European project led by ELIOS Research Group, University of Genova, Italy in cooperation with Program for learning with ICT (LIKT), Norwegian University of Science and Technology (NTNU) and other organizations. TiE is a virtual world where young people and the curious can enjoy challenging and engaging travels through European heritage. The main objective of the project is to implement innovative means to promote and divulgate heritage to European people (http://www.tieproject.eu/). Experience from the development of the TiE Trondheim environment and project findings were used in this PhD work.

- Virtual Campus of NTNU in Second Life

Virtual Campus of NTNU in Second Life is a project led by the Program for Learning with ICT. Virtual Campus of NTNU is a region in Second Life. It was developed as a place for educational and social activities, a source of information about the university (http://maps.secondlife.com/secondlife/NTNU/). This PhD work includes three exploratory case studies that were conducted in the virtual campus.

The virtual campus environment was enriched by the Virtual Science Fair – a prototype developed based on the Virtual Research Arena framework. It served as a virtual representation of the Norwegian Science Fair in the city of Trondheim – an annual festival for presenting science projects to the general public.

- Transformative, Adaptive, Responsive and enGaging EnvironmenT (TARGET)

TARGET is a collaborative project funded by the European Community under the Seventh Framework Programme. The main aim of the project is to develop a new genre of technology-enhanced learning environment that supports rapid competence development, and the domains of innovation and project management have been selected as pilot areas (http://www.reachyourtarget.org/). This PhD work contributes to two TARGET International Summer Schools on Technology Enhanced Learning, Serious Games and Collaborative Technologies that were conducted in the Virtual Campus of NTNU in Second Life in 2010 and 2011.

- Enabling Creative Collaboration through Supportive Technologies (CoCreat)

CoCreat is a project, supported by the European Commission under the Life Long Learning programme. The aim of this project is to find out how to enhance creative collaboration by applying the theory of collaborative learning. The outcome of the project will be increased competence in acting and learning in complex and dynamic environments where collaboration and creative solutions for problems are required (http://www.cocreat.eu/). This PhD work includes a CoCreat pre-study conducted in the Virtual Campus of NTNU.

## 3.2 Research topics

The challenges presented in section 2.5 appeared in the research work at different points of time. Some of them have been separated or merged over time. They have also been analysed considering what was possible to address in the given time and the context of R&D projects presented in section 3.1. Finally, the challenges were divided into three topics, and the research questions were re-structured in accordance with them:

**Topic 1**: Collaborative work on 3D educational content

**Topic 2**: Design of tools and environments within 3D CVEs

**Topic 3**: Support for learning communities in 3D CVEs

In the following, the topics are presented in more detail, including connection to the challenges and elaboration on the related research questions.

### 3.2.1 Collaborative work on 3D content

The challenge that fits this topic was formulated as follows: There is a need for learning approaches and methods that exploit advantages of 3D CVEs and overcome limitations. Several studies report that despite the popularity and discovered potential of 3D CVEs for learning, little is known about suitable methods and approaches (Jarmon, et al., 2009; Twining, 2009).

Collaborative work on 3D content is only a part of activities that are possible to conduct with 3D CVEs. However, this activity exploits the majority of the technology advantages. 3D content can be uploaded or created inside a 3D CVE; it can be shared, stored, and collaboratively explored and modified.

Topic 1 of this thesis is focused on exploring the educational potential of collaborative work on 3D content. It was explored in three empirical studies conducted within the Cooperation Technology course at NTNU, in which the students were working on educational visualizations.

In order to distinguish between the terms “Collaborative work on 3D content” and “Educational visualization in 3D CVEs”, the following rationale is applied. Collaborative work on 3D content is seen as an affordance of the 3D CVE technology or a series of any collaborative actions performed with 3D content. Educational visualization in 3D CVEs is understood as an educational activity that uses the mentioned affordance of the 3D CVE technology or the resultant 3D construction.

The research question related to Topic 1 is:

**RQ1:** How can *collaborative work on 3D content* benefit educational activities?

This particular question was chosen for the following reasons, which are based on the observation in Section 2. The research community is interested in exploring new technologies for learning and 3D CVEs in particular. This interest is supported by many reports on the potential of 3D CVEs in this area. Further, the gap between theoretical discussions and experimental practical studies was identified as especially noteworthy. Answering the question could contribute to the development of practical guidelines on the use of 3D CVEs in education. In addition, the curriculum of the Cooperation Technology course at NTNU, students from which acted as a target group for the studies, has influenced the choice of the research question.

The corresponding theoretical proposition was formulated as follows:

**TP1:** Educational activities can benefit from using collaborative work on 3D content as a teaching method in a university course.

The research question related to Topic 1 was decomposed into two more specific questions, which appeared in the process of conducting the first empirical study on educational visualizations:

RQ1a: How to characterise 3D content and educational visualizations in CVEs?

RQ1b: How to facilitate learning by means of educational visualizations in 3D CVEs?

### 3.2.2 Design of tools and environments within 3D CVEs

The challenge for the second topic was formulated as follows: There is a need for convenient educational tools and environments that would support educational activities in 3D CVEs. It is a fact that most 3D CVEs were not created for educational purposes, but adapted. Many researchers report that existing 3D CVEs lack educational tools, especially when it comes to exploiting the full potential of the technology (Kluge & Riley, 2008; Twining, 2009). Also, little is known about the specifics of designing learning environments in 3D CVEs (Minocha & Reeves, 2010).

In general, designing tools and environments within 3D CVEs is a wide area. Therefore, it was decided to focus on the design of two specific types of environments (virtual campuses and virtual cities) and tools for them. Later, a possibility of integrating these two types of environments was explored, and the scope was further narrowed down to an educational virtual city, which might include a virtual campus. It was also decided to concentrate on the design of tools for one type of activities that can be conducted within such an environment – collaborative work on 3D content.

Topic 2 of this thesis is focused on exploring first – the design principles of educational virtual cities and virtual campuses and second – the design of tools to support collaborative work on 3D content in such environments.

In this context, collaborative work on 3D content included not only educational visualizations, but also other activities such as collaborative explorations and annotations of 3D objects.

The research question related to Topic 2 is:

**RQ2:** How to design *tools and environments* in 3D CVEs to benefit educational activities?

This particular question was chosen for the following reasons, which are based on the observation in Section 2. The research community recognize the potential of 3D CVEs for learning as they allow simulating environments where learners can communicate and interact. However, there is a gap between theoretical discussions and practice, as, for example, 3D CVE tools are, in most cases, not designed for learning purposes. This gap was identified as deserving maximum consideration. Answering the question could contribute to the development of practical guidelines on the design of 3D CVEs for educational purposes. In addition, the curriculum of the Cooperation Technology course at NTNU and available platforms (virtual campus in Second Life and VCYO) have influenced the choice of the research question.

The corresponding theoretical proposition was formulated as follows:

**TP2:** Tools and environments in educational CVEs should be designed so that they facilitate collaborative work on 3D content and support learning communities.

The research question related to Topic 2 was decomposed into two questions that are more specific: one for the design of tools and the other for environments:

RQ2a: How to design tools for a virtual campus and a virtual city?

RQ2b: How to design environments of a virtual campus and a virtual city?

### 3.2.3 Support for learning communities in 3D CVEs

The challenge for the third topic is the following: There is a need for exploring how 3D CVEs can support learning communities. Researchers state that although virtual communities have long been studied, there is a lack of empirical data (Campbell & Jones, 2008) in (Leong, et al., 2010). At the same time, the potential of 3D CVEs for supporting learning communities was emphasized (Bronack, et al., 2008; Molka-Danielsen, 2011).

This topic appeared during the first studies of the research work. The area of supporting learning communities in 3D CVEs is very wide, and it needs to be specified that the work is focused on supporting learning communities in educational virtual cities and virtual campuses.

First, community support within a virtual city environment was explored. Then, a possibility of creating a community around different generations of students working on educational visualizations within the virtual campus environment was studied. Later, a possibility of connecting an education and research focused virtual environment to the general public both in a virtual environment and in reality was also explored.

In addition, the data from Travel in Europe project was taken into consideration. Even though the virtual environment developed within the project was not a multiuser one, it provided useful insights on the support of cultural and entertainment aspects of a virtual city.

Topic 3 of this thesis is focused on exploring how learning communities can be supported in CVEs, and more specifically, how collaborative work on 3D content can contribute to this process.

The research question related to Topic 3 is:

**RQ3:** How to support *learning communities* in 3D CVEs?

This particular question was chosen for the following reasons, which are based on the observation in Section 2. The importance of providing instructional and technological support for learning communities is recognized by the existing research. At the same time, there is little practical information or guidelines on, for example, how community environments should be designed. This gap was identified as the most important and deserving exploration. Answering the question could contribute to the exploration of how educational activities in 3D CVEs can facilitate connections between communities on the practical level. In addition, the Cooperation Technology course curriculum and R&D projects (TiE, TARGET, and CoCreat) have influenced the choice of the research question.

The corresponding theoretical proposition was formulated as follows:

**TP3:** Learning communities in 3D CVEs can be supported by means of collaborative work on 3D content in a specially designed environment.

The research question related to Topic 3 was decomposed into two more specific questions. The first one is focused on the support that collaborative work on 3D content can provide for learning communities. The second one is focused on the affordances that an educational virtual city can provide for learning communities support.

RQ3a: How to support learning communities by means of collaborative work on 3D content?

RQ3b: How to support learning communities in an educational virtual city?

## 3.3 Research Design

The research approach of the work presented in this thesis emerged over time. Overall, an iterative method was applied as follows. The work started from setting initial theoretical propositions that were later tested and evaluated. Then, the first explorative study was conducted and empirical data were collected. The data were analysed and used for two different purposes: deriving requirements for a prototype and building a theoretical framework. Both the prototype and the framework were intended to be used and tested in the next empirical study.

In such a way, four empirical studies were conducted. The studies were augmented with developing and testing prototypes and shaping theoretical frameworks. The details are presented in Figure 1.

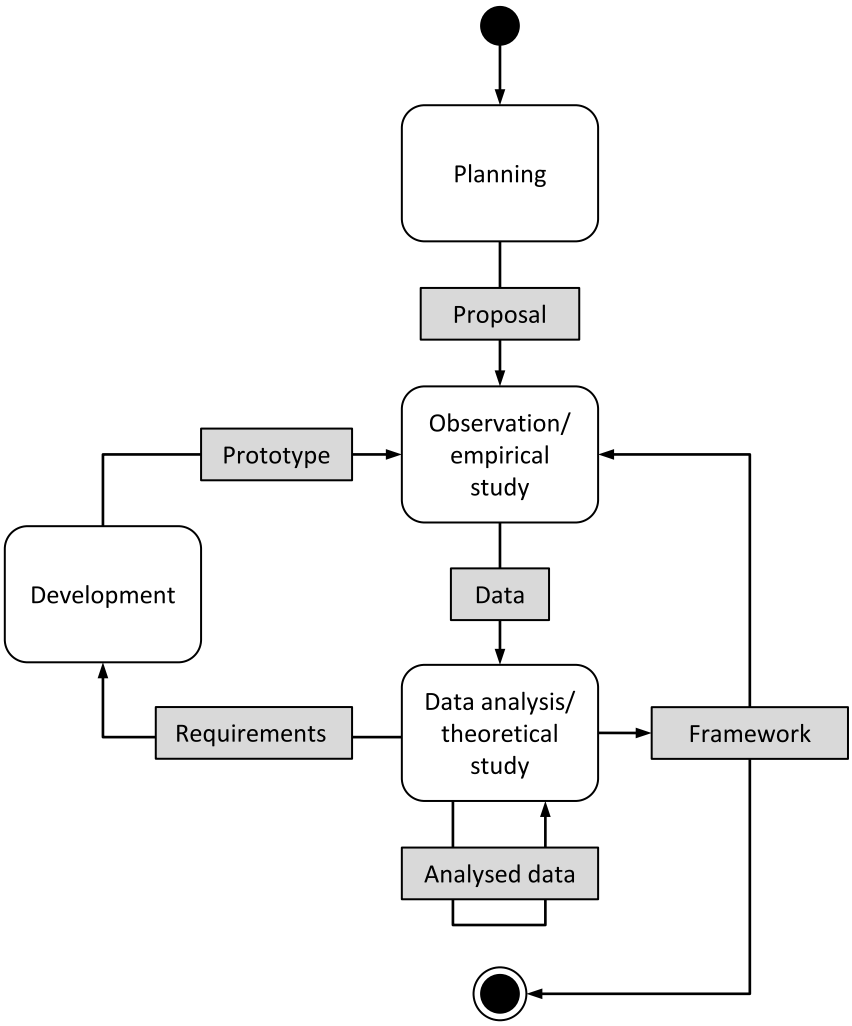


Figure 1: General research approach

Research methods applied in this thesis are both theoretically and empirically based. Both primary and secondary research strategies were used. Primary data were collected in all empirical studies that were conducted. They were analysed using qualitative methods, including discourse analysis, content analysis, and, to some degree, constant comparison. The use of quantitative methods was complicated due to the nature of the data and the constraints of the research context. At the same time, the initial propositions and theoretical studies were based on secondary data or on a mix of primary and secondary data.

The primary data were collected from the following sources of evidence: direct observation of students' activities online, virtual artefacts, such as chat log and 3D constructions, and users' feedback in the form of pre- and post-questionnaires and individual and group essays or blogs.

Direct observation was used in each empirical study and allowed to capture activities of the participants without depending on their individual perceptions expressed while answering questionnaires and writing essays or keeping blogs. Screen-capture video recordings and screenshots were used to strengthen the observation.

Virtual artefacts were collected in each empirical study and used to triangulate the data from other sources. Chat logs were used for revealing students' understanding of the subject and attitude towards different topics. 3D constructions were analysed to study the use of 3D content and visualization means in CVEs.

Students provided feedback on their activities in each empirical study. Quantitative data were collected by means of questionnaires. Pre-questionnaires were used to determine students' previous experience in the area of 3D CVEs, expectations about the forthcoming work, and opinions about other matters specific to each study. Post-questionnaires were used to collect students' individual perception on how much they learned during the study, how their expectations changed, how useful certain tools and environments were, and other data specific to each study. In addition, questionnaire data were collected from the international visitors and NTNU students from courses other than Cooperation Technology.

More data were collected in the form of students' individual and group essays or blogs in each empirical study. They were used as a source of in-depth feedback, discussion, and self-evaluation. In order to structure essays and blogs, the students followed sets of questions and discussion topics, which also allowed triangulating these data with questionnaire data.

In order to overcome the lack of a well-defined methodology of case study research, two types of approaches are usually used: multiple sources of evidence or multiple cases (Schell, 1992). In the research work presented in this thesis, both approaches were applied. The data were collected from at least two sources of evidence in each of the studies, and, in addition, empirical studies on educational visualizations can be considered as multiple cases.

The research work presented in the thesis falls under the categories of exploratory and descriptive research, which are not used for creating causal relationships and have a low requirement for internal validity (Slavin, 1991; Stebbins, 2001).

The case study method was chosen for the empirical studies of this thesis. This method is a common strategy in social science and education (Ary, Jacobs, Razavieh, & Sorensen, 2009; Yin, 2003). It was selected from alternatives based on the following rationale. Four methods were considered: history, survey, experiment, and case study.

History was considered not suitable, as it is applied to the phenomena which the investigator has virtually no access to and no control over, past events (Yin, 2003). However, in the research work presented in this thesis, it was possible to have both access and, to some degree, control.

Survey was deselected for the reason that it is usually applied as an exploratory study with “who”, “what”, “where”, “how many”, and “how much” forms of research questions (Yin, 2003). However, the research work presented in this thesis has the “how” form of research questions.

Experiment was eliminated, as it requires full control over the phenomena studied and often used for causal research (Yin, 2003). However, in the research work presented in this thesis, it was impossible to have full control over the phenomena studied.

In such a way, the case study method was chosen. Its technical definition consists of two parts. The first part is:

> *A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident* (Yin, 2003).

The research work presented in this thesis fits the definition as it deals with contemporary events that are studied together with their context. The second part of the technical definition is:

> *The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis* (Yin, 2003).

The research work presented in this thesis fits the definition as it attempted to study many interconnected phenomena, it uses multiple sources of evidence, and it benefited from theoretical propositions developed prior to the data collection.

## 3.4 Research process

Initial research proposal aimed at developing a framework for virtual campus learning tools, which now fits RQ1b and RQ2a. However, the scope of the study was modified during the work to match the resources available and new ideas. Among the main influencing factors were the facilities of Cooperation Technology course at NTNU and the requirements provided by R&D projects.

The research work presented in this thesis included four empirical studies and several theoretical studies (Figure 2). Most of the theoretical studies were based, at least partly, on the primary data from earlier empirical studies conducted within this research work. Therefore, the borders between the analysis of data in empirical studies and independent theoretical studies are often blurred.

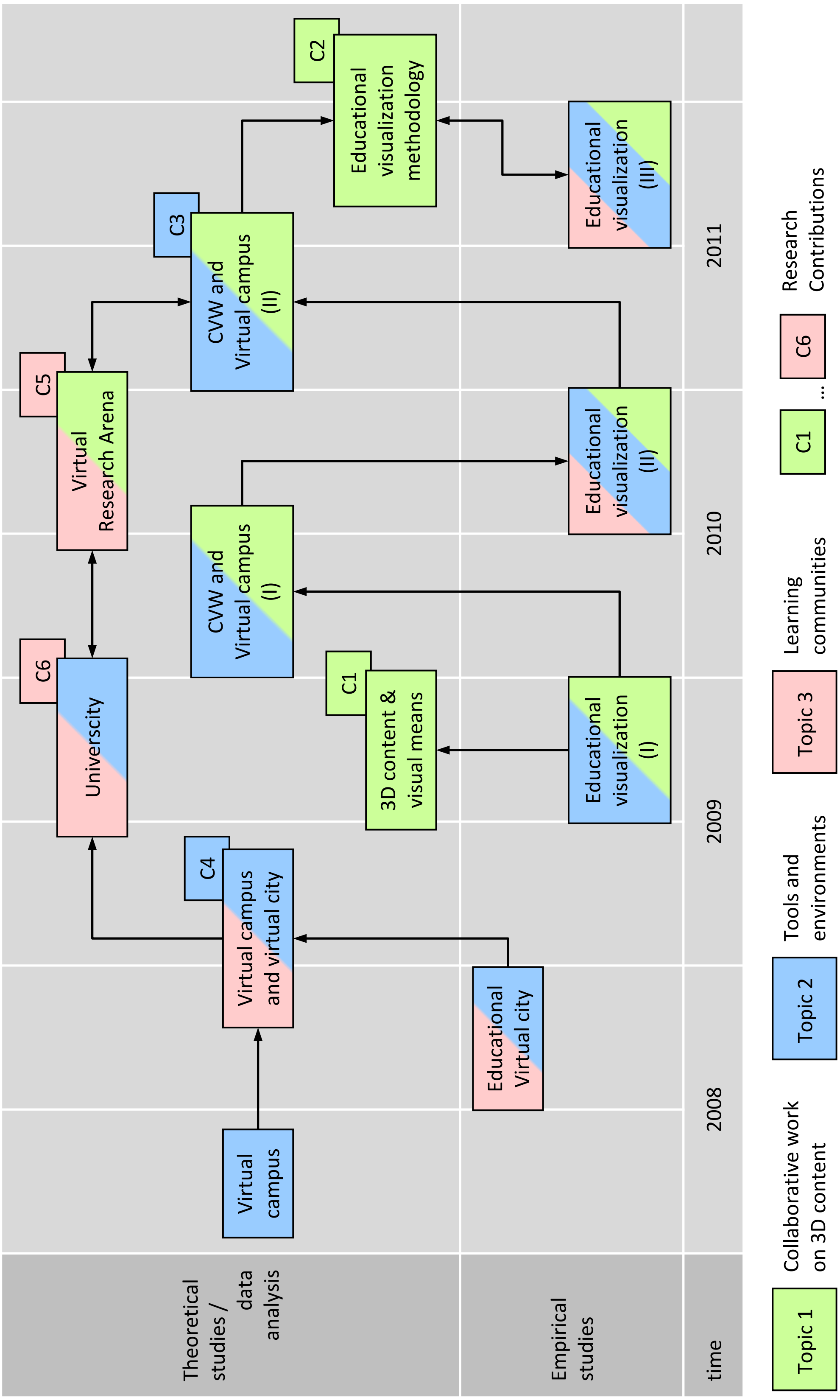


Figure 2: Timeline of research activities and contributions

### 3.4.1 Studies on the collaborative work on 3D content

Under the topic of collaborative work on 3D content, one theoretical and three empirical studies were conducted. The research began from the wide topic, but, over time, it was narrowed down to studying educational visualizations in 3D CVEs (Figure 3).

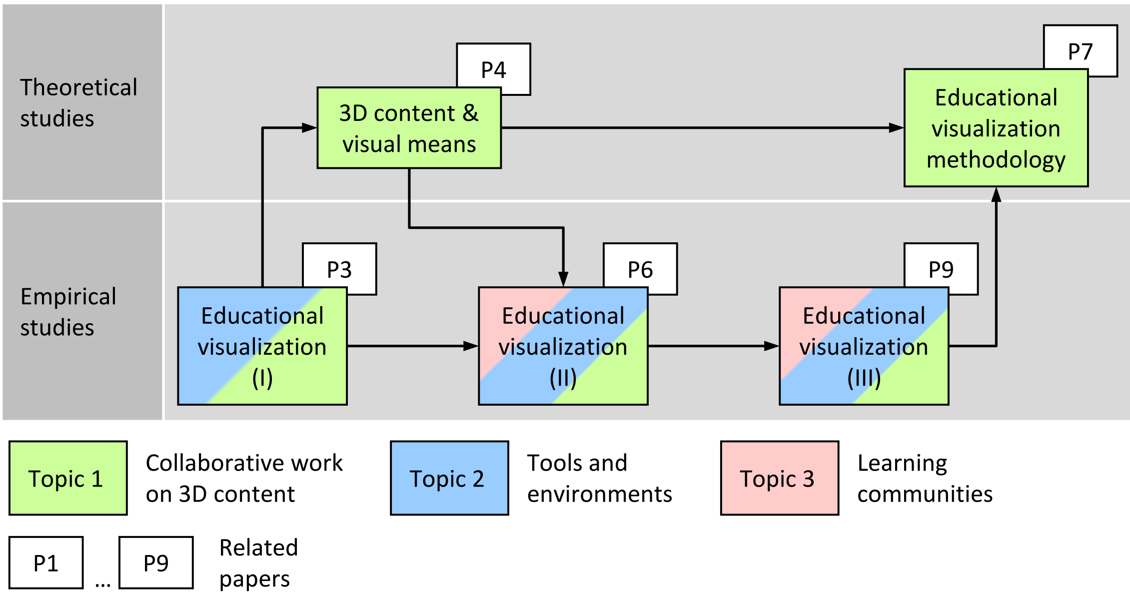


Figure 3: Studies on the collaborative work on 3D content

The first empirical study on educational visualizations was conducted in a recently established environment of the NTNU virtual campus in the autumn semester 2009. Students from the Cooperation Technology course at NTNU were working on visualizing university's research areas. Collected data were used for analysing the possibilities of the 3D CVE technology (and, in particular, Second Life) for educational visualizations. The first feedback was received on the idea of the Creative Virtual Workshop, which was not yet implemented as a prototype. This study is presented in more detail in Paper 3 of this thesis.

Theoretical study on 3D content and visualization means was conducted in two stages, starting after the first empirical study on educational visualizations. The goal of the study on the first stage was to summarize experience on collaborative construction of educational visualizations in 3D CVEs and address the challenges the students faced. In addition to the results of the first empirical study on educational visualizations, data from three earlier studies conducted within the Cooperation Technology course at NTNU were observed. The first stage of the study resulted in a set of implications for working on 3D educational content and visualizations in 3D CVEs.

A part of the study was dedicated to finding a way for analysing student constructions. It was proposed that 3D educational visualizations can be described and analysed along two dimensions: types of content and visual shells. The results of the first stage of the theoretical study on 3D content and visualization means are presented in Paper 4 of this thesis.

Next, in the autumn semester 2010, the second empirical study on educational visualizations was conducted. By that time, the environment of the NTNU virtual campus was improved and the first prototype of Creative Virtual Workshop was developed. Students from the Cooperation Technology course at NTNU were working on visualizing research projects. Collected data were used for analysing the possibilities of the 3D CVE technology for educational visualizations and for presenting research projects in particular. Another portion of feedback was received on the Creative Virtual Workshop, which was partly implemented as a prototype.

During this study, a new framework was developed and evaluated. It was called Virtual Research Arena and designed for creating awareness about educational and research activities, promoting cross-fertilization between different environments, and engaging the general public. Both the study and the new framework are presented in Paper 6 of this thesis.

The third empirical study on educational visualizations was conducted in the autumn semester 2011. By the time of this study, the environment of the NTNU virtual campus was improved again and the prototype of Creative Virtual Workshop was improved. Students from the Cooperation Technology course at NTNU were working on visualizing major course concepts. Collected data were used for analysing the possibilities of the 3D CVE technology for educational visualizations and for creativity support. Additional feedback was received on the Creative Virtual Workshop. In the time of writing the thesis, the results of the study were not fully analysed. However, the details of the study are presented in Paper 9 of this thesis.

During the second and third empirical studies on educational visualizations, the theoretical study on 3D content and visualization means had been continued. The second stage of the study was dedicated to the development of a methodology for educational visualizations in 3D CVEs. In addition, a characterisation framework Typology of 3D Content and Visualization Means was developed. Both the methodology and the framework are presented in Paper 7 of this thesis.

### 3.4.2 Studies on the design of tools and environments in 3D CVEs

The topic of design of tools and environments in 3D CVEs embraces almost all the studies presented in this thesis. Over time, the scope was narrowed down to the design of an educational virtual city, which might include a virtual campus, and the design of tools for collaborative work on 3D content, which can be conducted within such an environment (Figure 4).

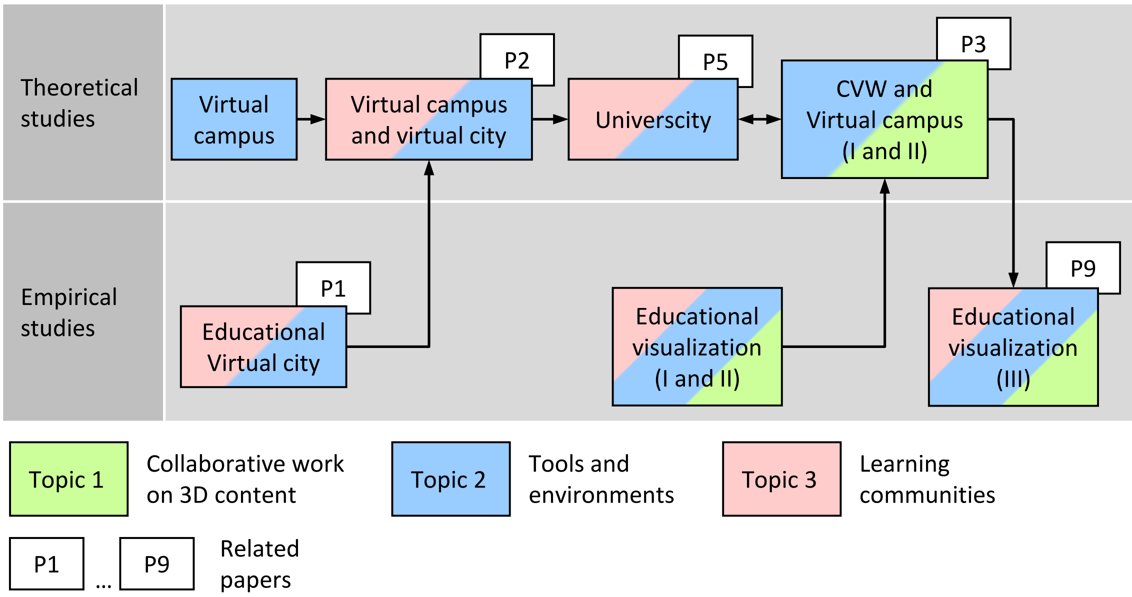


Figure 4: Studies on the design of tools and environments in 3D CVEs

Theoretical propositions were outlined in the beginning of the research work. Later, a framework Creative Virtual Workshop was developed based on these propositions, literature study, and results of previous research work. The framework described a toolset for conducting various activities in the context of a virtual campus. The proposal of the framework was described in Paper 10, which is not included in this work. However, it determined the major questions that are discussed in the thesis, such as the use of 3D CVEs for education, socialization, cultural development, and entertainment.

The first study conducted within presented research work was theoretical. Using data from previous research at NTNU, a framework Virtual Campus as a Place for Educational and Social Activities was developed. The results of the study were published in Paper 11, which is not included in this work. Although the framework itself is not a part of this thesis, it was extensively used in the research. This framework was improved based on the results of the empirical studies used for development of the Virtual Campus of NTNU, and later in other theoretical studies.

Next, in the autumn semester 2008, the first empirical study was conducted. It was an exploratory case study aimed at observing users' activities and behaviour in a virtual city context and investigating how such a city can facilitate learning and socializing, also in a cross-cultural context. The study was conducted within the Cooperation Technology course at NTNU, using the environment of VCYO. Based on the results of the study, a list of recommendations for a virtual city as a place for social and educational activities was derived and presented in Paper 1 of this thesis. In addition, the results of the study contributed to the development of VCYO project.

The second goal of the described study and some of the collected data were dedicated to exploring a possibility of integrating virtual campus and virtual city environments. Later, this enquiry became an independent theoretical study. As a result, a framework Virtual Campus in the Context of an Educational Virtual City was developed. It comprises the results of the empirical study in VCYO and the framework of virtual campus. The new framework was presented in Paper 2 of this thesis.

Later, after conducting the first empirical study in the virtual campus of NTNU and participating in TiE project, the idea of an educational virtual city evolved again. We sought to develop a holistic approach to educational virtual cities, introducing a concept of 'Universcity' as a framework for social, cultural, educational, and entertaining activities, a city for students, researchers, and other learners to live and work in. Although, the metaphor of a city was used in the design of virtual worlds, a systematic approach to learning support in virtual cities was not developed. A new study was dedicated to filling this gap. The results of this study and the 'Universcity' framework are published in Paper 5 of this thesis.

Research on the design of tools for collaborative work on 3D content was continued in the following three empirical studies. The framework Creative Virtual Workshop had been evolving from one study to another, based on the user feedback and data collected. Creative Virtual Workshop became a framework that supports creating, demonstrating, storing, and retrieving of 3D constructions, by providing an environment equipped with a set of tools. In such a way, the framework became more specialized in supporting educational visualizations and a learning community around this activity.

Based on this framework, a prototype was developed in the virtual campus of NTNU after the first empirical study on educational visualizations. The prototype was improved after the second empirical study on educational visualizations based on the user feedback and data collected. Creative Virtual Workshop framework is presented most thoroughly in Paper 3 of this thesis.

Creative Virtual Workshop was used in the third empirical study on educational visualizations, but at the time of writing the thesis, the results of the study were not fully analysed. However, the details of this study are presented in Paper 9 of this thesis.

### 3.4.3 Studies on the support for learning communities in 3D CVEs

Topic 3 appeared during the first studies of the research work presented in this thesis. The area of supporting learning communities in 3D CVEs was narrowed down to learning communities in educational virtual cities and virtual campuses (Figure 5).

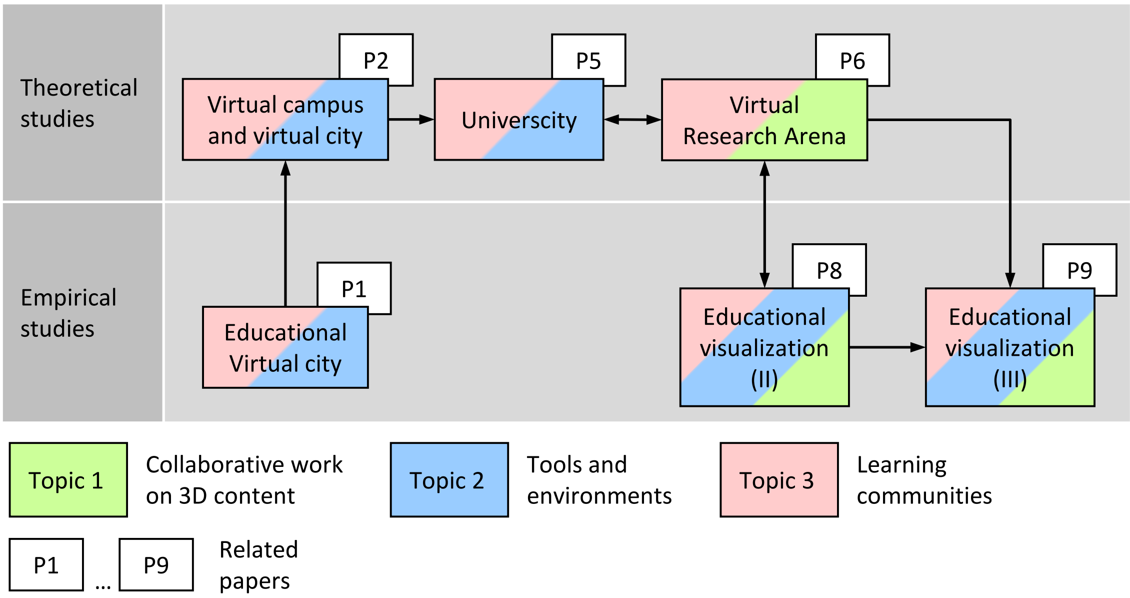


Figure 5: Studies on the support for learning communities in 3D CVEs

The topic of supporting learning communities in 3D CVEs was addressed in the first empirical study on the virtual city and the theoretical study that followed on the integration of virtual city and virtual campus.

In addition to exploring the design of virtual cities as learning environments, community support was studied in the first empirical study. Based on the results of the study, a list of recommendations for a virtual city as a place for social and educational activities was derived. Some of the points in the list were related to the community support and therefore contribute to this topic. The study is presented in Paper 1 of this thesis.

In the theoretical study on integrating virtual campus and virtual city, community support was considered one of the major features of the environment. The results of this study were presented in Paper 2 of this thesis.

Later, the topic of supporting learning communities in 3D CVEs became stronger. In the theoretical study on developing a holistic approach to educational virtual cities, a concept of 'Universcity' was proposed as a framework for social, cultural, educational, and entertaining activities, a city for students, researchers, and other learners to live and work in. One of the major purposes of such a virtual city was supporting communities by creating an environment where people can interact, learn, and play. The results of this study and the 'Universcity' framework are published in Paper 5 of this thesis.

The exploration of learning communities support in 3D CVEs continued during the second empirical study on educational visualizations. Possibilities of 3D CVEs for creating a connection between education and research communities to the general public by exhibiting and presenting research projects in the form of 3D visualizations were explored. For these purposes, a new framework was developed and evaluated. It was called Virtual Research Arena and designed for creating awareness about educational and research activities, promoting cross-fertilization between different environments, and engaging the general public. Based on this framework, a prototype was developed and evaluated at the Norwegian Science Week festival in 2010. Both the study and the new framework are presented in Paper 6 of this thesis.

The second empirical study on educational visualizations included the first International Summer School on Collaborative Technologies, Serious Games, and Educational Visualizations, organized by the TARGET project. The summer school was defined as a forum for the presentation of innovative approaches, developments, and outcomes of research projects, facilitating the exchange of ideas between students, researchers, and practitioners. The design of the summer school activities was intended to facilitate reflective dialogue in communities.

Virtual campus of NTNU in Second Life was chosen as preliminary environment to evaluate ideas and concepts within the TARGET project. The details of the summer school are presented in Paper 8 of this thesis.

The exploration on the support of learning communities in 3D CVEs continued in the third empirical study on educational visualizations, but at the time of writing the thesis, the results of the study were not fully analysed. However, the details of this study are presented in Paper 9 of this thesis.

# 4 Results

This chapter summarises the results of the research work paper by paper. Primary papers are presented in detail. Short description on the secondary papers in also given in the conclusion of the chapter.

## 4.1 Primary papers

Each of the primary papers is presented below, containing the following information:

- The authors and their contributions to the paper
- The full title
- Publication source
- Description of the studies conducted and results achieved
- Input to contributions
- Research question answered

The following papers have been published as part of this research work. The papers answer research questions and provide significant contributions to the field. Papers themselves are presented in Part II of this thesis.

The summaries of papers presented in this section are the following:

**P1:** Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov: "Virtual City as a Place for Educational and Social Activities," *International Journal of Emerging Technologies in Learning, 4*(s2), 2009, Universität Kassel, ISSN: 1863-0383, pp. 13–18.

**P2:** Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov: "Virtual Campus in the Context of an educational Virtual City," *International Journal of Interactive Learning Research, 22*(2), 2011, AACE, ISSN: 1093-023X, pp. 299–328.

**P3:** Ekaterina Prasolova-Førland, Mikhail Fominykh and Theodor G. Wyeld: "Virtual Campus of NTNU as a place for 3D Educational Visualizations," in *the 1st Global Conference on Learning and Technology (G-Learn)*, Penang, Malaysia, May 17-20, 2010, AACE, ISBN: 1-880094-79-7, pp. 3593-3600.

**P4:** Ekaterina Prasolova-Førland, Mikhail Fominykh and Theodor G. Wyeld: "Working on Educational Content in 3D Collaborative Virtual Environments: Challenges and Implications," in *the 13th International Conference on Computers and Advanced Technologies in Education (CATE)*, Maui, Hawaii, USA, August 23-25, 2010, ACTA Press, ISBN: 978-0-88986-844-1, pp. 183-190.

**P5:** Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov, Alexey Gerasimov, Francesco Bellotti, Alessandro De Gloria, Riccardo Berta and Rosario Cardona: "Universcity: Towards a Holistic Approach to Educational Virtual City Design," in *the 16th International Conference on Virtual Systems and Multimedia (VSMM),* Seoul, Korea, October 20-23, 2010, IEEE, ISBN: 978-1-4244-9025-7, pp. 371-374.

**P6:** Mikhail Fominykh and Ekaterina Prasolova-Førland: "Virtual Research Arena: Presenting Research in 3D Virtual Environments," in *the 2nd Global Conference on Learning and Technology (G-Learn),* Melbourne, Australia, March 28-April 1, 2011, AACE, ISBN: 1-880094-79-7, pp. 1558-1567.

**P7:** Mikhail Fominykh and Ekaterina Prasolova-Førland: "Collaborative Work on 3D Content in Virtual Environments: a Methodology," *Interactive Technology and Smart Education*, *9*(1), 2012, Emerald, ISSN: 1741-5659, in press.

**P8:** Leif Martin Hokstad, Ekaterina Prasolova-Førland and Mikhail Fominykh: "TARGET International Summer School: Use of 3D Collaborative Virtual Environments for Community Building," in Sean Goggins and Isa Jahnke (Ed), *CSCL at work*, 2012, Springer, ISBN: 978-1-4614-1739-2, in press.

**P9**: Mikhail Fominykh, Ekaterina Prasolova-Førland and Monica Divitini: "Constructing a 3D Collaborative Virtual Environment for Creativity Support," in *the 16th World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education (E-Learn)*, Honolulu, Hawaii, USA, October 18-21, 2011, AACE, ISBN: 1-880094-90-8, pp. 1919-1928.

### 4.1.1 Paper 1

| | |
|---|---|
| **Authors** | Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov |
| **Title** | Virtual City as a Place for Educational and Social Activities |
| **Published in** | International Journal of Emerging Technologies in Learning, 4(s2), 2009, Universität Kassel. |
| **Authors' contributions** | Mikhail Fominykh and Ekaterina Prasolova-Førland conducted the study and wrote the paper. Mikhail Morozov provided feedback throughout the writing process and participated in conducting the study. Alexey Gerasimov led the development of the environment, participated in conducting the study and data analysis. |
| **Description** | In this paper, we present a case study conducted using VCYO. We explore user activities and behaviour in a virtual city context. Our goal was to investigate how such a city can facilitate learning and socializing, also in a cross-cultural context. Based on the analysis of the study results, we present initial guidelines for designing a virtual city as a place for social and educational activities. |
| **Contribution** | The paper contributes towards C4: Guidelines for designing virtual campuses and educational virtual cities. |
| **Relation to research questions** | The paper partly answers research question RQ2b: How to design environments of a virtual campus and a virtual city? |

### 4.1.2 Paper 2

| | |
|---|---|
| **Authors** | Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov |
| **Title** | Virtual Campus in the Context of an educational Virtual City |
| **Published in** | International Journal of Interactive Learning Research, 22(2), 2011, AACE. |
| **Authors' contributions** | Mikhail Fominykh and Ekaterina Prasolova-Førland conducted the study and wrote the paper. Mikhail Morozov provided feedback throughout the writing process and participated in conducting the study. Alexey Gerasimov led the development of the environment, participated in conducting the study and data analysis. |
| **Description** | In this paper, we propose and discuss the concept of a virtual campus integrated into a virtual city. The concept is built based on the results of the empirical study and earlier elaborated concepts of virtual campus and virtual city. The paper presents a set of the principal guidelines for designing a virtual campus in the context of a virtual city. |
| **Contribution** | The paper contributes towards C4: Guidelines for designing virtual campuses and educational virtual cities. In addition, it makes minor contributions to C6: 'Universcity' framework. |
| **Relation to research questions** | The paper answers research question RQ2b: How to design environments of a virtual campus and a virtual city? |

### 4.1.3 Paper 3

| | |
|---|---|
| **Authors** | Ekaterina Prasolova-Førland, Mikhail Fominykh and Theodor G. Wyeld |
| **Title** | Virtual Campus of NTNU as a place for 3D Educational Visualizations |
| **Published in** | Global Conference on Learning and Technology, 2010, AACE. |
| **Authors' contributions** | Ekaterina Prasolova-Førland and Mikhail Fominykh conducted the study and wrote the paper. Theodor G. Wyeld provided feedback throughout the writhing process and participated in conducting the study. |
| **Description** | In this paper, we present an empirical study on collaborative visualizations that were conducted in the Virtual Campus of NTNU. The results are discussed in light of how to develop and improve the campus. This includes in particular the design of Creative Virtual Workshop – a framework that supports creating, demonstrating, storing, and retrieving of 3D constructions. |
| **Contribution** | The paper contributes towards C3: Creative Virtual Workshop framework. In addition, it makes a minor contribution to C2: Methodology for learning with educational visualizations in 3D CVEs. |
| **Relation to research questions** | The paper partly answers research question RQ2a: How to design tools for a virtual campus and a virtual city? |

### 4.1.4 Paper 4

| | |
|---|---|
| **Authors** | Ekaterina Prasolova-Førland, Mikhail Fominykh and Theodor G. Wyeld |
| **Title:** | Working on Educational Content in 3D Collaborative Virtual Environments: Challenges and Implications |
| **Published in** | International Conference on Computers and Advanced Technologies in Education, 2010, ACTA Press. |
| **Authors' contributions** | Ekaterina Prasolova-Førland and Mikhail Fominykh conducted the study and wrote the paper. Theodor G. Wyeld provided feedback throughout the writing process and participated in conducting some of the earlier studies observed in the paper. |
| **Description** | In this paper, we focused on collaborative construction of educational visualizations and elaboration of 3D educational content, analysing results from a number of earlier case studies. We discussed various aspects of presenting educational content in a 3D environment, various design solutions adopted by students in their constructions, and the challenges they faced. We outlined the implications for working on 3D educational content and visualizations, providing some recommendations for educators. |
| **Contribution** | The paper contributes towards C1: Typology of 3D Content and Visualization Means. |
| **Relation to research questions** | The paper partly answers research question RQ1a: How to characterise 3D content and educational visualizations in CVEs? |

### 4.1.5 Paper 5

| | |
|---|---|
| **Authors** | Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov, Alexey Gerasimov, Francesco Bellotti, Alessandro De Gloria, Riccardo Berta and Rosario Cardona |
| **Title** | Universcity: Towards a Holistic Approach to Educational Virtual City Design |
| **Published in** | International Conference on Virtual Systems and Multimedia, 2010, IEEE CS Press. |
| **Authors' contributions** | Mikhail Fominykh developed presented framework and wrote the paper with Ekaterina Prasolova-Førland. Francesco Bellotti and Mikhail Morozov provided feedback throughout the writing process. All the authors participated in projects which the study is based on. |
| **Description** | In this paper, we propose a holistic approach to the educational virtual city design. The concept of 'Universcity' is a general framework with hierarchical and multilayer structure that can be used for designing virtual cities, most relevant for research- or/and education-intensive cities. The presented approach was developed based on related work and the experience in two projects: VCYO and TIE. |
| **Contribution** | The paper contributes towards C6: 'Universcity' framework. In addition, it makes a minor contribution to C4: Guidelines for designing virtual campuses and educational virtual cities and C5: Virtual Research Arena framework. |
| **Relation to research questions** | The paper answers research question RQ3b: How to support learning communities in an educational virtual city? |

### 4.1.6 Paper 6

| | |
|---|---|
| **Authors** | Mikhail Fominykh and Ekaterina Prasolova-Førland |
| **Title** | Virtual Research Arena: Presenting Research in 3D Virtual Environments |
| **Published in** | Global Conference on Learning and Technology, 2011, AACE. |
| **Authors' contributions** | Mikhail Fominykh developed presented framework and wrote the paper. Ekaterina Prasolova-Førland provided feedback throughout the writing process. Both authors conducted the study. |
| **Description** | In this paper, we present Virtual Research Arena – a framework for creating awareness about educational and research activities, promoting cross-fertilization between different environments, and engaging the general public. We describe the settings and the results of the studies conducted to evaluate the framework idea. The results show that the arena connects research community to the general public and contributes to the university promotion. |
| **Contribution** | The paper contributes towards C5: Virtual Research Arena framework. In addition, it makes a minor contribution to C3: Creative Virtual Workshop framework. |
| **Relation to research questions** | The paper answers research question RQ3a: How to support learning communities by means of collaborative work on 3D content? |

### 4.1.7 Paper 7

| | |
|---|---|
| **Authors** | Mikhail Fominykh and Ekaterina Prasolova-Førland |
| **Title** | Educational Visualizations in 3D Collaborative Virtual Environments: a Methodology |
| **Published in** | International Journal on Interactive Technology and Smart Education, 9(1), 2012, Emerald, in press. |
| **Authors' contributions** | Mikhail Fominykh wrote the paper. Ekaterina Prasolova-Førland provided feedback throughout the writing process. Both authors conducted the study. |
| **Description** | In this paper, we introduce the methodology for learning with educational visualizations in 3D CVEs. In addition, we present an improved version of the Typology of 3D Content and Visualization Means – a characterisation framework which can be used for analysing educational visualizations in 3D CVEs. The main contributions of the paper are based on the results of the exploratory case studies conducted as part of this research work. |
| **Contribution** | The paper contributes towards C2: Methodology for learning with educational visualizations in 3D CVEs. In addition, it makes a minor contribution to C1: Typology of 3D Content and Visualization Means. |
| **Relation to research questions** | The paper answers research question RQ1b: How to facilitate learning by means of educational visualizations in 3D CVEs? |

### 4.1.8 Paper 8

| | |
|---|---|
| **Authors** | Leif Martin Hokstad, Ekaterina Prasolova-Førland and Mikhail Fominykh |
| **Title** | Collaborative Virtual Environments for Reflective Community Building at Work: the Case of TARGET |
| **Published in** | Sean Goggins and Isa Jahnke (Eds.): CSCL at work, 2012, Springer, in press. |
| **Authors' contributions** | All authors wrote the paper. Mikhail Fominykh and Ekaterina Prasolova-Førland conducted the empirical study. Leif Martin Hokstad and Ekaterina Prasolova-Førland participated in the project the results of the study are applied for. |
| **Description** | In this paper, we discuss community-building techniques in CVEs based on the TARGET summer school example. The summer school was held in conjunction with the Cooperation Technology course at NTNU within one of the empirical studies conducted in this research work. The results of the study were analysed to complement the TARGET community, seeding methodology as well as to provide implications for the use of 3D CVEs for community building. |
| **Contribution** | The paper contributes towards C5: Virtual Research Arena framework. |
| **Relation to research questions** | The paper partly answers research question RQ3a: How to support learning communities by means of collaborative work on 3D content? |

### 4.1.9 Paper 9

| | |
|---|---|
| **Authors** | Mikhail Fominykh, Ekaterina Prasolova-Førland and Monica Divitini |
| **Title** | Constructing a 3D Collaborative Virtual Environment for Creativity Support |
| **Published in** | World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education, 2011, AACE. |
| **Authors' contributions** | All authors conducted the study and wrote the paper. Mikhail Fominykh led the development of the environment. |
| **Description** | In this paper, we present requirements and design for a 3D CVE that is used in CoCreat project. We propose a set of requirements and a design for a 3D CVE that supports creative collaboration among university students. This 3D environment is to be used in the university course "Designing Technology-Enhanced Learning" for developing creative solutions for informal and formal learning in virtual places and involving students from different European countries and partner organizations participating in the CoCreat project. In addition, we outline a general methodology for facilitating collaborative creative activities in 3D CVEs. |
| **Contribution** | The paper contributes towards C4: Guidelines for designing virtual campuses and educational virtual cities. In addition, it makes a minor contribution to C2: Methodology for learning with educational visualizations in 3D CVEs. |
| **Relation to research questions** | The paper partly answers research question RQ2b: How to design environments of a virtual campus and a virtual city? |

## 4.2 Secondary papers

Papers P10–P16 were published as part of the research work presented in the thesis but not included to the primary papers for various reasons. Papers P12, P13, and P16 are not included since extended versions of them were published in journals as papers P1, P2, and P7 correspondingly. Papers P10, P11, P14, and P15 are not included either since they do not report on research results that answer any of the research questions or overlap with other papers.

**P10:** Mikhail Fominykh, Ekaterina Prasolova-Førland and Mikhail Morozov: "From 3D virtual museum to 3D collaborative virtual workshop," in *the 8th International Conference on Advanced Learning Technologies (ICALT)*, Santander, Spain, 1–5 July, 2008, IEEE, ISBN 978-0-7695-3167-0, pp. 443–445.

In this paper, a framework for collaborative work with 3D content called Creative Virtual Workshop is proposed. Major topics that are discussed in the thesis are outlined in the paper. These include the use of CVEs for education, socialization, cultural development, and entertainment.

**P11:** Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov: "Virtual Campus as a Framework for Educational and Social Activities," in *the 11th International Conference on Computers and Advanced Technologies in Education (CATE)*, Crete, Greece, September 29–October 1, 2008, ACTA Press, ISBN 978-0-88986-767-3, pp. 32–37.

The paper outlines an initial set of requirements for a virtual campus based on the previous studies conducted at NTNU and a literature study.

**P12:** Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov: "Virtual City as a Place for Educational and Social Activities: a Case Study," in *the 4th International Conference on Interactive Mobile and Computer Aided Learning (IMCL)*, Amman, Jordan, April 21–24, 2009, ISBN 978-3-89958-479-0, pp. 342–345.

This paper describes the case study conducted as part of this research work using VCYO. Initial guidelines for designing an educational virtual city are presented based on the results of the study. An extended version of this paper is published as P1.

**P13:** Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov: "Virtual Campus in the Context of an educational Virtual City: a Case Study," in *the 21th International conference on Educational Multimedia, Hypermedia & Telecommunications (Ed-Media)*, Honolulu, Hawaii, June 22–26, 2009, AACE, ISBN 1-880094-73-8, pp. 559–568.

This paper discusses the results of the case study conducted as part of this research work using VCYO. The idea of integrating a virtual campus into a virtual city context is proposed. In addition, an initial set of the guidelines for designing a virtual campus in the context of a virtual city is presented. An extended version of this paper is published as P2.

**P14:** Mikhail Fominykh: "Learning in Technology-Rich Environments: Second Life vs. Moodle," in *the 9th International Conference on Web-based Education (WBE)*, Sharm El Sheikh, Egypt, March 15–17, 2010, ACTA Press, ISBN: 978-0-88986-829-8, pp. 266–273.

This paper provides an overview of the topic "Learning in Technology-Rich Environment". Two platforms, Second Life and Moodle, are compared in terms of their educational use.

**P15:** Ekaterina Prasolova-Førland, Theodor G. Wyeld and Mikhail Fominykh: "Virtual Campus of NTNU as an Arena for Educational Activities," in *the 9th International Conference on Web-based Education (WBE)*, Sharm El Sheikh, Egypt, March 15–17, 2010, ACTA Press, ISBN: 978-0-88986-829-8, pp. 244–251.

This paper presents our initial findings on collaborative work with 3D content in a virtual campus. The discussion is based on the results of the exploratory study conducted as part of this research work in 2009.

**P16:** Mikhail Fominykh and Ekaterina Prasolova-Førland: "Collaborative Work on 3D Content in Virtual Environments: Methodology and Recommendations," in *the 5th International Conference e-Learning (EL)*, Rome, Italy, July 20–23, 2011, IADIS press, ISBN: 978-972-8939-38-0, pp. 227–234.

In this paper, a set of recommendations for organizing collaborative work with 3D content is presented. Besides that, an approach to describing and analysing educational visualizations is introduced. The discussion is based on the results of two exploratory studies conducted as part of this research work in 2009 and 2010. An extended version of this paper is published as P7.

## 4.3 Relations between papers and research topics

Figure 6 provides an overview of the relations between the papers and their belonging to one of the three major research topics of the thesis. An arrow from one paper towards another indicates that the latter was influenced by the former. A dotted arrow from one paper to another signifies that the latter is an extended version of the former. This division is conditional in some cases. For example, papers P1, P2, and P9 make minor contributions towards the learning communities support. Papers P3 and P9 make minor contributions towards collaborative work on 3D content. Finally, papers P5 and P6 make minor contributions towards designing tools and environments.

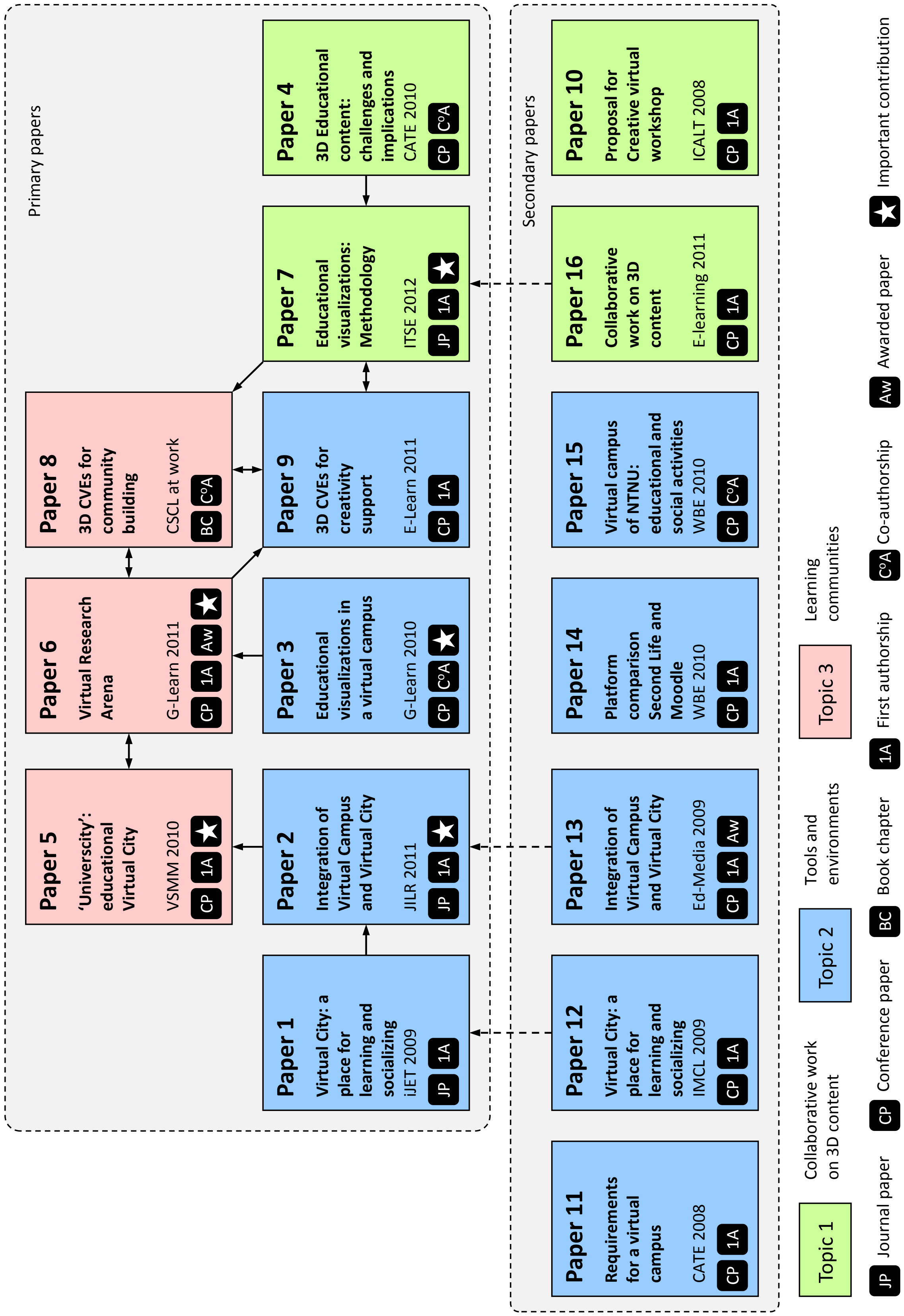


Figure 6: Relations between papers and research topics

# 5 Evaluation

This chapter provides an overall discussion and evaluation of the results. The answers to the main research question and all sub-questions are presented. Contributions to the research work are evaluated against the challenges and theoretical propositions formulated based on the background. In addition, validity threats are discussed in the chapter.

## 5.1 Evaluation of research questions and contributions

The main research goal of the thesis was to explore collaborative work on 3D content including its use in educational context, design of tools and environments, and support of communities.

The goal was reached by answering the main research question, which was formulated as follows:

**MRQ:** How to provide learning communities with an adequate support for collaborative work on 3D educational content in a virtual campus and virtual city context?

Learning communities can be provided with the support for collaborative work on 3D content by means of tools and environments properly designed and by the following elaborated methodologies. Collaborative work on 3D content, in its turn, is a means for developing educational environments and supporting learning communities.

The main question was decomposed into three topics with two sub-questions in each. The answers are provided with the six contributions presented below.

### 5.1.1 Typology of 3D Content and Visualization Means

The corresponding research question RQ1a was formulated as follows:

**RQ1a:** How to characterise 3D content and educational visualizations in CVEs?

The question was answered by developing the Typology of 3D Content and Visualization Means. The typology was developed based on the results of three exploratory studies conducted within this PhD work in the virtual campus of NTNU. Other relevant studies previously conducted at NTNU were used to a minor degree.

In the second and third empirical studies on educational visualizations, the typology was successfully used for analysing constructions, structuring feedback and peer- and self-evaluations. The Typology of 3D Content and Visualization Means can be considered as a contribution to Topic 1 of this thesis – Collaborative work on 3D educational content as the framework is based on empirical data and, to my knowledge, there were no other frameworks, developed for educational visualizations specifically. It meets one of the challenges formulated on the basis of the background that there is a need for learning approaches and methods that exploit advantages of 3D CVEs and overcome limitations.

The corresponding theoretical proposition was formulated as follows:

**TP1:** Educational activities can benefit from using collaborative work on 3D content as a teaching method in a university course.

The Typology of 3D Content and Visualization Means partly proves the theoretical proposition by the results of three empirical studies on educational visualizations where it was applied. The results indicated that educational visualizations in fact benefit from the structuring and organization provided by the framework.

This contribution is most thoroughly presented in Paper 7 of this thesis.

### 5.1.2 Methodology for learning with educational visualizations in 3D CVEs

The corresponding research question was formulated as follows:

**RQ1b:** How to facilitate learning by means of educational visualizations in 3D CVEs?

The question was answered by developing the methodology for learning with educational visualizations in 3D CVEs. This approach was developed based on the results of three exploratory studies conducted within this PhD work in the virtual campus of NTNU.

In the second and third empirical studies on educational visualizations, the principles, which later became the methodology, were evaluated. The methodology for learning with educational visualizations in 3D CVEs can be considered as a contribution to Topic 1 of this thesis – Collaborative work on 3D educational content, as it helps to fill the gap in practical guidelines for the advanced use of 3D CVEs. It answers one of the challenges drawn from the background that there is a need for learning approaches and methods that exploit advantages of 3D CVEs and overcome limitations.

The corresponding theoretical proposition was formulated as follows:

**TP1:** Educational activities can benefit from using collaborative work on 3D content as a teaching method in a university course.

The methodology partly proves the theoretical proposition by the results of three empirical studies on educational visualizations where it was applied. The results indicated that educational visualizations in fact benefit from the elaborated phases of the methodology.

This contribution is most thoroughly presented in Paper 7 of this thesis.

### 5.1.3 Creative Virtual Workshop framework

The corresponding research question was formulated as follows:

**RQ2a:** How to design tools for a virtual campus and a virtual city?

The question was answered by developing the framework Creative Virtual Workshop (CVW). The first version of this framework was described in the research proposal for this PhD work. It had been improved based on the results of three exploratory studies conducted in the virtual campus of NTNU. A CVW prototype was developed and further elaborated based on the results of each study.

The framework Creative Virtual Workshop can be considered as a contribution to Topic 2 of this thesis – Design of tools and environments within 3D CVEs. CVW is developed based on empirical data, describes the design of tools required for collaborative work on 3D content, and therefore helps to fill the gap in required functionality of educational CVEs. The framework rises to one of the challenges derived from the background that there is a need for convenient educational tools and environments that would support educational activities in 3D CVEs.

The corresponding theoretical proposition was formulated as follows:

**TP2:** Tools and environments in educational CVEs should be designed so that they facilitate collaborative work on 3D content and support learning communities.

The CVW framework partly proves the theoretical proposition by the results of three empirical studies on educational visualizations where it was applied. The results indicated that collaborative work on 3D content in fact required specific tools.

This contribution is most thoroughly presented in Paper 3 of this thesis.

### 5.1.4 Guidelines for designing virtual campuses and educational virtual cities

The corresponding research question was formulated as follows:

**RQ2b:** How to design environments of a virtual campus and a virtual city?

The question was answered by developing the guidelines for designing virtual campuses and educational virtual cities. The guidelines are developed based on the results of the exploratory study conducted in the VCYO and the first two exploratory studies on educational visualizations.

The Guidelines for designing virtual campuses and educational virtual cities can be considered as a contribution to Topic 2 of this thesis – Design of tools and environments within 3D CVEs. The guidelines are based on empirical data and help to fill the gap in the design of educational environments in 3D CVEs. In addition, an original idea of integration a virtual campus into a virtual city is suggested in the research work presented in this thesis. The guidelines meet one of the challenges received through the background analysis that there is a need for convenient educational tools and environments that would support educational activities in 3D CVEs.

The corresponding theoretical proposition was formulated as follows:

**TP2:** Tools and environments in educational CVEs should be designed so that they facilitate collaborative work on 3D content and support learning communities.

Suggested guidelines partly prove the theoretical proposition as they were developed based on the results of empirical studies, in which user feedback indicated that collaborative work on 3D content and other activities in CVEs in fact required specially designed environments.

This contribution is most thoroughly presented in Paper 2 of this thesis.

### 5.1.5 Virtual Research Arena framework

The corresponding research question was formulated as follows:

**RQ3a:** How to support learning communities by means of collaborative work on 3D content?

The question was answered by developing the Virtual Research Arena framework (VRA). This framework was developed based on the results of the second empirical study on educational visualizations and experience of participating in the Norwegian Science Week festival.

The Virtual Research Arena framework can be considered as a contribution to Topic 3 of this thesis – Support for learning communities in 3D CVEs as it helps to fill the gap in connecting learning communities by means of collaborative work on 3D content. The novelty of the framework is in seeing a virtual environment as an arena for meeting and cooperation among members of different Communities of Interest. It answers one of the challenges extracted from the background that there is a need for exploring how 3D CVEs can support learning communities.

The corresponding theoretical proposition was formulated as follows:

**TP3:** Learning communities in 3D CVEs can be supported by means of collaborative work on 3D content in a specially designed environment.

The VRA framework partly proves the theoretical proposition by the results of the second empirical study on educational visualizations in which it was applied and where learning communities were supported by means of collaborative work on 3D content.

This contribution is most thoroughly presented in Paper 6 of this thesis.

### 5.1.6 'Universcity' framework

The corresponding research question was formulated as follows:

**RQ3b:** How to support learning communities in an educational virtual city?

The question was answered by developing the 'Universcity' framework. This framework is a result of a theoretical study conducted within this PhD work though it was inspired by the empirical studies and R&D projects. 'Universcity' incorporates earlier developed frameworks of virtual campus, virtual city, CVW, and VRA.

The 'Universcity' framework can be considered as a contribution to Topic 3 of this thesis – Support for learning communities in 3D CVEs as it helps to fill the gap in the design of 3D CVEs for support of learning communities. In addition, it provides an original holistic approach to a virtual city design. The framework meets one of the challenges formulated based on the background that there is a need for exploring how 3D CVEs can support learning communities.

The corresponding theoretical proposition was formulated as follows:

**TP3:** Learning communities in 3D CVEs can be supported by means of collaborative work on 3D content in a specially designed environment.

The 'Universcity' framework partly proves the theoretical proposition by suggesting a design of an educational virtual city that supports learning communities.

This contribution is most thoroughly presented in Paper 5 of this thesis.

## 5.2 Validity discussion

The research approach taken in this research work has a number of limitations. Validity threats to the four case studies conducted within this research work are discussed together in this section, as they had similar design.

### 5.2.1 Construct Validity

This type of validity deals with establishing correct operational measures for the concepts being studied.

In the research work presented in this thesis, the quality of support that collaborative work on 3D content provided for educational activities was measured. The measures used included individual perception of the participating students and, in some cases, external visitors collected in the form of pre- and post-questionnaires as well as individual and group essays or blogs. Yet the measures varied within three major topics that were studied.

In addition, within Topic 1, the measures included the quality of the resultant constructions in each study (analysed using the Typology of 3D Content and Visualization Means) and the overall level of organization of the educational process (analysed by comparing the results and feedback on different phases within conducted studies). As part of Topic 2, some additional measures were the feedback on prototype proposals and different stages of their implementation. In relation to Topic 3, among measures were the feedback collected during the demonstration of the Virtual Science Fair on the real life event of the Norwegian Science Week festival.

Overall, the subjective perception of the participants can be seen as the main threat to the construct validity. However, as multiple sources of evidence were used, the construct validity of the results received in the presented research can be considered satisfactory.

### 5.2.2 Internal Validity

This type of validity deals with establishing causal relationships between observed phenomena or making inferences based on collected data.

In the context of the research presented, there was no possibility to have control over most of the variables of the observed phenomena. However, the chosen research strategy allowed studying collaborative work on 3D content together with its context and making certain inferences based on the empirically collected data. The main threat to the inferences made is the limited analysis of all the rival explanations of the studied phenomena, which is typical of the case study method.

Most of the inferences in the presented research are made based on such grounding as multiple sources of evidence, comparison of the same type of data collected from similarly designed case studies or comparison of the feedback on prototype proposals and different stages of their implementation. The data were extracted from a number of sources, including direct observation, digital artefacts created by the participants and recorded interaction, reflection and feedback.

Overall, the generally low level of internal validity in case studies should be considered, and the internal validity of the results received in the presented research can be considered satisfactory.

### 5.2.3 External Validity

This type of validity deals with establishing a domain in which the findings of the research are generalizable.

In the context of the presented research, there was no possibility to draw a representative sample of the population on which the results could be generalized. However, the chosen research strategy allowed making generalizations based on the proximal similarity of cases.

Although in the presented research work, the empirical studies were conducted using only two technological platforms (VCYO and Second Life) and some secondary data form one more (Active Worlds), most of the inferences made are platform-independent and consider only basic affordances of 3D CVEs. Therefore, the results can be generalized to the similar technological platforms that have the same basic affordances.

Another generalization can be made for the context. Although in the presented research work, the empirical studies were conducted within one university course, in each of the studies some of the data were collected outside of this course. In some cases, additional data were collected from students taking other university courses, in some other cases – from other users of the platform or from the invited international visitors, including students, researchers, and the general public.

In addition, the two latest empirical studies were conducted in conjunction with the events that extended their context. Virtual Science Fair extends the context of the presented research into the area of presenting research results to the general public and connecting communities. Two virtual summer schools were used for evaluating ideas and concepts within the TARGET project and therefore extend the context of the presented research into the area of corporate learning. The latest empirical study on educational visualizations acted as a pre-study for CoCreate project, extending the context of this research into the area of creativity support.

In order to make a conclusion, the results of the research work presented in this thesis can be generalized to other proximally similar cases, as it was discussed above.

# 6 Conclusions and Future Work

This chapter summarizes the major implications of the conducted research, presents a summary of contributions, and outlines the directions for future work.

## 6.1 Major conclusions

The main goal of this research was partly achieved as the scope was narrowed down over time and specific research questions were set and answered. In consequence of the multidisciplinary nature of this research, many additional topics and parts of the context needed to be considered. Dealing with a multidisciplinary challenge, presented work provides a holistic approach that combines technological guidelines and social insights. The chosen approach provided necessary flexibility for adapting to the current constantly changing settings of the research work presented in this thesis.

The results of the presented research work can be used by teachers, researchers, instructors, and technicians as a guideline for organizing educational activities using collaborative work with 3D content in CVEs.

## 6.2 Summary of contributions

Collaborative work on 3D content is the major activity that was studied in this research work. Two of the contributions (C1 and C2) describe the way of applying it in educational settings.

**C1:** Typology of 3D Content and Visualization Means

This framework is empirically based and suggests a way for describing, analyzing, and evaluating educational visualizations in 3D CVEs. It was observed that the use of the framework benefits the organization and management of the studied educational activities. In addition, it helps students by identifying advantages and limitations of the 3D CVE technology and applying this knowledge in their project work.

**C2:** Methodology for learning with educational visualizations in 3D CVEs

This methodology is empirically based and suggests a way for conducting educational visualizations in 3D CVEs. The methodology was constantly evaluated in practical settings and then improved. It was observed how important certain phases are for the goals set, how much time they usually take, what virtual places and tools are required, and what assistance students need. Thus, the methodology benefits structuring and planning of the educational activity.

Tools and environments are the major aspects of the 3D CVE technology that were studied in this research work. The next two contributions (C3 and C4) provide practical guidelines for their design. Tools and environments were seen, in the first place, as a means for facilitating collaborative work on 3D content, but also for supporting learning communities.

**C3:** Creative Virtual Workshop framework (CVW)

This framework is empirically based and suggests a way of designing tools for supporting collaborative work on 3D content in CVEs. A prototype was developed based on this framework and tested in practical settings, which allowed evaluating and improving the framework. The original combination of the functions suggested by the framework supports creating, editing, storing, and exhibiting 3D content. As a result, the tools developed based on the CVW framework facilitate educational activities and benefit the learning community.

**C4:** Guidelines for designing virtual campuses and educational virtual cities

These guidelines are based on the data from both theoretical and empirical studies. They provide practical information on the design of educational environments based on the metaphors of campus and city. Most of the suggested functions and design features were evaluated in practical settings or based on the feedback from users. They contribute to the organization of the environments for particular educational activities, creation of an appropriate atmosphere, selecting necessary tools, and exhibiting suitable content.

Supporting learning communities was studied in this research work as a high level effect achieved by conducting educational activities and designing tools and environments within 3D CVEs. The last two contributions (C5 and C6) describe how this can be done.

**C5:** Virtual Research Arena framework (VRA)

This framework is based on the data from both theoretical and empirical studies. It describes how education and research communities can be supported and connected to the general public in a 3D CVE. A prototype was developed based on this framework and tested in practical settings. This allowed evaluating and improving the framework. The feedback confirmed the potential of the framework for supporting learning communities. In addition, the VRA framework connects the other two frameworks that were developed in this research work. The tools of the VRA are designed based on the CVW framework and, at the same time, it was developed as an element of 'Universcity'.

**C6:** 'Universcity' framework

This framework is based on the data from theoretical and empirical studies as well as R&D projects. A holistic approach to a virtual city design is applied to describe how different aspects of city life, such as culture, society, research and education, and entertainment can be integrated. This framework integrates all other frameworks that were developed in this research work. Virtual city serves as the general design idea, virtual campus and VRA as infrastructure elements, and CVW as a pattern for creating infrastructure elements and designing their tools. There were no prototypes developed based on the 'Universcity' framework, however, the data gathered from studying its infrastructure elements are considered an empirical grounding.

## 6.3 Future Work

The research work presented in this thesis will be continued in several directions. One of the most probable of them is continuing the general exploration of the use of 3D CVEs in educational settings. It will be useful to extend the findings of this research work by conducting studies comparing the use of 3D CVEs with other technologies as well as comparing different CVE platforms. Another valuable extension of the presented research will be conducting studies involving NTNU students from courses other than Cooperation Technology and, possibly, from other universities. Future work in this direction will also benefit from applying other research methods and data collection techniques.

The second important direction for future work is further studying the design of educational tools for 3D CVEs. This direction will include exploring the integration of traditional web-based learning and teaching tools into 3D CVEs and making maximum advantage of the unique affordances of the technology. The work in this direction has already started within vAcademia project in collaboration with the Multimedia Systems Laboratory, Russia.

The third direction for future work is further studying the design of educational environments within 3D CVEs. This direction will include exploring the demands of educational simulations and serious games. The work in this direction has already started within a pilot project Cultural Awareness in Military Operations in collaboration with the Norwegian Armed Forces and the University of Oslo.

The fourth direction is further exploration of the support for learning communities in 3D CVEs. This direction might include studying new ways of using 3D CVE affordances for supporting creative communities and Communities of Interest in a cross-disciplinary and multi-cultural context. More studies can be conducted strengthening the 'Universcity' framework by implementing other infrastructure elements and testing them as it was done with the Virtual Science Fair.

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**Part II**

# Papers

# Research papers

**P1:** Fominykh, M., Prasolova-Førland, E., Morozov, M. & Gerasimov, A.: "Virtual City as a Place for Educational and Social Activities," *International Journal of Emerging Technologies in Learning, 4*(s2), 2009, Universität Kassel.

**P2:** Fominykh, M., Prasolova-Førland, E., Morozov, M. & Gerasimov, A.: "Virtual Campus in the Context of an educational Virtual City," *International Journal of Interactive Learning Research, 22*(2), 2011, AACE.

**P3:** Prasolova-Førland, E., Fominykh, M. & Wyeld, T. G.: "Virtual Campus of NTNU as a place for 3D Educational Visualizations," in *the 1st Global Conference on Learning and Technology*, 2010, AACE.

**P4:** Prasolova-Førland, E., Fominykh, M. & Wyeld, T.G.: "Working on Educational Content in 3D Collaborative Virtual Environments: Challenges and Implications," in *the 13th International Conference on Computers and Advanced Technologies in Education*, 2010, ACTA Press.

**P5:** Fominykh, M., Prasolova-Førland, E., Morozov, M. & Gerasimov, A., Bellotti, F., De Gloria, A., Berta, R. & Cardona, R.: "Universcity: Towards a Holistic Approach to Educational Virtual City Design," in *the 16th International Conference on Virtual Systems and Multimedia,* 2010, IEEE.

**P6:** Fominykh, M. & Prasolova-Førland, E.: "Virtual Research Arena: Presenting Research in 3D Virtual Environments," in *the 2nd Global Conference on Learning and Technology,* 2011, AACE.

**P7:** Fominykh, M. & Prasolova-Førland, E.: "Collaborative Work on 3D Content in Virtual Environments: a Methodology," *Interactive Technology and Smart Education*, *9*(1), 2012, Emerald, in press.

**P8:** Hokstad, L. M., Prasolova-Førland, E. & Fominykh, M.: "TARGET International Summer School: Use of 3D Collaborative Virtual Environments for Community Building," in Sean Goggins and Isa Jahnke (Ed), *CSCL at work*, 2012, Springer, in press.

**P9**: Fominykh, M., Prasolova-Førland, E. & Divitini, M.: "Constructing a 3D Collaborative Virtual Environment for Creativity Support," in *the 16th World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education*, 2011, AACE.

# Paper 1

**Authors:** Mikhail Fominykh, Ekaterina Prasolova-Førland, Mikhail Morozov and Alexey Gerasimov

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# Virtual City as a Place for Educational and Social Activities

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***Abstract*—In recent years, virtual worlds have become increasingly popular in education and social life. Using a 'city' metaphor, we are developing a 3D virtual world enriched with social and educational tools. This virtual world allows performing a number of activities, such as exploring the city, learning and communicating with its citizens, building a social network. In this paper we report the results of case studies we have performed to explore users' activities and behavior in a virtual city context. Our goal was to investigate how such a city can facilitate learning and socializing, also in a cross-cultural context. Based on the empirical results, we derive a list of recommendations for a virtual city as a place for social and educational activities.**

***Index Terms*—3D educational virtual worlds, collaborative learning, virtual city.**

## I. INTRODUCTION

During the recent years, 3D virtual worlds have become increasingly popular in educational settings. In [1] we have argued that such virtual worlds have promising potential for supporting learning communities because of their capability to provide a social arena where students and teachers can meet overcoming the barriers of the physical world. According to [2], virtual worlds offer an opportunity for people to interact in a way that conveys a sense of presence lacking in other media. Such environments can provide a social context for learning and a sense of presence, which is important for the students' emotional involvement and implies a level of engagement that might not be present otherwise. The design of educational virtual worlds is often based on the social constructivism approach [3], allowing learners to co-construct their environment and understanding together with their peers.

In this work we focus on a 'virtual city' as a place for social and educational activities. A virtual city can be defined as an environment representing a real or fictional city and supporting a range of different activities for the purposes of education, entertainment and socializing for local communities. Other possible roles of a virtual city include attracting potential tourists, visitors and students and providing them with explicit information about the city, the local educational institutions and so on. Dissemination and sharing of the user-generated content related to the city could also play an important role in this context.

'City' is a powerful metaphor that most people are familiar with. A brief exploration shows that this metaphor is used in quite a broad range of virtual worlds projects [4, 5]. In the virtual city design the quality of environment and the level of detail are often of high importance [6]. Still it is not only an issue of creating a realistic 3D model, but a place that is invested with social meaning. Therefore other questions appear: for what purposes and how virtual cities can be used [6].

The most known virtual cities are made for Geo-navigation, such as Google Earth (http://earth.google.com), heritage preservation, such as Rome Reborn (http://www.romereborn.virginia.edu) and Forbidden City (http://www.beyondspaceandtime.org), others for gaming and socializing, for example Cybertown (http://www.cybertown.com) and Citypixel (http://www.citypixel.com). However, virtual worlds that represent the physical world in a very direct and realistic way, known as 'mirror worlds', do not have satisfactory support of learning and socializing [5]. Many of the experiences in these virtual worlds are reported as disconnected with those of their real-world counterparts. At the same time, social virtual worlds, such as Second Life [2], resemble only little parts of real world or even do not have anything in common with the reality.

The work in this paper reports on addressing these issues and outlines a strategy for reconnecting the virtual and the physical in a city context, considering both learning communities and realistic representation. It requires the integration of the 3D virtual worlds with social software tools as we presented earlier within the concept of Collaborative Virtual Workshop [7]. In general, while virtual worlds focus on collaboration among people that are geographically distributed, the metaphor of 'virtual city' brings local issues back into the distributed virtual environment, recognizing the critical role of place and local communities in learning. This not only supports interactions with "others around the world, but also – and, perhaps more importantly, with people nearby" [8]. The challenge therefore is to design, what Thackara calls, new geographies of learning, "configurations of space, place, and network that respect the social and collaborative nature of learning – while still exploiting the dynamic potential of networked collaboration" [9].

In the next section we present 2 empirical studies where we explore the possibilities of using a virtual city for supporting learning communities. Based on the results of these studies, we provide a set of guidelines for designing a virtual city as a place for social and educational activities.

## II. VIRTUAL CITY AS A PLACE FOR EDUCATIONAL AND SOCIAL ACTIVITIES

To identify the expectations that learners have of a virtual city and to investigate what functionality and content are needed for such a system, we performed 2 studies among the students of the Norwegian University of Science and Technology (NTNU). In the first one the students had a number of educational activities in the Virtual City of Yoshkar-Ola (VCYO).

### *A. System Description*

This sub-section presents a short description of the system VCYO. In reality Yoshkar-Ola is a little city in the Volga region in Russia, where MMLab (VCYO developer) is located. VCYO is a multiuser virtual environment, providing an accurate recreation of the central part of the real city with buildings (with examples of interiors), streets, yards and other elements (Fig. 1).

The model of the city contains also the main building of NTNU (Fig. 2) as a symbol of collaboration between universities and as a fun element. The system is freeware and available on the web (http://virtyola.ru/index.php?lang=english).

The system's functionality includes realistic customizable avatars with different navigational possibilities, including a big and a mini-map as well as teleportation. Users can communicate to each other by text chatting; voice chatting is under testing.

The system also supports social software functionality. A user can add comments to existing notes or photos, as well as leave own notes and pictures around the world (Fig. 1, Fig. 2). It is also possible to examine descriptions of places and buildings in the city as well as other users' notes and photos. A citizen of the virtual city can also create a social network with other users, filling the profile, adding friends to the friend list, keeping blog and commenting others' blogs. VCYO also contains some educational tools to enable live virtual lectures such as facilities for slide show, video and web.

### *B. Study Settings*

The goal of the first case study was to investigate how a 3D virtual city can support collaborative learning and socializing among students.

34 students from NTNU divided into 8 groups participated in the case study, most of them in their 4th year of study; plus a small group of Russian students. The NTNU students included both ethnical Norwegians and exchange students from other cultural backgrounds. The students were given an exercise where during the preparatory phase they were supposed to explore the virtual world of VCYO, aiming at analyzing the different design features used and discussing the usage of virtual worlds for learning and socializing. The students were also asked to make suggestions how they would have designed a virtual campus representing NTNU and a virtual city of Trondheim (where NTNU is situated) in the most appropriate way.

A central task was participation in a virtual lecture. The lecture took place in the open-air auditorium (Fig. 3) in VCYO, where several tools for learning are situated.

Lecture theatre with slide show, web browser and video screens with a pointer, as well as chat were used during the lecture. After the lecture, the students had a discussion on virtual worlds and virtual cities in educational settings.

The students also delivered essays answering a number of questions regarding their experience in the virtual city.


Figure 1. The main square in the Virtual City of Yoshkar-Ola

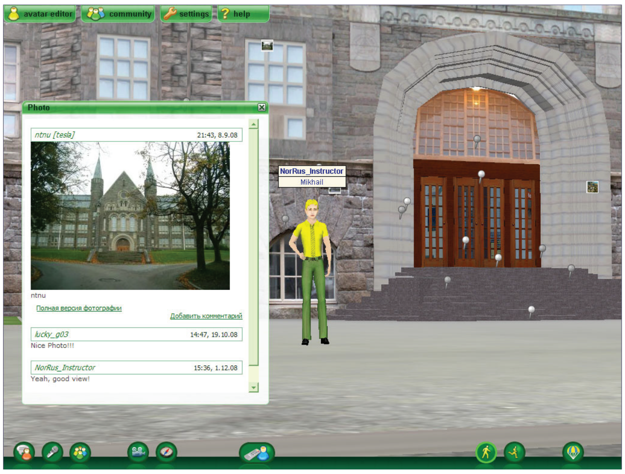


Figure 2. Photo-sharing in the Virtual City of Yoshkar-Ola


Figure 3. Virtual lecture in the open-air auditorium in the Virtual City of Yoshkar-Ola

All the data in this explorative case study was gathered from the following sources of evidence:

- direct observation of students' activities online;
- archival records (visiting statistics, chat log as well as notes, pictures and comments recording);
- users' feedback (essays and questionnaires)

We have also performed a study among students taking a different course on an advanced level who are not very familiar with virtual worlds and virtual cities. We distributed a questionnaire among these students with a short definition of a virtual city, asking them to answer the following questions:

- What virtual city would you like to visit/participate in its life?
- What tools and facilities would you need in a virtual city?
- If a virtual city of Trondheim (where NTNU is situated) will be created, would you visit it/participate in its life?

The students were asked to position their answer on a Likert scale. The questionnaire also contained questions on a virtual campus but they are outside the scope of this paper. Out of totally 48 students 26 responded, which constitutes the response rate of 54%.

## III. RESULTS AND DISCUSSION

### A. *Results from the case studies*

This sub-section presents the empirical data that was gathered during the case studies. This includes mostly how the students used communication and social software tools, path recording data and some examples, as well as their opinions on the potentials and the usage of a virtual city.

From the 34 students participating in the study, 27 communicated by chat and posted text-notes and pictures. We selected 28 discussions that students took part in from the chat-log (excluding the lecture). Most commonly in these discussions students helped each other to understand the system's functionality details and how to navigate in the virtual city, as well as shared their impressions about the VCYO (Table I). Some of the observed students also met local visitors of VCYO and had some informal conversations. In general, we observed a number of examples of 'social navigation', where the students were guided by peers (for example, how to enter buildings or to get to the lecture place) or invited friends to take a walk on the city's roofs.

Students left 135 notes in the virtual city; some of them were commented by their peers or other virtual citizens. Notes were tagged to particular places so that students from the observed group used them mostly to ask about interesting places, buildings and objects, while local virtual citizens often answered by commenting on those notes (Table II). For example, there were discussions (Table III) around the virtual gallery in VCYO replicating the one available in reality in the city of Yoshkar-Ola (Fig 4). Some of the Norwegian students expressed their interest in the exposition, wishing to learn more about Russian art.

The students from the observed group were interested in the photos of the real city posted in appropriate places in the virtual one; however, they uploaded relatively few pictures of their own. But there was one exception – the main building of NTNU that was created and placed in the outskirts of the virtual city. All of Norwegian students could easily recognize this building and some of them posted photos of it, also leaving a lot of notes discussing the building, the university and other issues (Fig. 2).

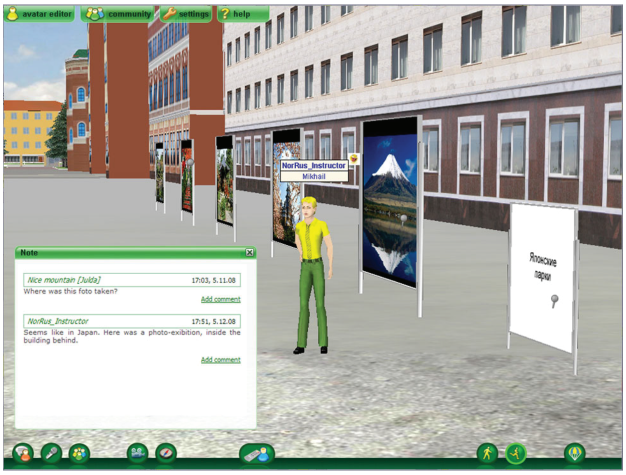


Figure 4. Example of Note with Comments in a Gallery in the Virtual City of Yoshkar-Ola

TABLE I.
CHAT LOG FRAGMENT

| | |
|---|---|
| NorRus_Inst :- | Veronica, I see you so often here... Do you like it? |
| veronica8 :- | I like it very much |
| NorRus_Inst :- | Actually this is my hometown :) I haven't been there 1 year... It is nice to see it in virtuality |
| veronica8 :- | It is a beautiful city I think |
| Vego :- | me too Im in Moscow now |
| veronica8 :- | I am often here to get familiar with it |
| NorRus_Inst :- | great |
| veronica8 :- | I have a bad feeling of direction |
| Vego :- | exactly? |
| veronica8 :- | so have to try more and remember road |
| veronica8 :- | and street |
| veronica8 :- | I always get lost in a new city |
| NorRus_Inst :- | Lets go to the roof! |
| veronica8 :- | How to? |
| Vego :- | where is it? |
| Vego :- | ok... show us how |
| NorRus_Inst :- | We are far away, use global chat, we cant hear you |
| Vego :- | Where are you? |
| NorRus_Inst :- | On the roof of the hotel, you know where |
| NorRus_Inst :- | There is a button to jump on the panel |
| Vego :- | funny bug.))) |
| Vego :- | or is this is a func? |
| NorRus_Inst :- | not a bug ))) |
| veronica8 :- | Great! |

TABLE II.
EXAMPLE OF NOTE WITH COMMENTS ON A BUILDING

| | | |
|---|---|---|
| group7_hilde :- | There is no one inside the building | |
| | hakonje :- | How do I get inside the building? |
| | lucky_g03 :- | hay man!! Just right click on the door and then click the open option. Thats it |

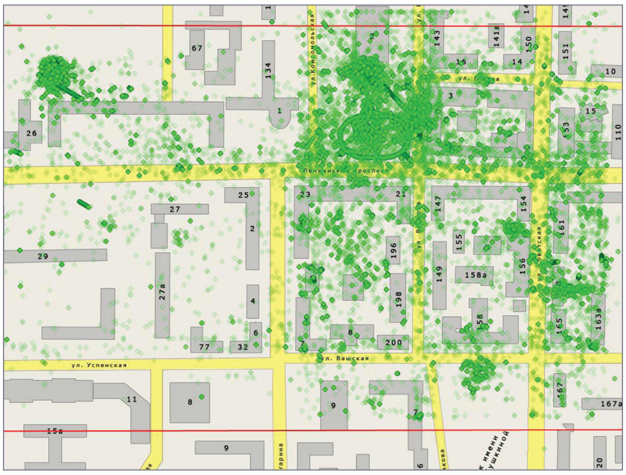

Figure 5. Visiting statistics in the VCYO during the case study (intensity of dots indicate time spent by users)

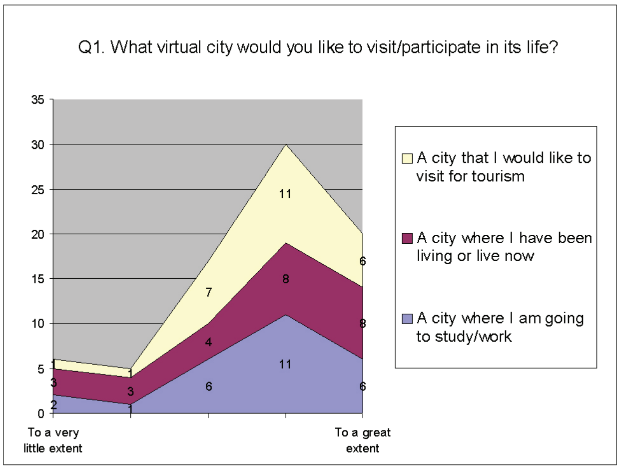


Figure 6. Results: What virtual city would you like to visit/participate in its life?

TABLE III.
EXAMPLE OF NOTE WITH COMMENTS IN A GALLERY

| | | |
|---|---|---|
| sasaciric:- | nice photo: not bad, but what is it? | |
| | Orchestra :- | these are photos from art gallery (a brick building with a tower). The current exposition... I don't remember the name... |
| | Julda :- | Which brick building you mean? and Is this from real exposition which is now available in russia? |
| | NorRus_Inst :- | The building is on the left side if you look at the picture:) I think some information notes will be tagged to every building very soon |

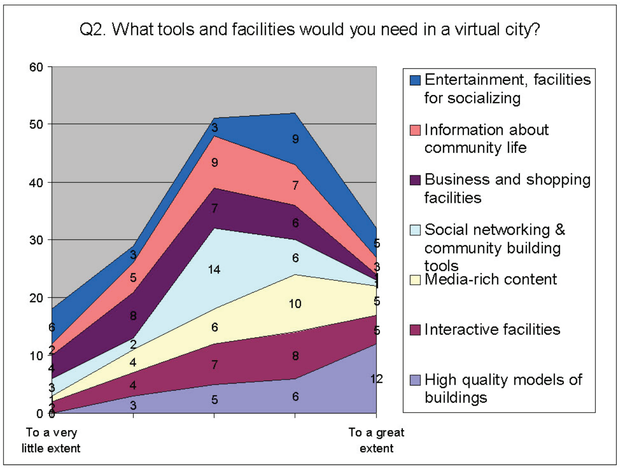


Figure 7. Results: What tools and facilities would you need in a virtual city?

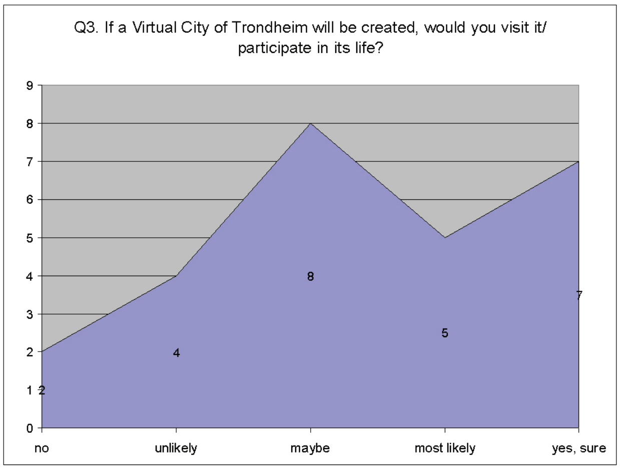


Figure 8. Results: If a virtual city of Trondheim will be created, would you visit it/participate in its life?

Concerning profiles, friend lists and personal blogs functionality, it should be said that it was used to a smaller degree, due to technical problems, relatively small size of the community and a short trial period.

We performed path recordings during the case study (Fig. 5). These data were used to analyze how much time students spent in the virtual city and what places they visited. Students used different 'movement patterns', but most of them explored the city moving towards familiar places (such as the main building of NTNU), discovering other places in the city mostly on the way there. Another discovered trend is the high attention to the fun elements such a moving train on the main square. Most of the students moved in the relative proximity of the default entry point to the system.

The results of the second study are summarized in Figs 6-8.

## B. Discussion

Based on the analysis of the results, we will now discuss how the system's existing functionalities support or limit educational and social experience in the VCYO. We will also discuss what activities and associated tools are suitable in an educational virtual city in general.

The *navigation* and exploration of the city was mostly concentrated around the default entry and a few other areas of interest such as the main square, the lecture place and the main building of NTNU as the visiting statistics (Fig. 5) and direct students' feedbacks showed. One of the reasons for that was that the students did not get sufficient information upon log-in about the different places in the city that might be interesting to visit, plus at this stage of development not all constructions had enough informational content to motivate in-depth exploration. In addition, existing avatar moving functionality (clicking on the place to move) turned out to be not efficient enough for the target audience used to playing computer games. The majority of students expressed the wish to use arrows or WASD keys. The function allowing jumping turned out to be useful to get an overview and as a 'fun' element. As an improvement a 'flying' mode was proposed, as well as a more transparent, searchable map with information about different locations. Still, the navigation patterns showed that the existing support for social navigation (by chat and leaving notes) was not fully efficient and that additional facilities are needed.

The *community network* development allowed us to analyze the efficiency and limitations of the different tools in the virtual city context. Considering the small quantity of virtual citizens in this case study, the limited time-span and some technical problems, the resulting community network (in terms of blogs and friend-lists) was moderate but satisfactory. One of the most useful tools was the one allowing to see 'who is on-line' and teleporting to any user from the list. User notes were used quite a lot, allowing students to discuss asynchronously particular places or objects and enriching the environment with user-generated content. Notes with comments often contained quite meaningful discussions and were usually attached to the places related to the discussion topic. For example, there were a lot of notes with questions about buildings and places, highlighting the need for 'tagging the buildings', explaining their purpose. The functionality allowing posting photos was mostly useful in relation to places familiar from reality, showing the importance of the connection between the real and the virtual.

The total amount of notes was less, but comparable to the amount of chat messages – the main communication tool. The findings above suggest that the notes functionality was easy to use and helpful, but most importantly, they highlight the importance of situatedness and context for community development in the virtual city. The students used the virtual city as a discussion board, connecting together the content and virtual places.

Such *virtual places* within a virtual city can play a number of different roles in an educational context. For example, the streets and squares could serve as natural meeting places, with prominent landmarks such as 'street corners' and famous buildings acting as navigation aids. The same landmarks (such as the main building of NTNU in our example) as well as designated places (libraries, campus, boards at teleportation hubs), where community members can store resources and leave their notes, announcements and comments, function as an information place set in a rich context. In our case, it allowed Norwegian students to learn about a foreign city by posting their questions on the buildings of interest and receiving answers from the locals. Here it is important to introduce mechanisms for structuring and moderating of information, as stressed by the students.

The virtual city can also function as an exhibition (Table III, Fig. 4), attracting public interest for the corresponding event in reality and allowing the community members to post comments and questions. As our experience with the virtual lecture shows, a virtual city can function as a workplace. Still this requires that corresponding facilities are in place. An important aspect here, as noted in almost all students' essays, is the 'disturbance' factor while having a lecture in an open space (a square) with other users wondering around and other visual impressions diverting attention from the lecture itself. It was suggested to keep such 'serious' educational events 'indoors' in settings close to real-life auditoriums, to create a better focus on the educational content. Such open places in the city are better suited serve as 'virtual stages' for concerts, city events and gatherings, promoting a feeling of 'togetherness' and presence among distributed users.

The *preliminary study* performed among students not very familiar with virtual environments, showed some interesting tendencies. When asked about different types of cities the students would like to visit, the answers were divided approximately evenly between the 3 categories (tourist destinations, place for study/work and home cities), with the slight prevalence for the 2 first categories (Fig. 6). This indicates the need for creation of virtual cities for different purposes. Concerning the tools and facilities, a slight preference was given to the ones enhancing user experience such a multimedia, interactivity and high-quality graphics and models. This corresponds to the feedbacks received from the students who used VCYO, as well as to earlier studies in 3D virtual environments [1]. This shows that these elements should be given a high priority when designing virtual cities for learning. Finally, the majority of the students answered that they would "maybe, most likely or for sure" engage in a virtual city of Trondheim. This supports our idea to create an educational virtual city of Trondheim closely intergraded with the virtual campus of NTNU.

### *C. Guidelines for designing an educational virtual city*

Based on the students' direct feedbacks and other empirical data, we can outline the following major guidelines for designing a virtual city as a place for learning (focusing primarily on the city of Trondheim):

The primary *purpose* of a virtual city and its *target audience* (e.g. tourists, inhabitants, students) should be kept in mind when creating an initial design. These considerations will affect the weight put on different features such as historical reconstructions and multimedia effects vs. tools for community support. At the same time, in order to create a virtual city that appeals to different user groups and supports a wide range of usage scenarios and situations, it is important to maintain a balance between different design aspects. A way of achieving such a balance might be to ensure sufficient flexibility and expandability of the virtual city so that its design can be easily changed and new features added to address changing needs of the users. Another solution is customized interfaces for different groups of users, allowing different modes of access, exploration and exploitation. For example, a tourist visiting the church of Our Lady in the virtual city of Trondheim would be primarily offered a historical overview while a local visitor would easily find a schedule of sermons and concerts to be held in the church.

The *appearance* of a virtual city should be as authentic as possible to create a familiar atmosphere, with all the major and most significant buildings and the overall city structure presented in a maximally realistic way. Still, the design of certain places for various educational activities (such as lecture halls and museums) might have a limited reality resemblance to serve the specific goals in a best possible manner.

*City atmosphere* plays an important role, according to students' feedbacks. Appropriate music and sounds, moving objects, presence of other users, real or artificial, will contribute to make the virtual world more 'alive' and appealing.

*Informational resources* should be an essential part of a virtual city as well as a set of tools for content manipulation. It was generally agreed that only models of buildings without corresponding information have a very limited value and meaning, especially for the users not familiar with the city. Therefore, there should be a strong correspondence between the constructions in the virtual city and the associated informational resources and facilities. For example, the city hall should contain information about local government; the doctors' offices should contain information about the medical services. The city should in general contain multimedia resources such as sound, pictures, video and 'enactments' with virtual agents associated with relevant important buildings and landmarks, allowing the users to learn about the city, its history and culture. There should also be a significant support for interactive elements such as adding user-generated content and educational games.

A wide array of *community resources and tools* reflecting and supporting the life of the community should be integrated in a virtual city, in a situated and contextualized manner. For example, there should be established virtual places for social activities (imaginary ones or representations of real places) such as squares, parks, art galleries, museums and clubs. Other examples include bulletin boards with announcements, blogs and virtual houses for community members, discussion forums and tools for supporting social networks with extensive possibilities for the users to share, annotate and modify the content. There should be clear connections between the community resources and the related virtual places. A basic support for commercial activities should be provided to ensure better integration of local businesses into the community.

Various *navigation facilities* should be available for users to access the content in a virtual city in the most efficient way, such as 'city tours' led by agents, and 'transportation routes' marked clearly between different places. A virtual city should also contain 'tourist offices' with information and links to the major points of interest plus searchable maps with filters where one can look for shops, local businesses and historical places. In order to support social navigation, there should be possibilities for sharing information on paths taken and places visited by other users.

*Virtual campus* in a 'student' city like Trondheim is supposed to act as a natural educational center, providing a broad range of educational resources. At the same time, such resources supporting learning and students' communities and social activities should be integrated throughout the city. Examples include virtual 'concert halls' for student festivals and history lessons in the city streets.

## IV. CONCLUSIONS AND FUTURE WORK

In this paper we discussed the concept of virtual city as a place for educational and social activities. We also presented basic results of 2 empirical case studies, where we explored different aspects of a virtual city as a place for educational and social activities. We analyzed the effectiveness of various tools supporting educational and social activities and suggested directions for their development and improvement. In addition, based on the empirical data, we derived and presented a set of the major guidelines for designing an educational virtual city.

Future research directions will include further work on the VCYO project, designing a virtual city representing Trondheim as well as the development of the theoretical framework for designing educational virtual cities.

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# Paper 2

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# Virtual Campus in the Context of an Educational Virtual City

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This paper is focused on virtual campuses, i.e. virtual worlds representing real educational institutions that are based on the metaphor of a university and provide users with different learning tools. More specifically, the idea of integrating a virtual campus into the context of a virtual city is suggested. Such a virtual city, where students live and work, can extend the possibilities of a virtual campus in supporting learning and socializing. This paper provides a description and analysis of an empirical case study that was performed to test and develop these ideas. Based on the results of the study, a set of guidelines for designing a virtual campus in a city context is presented.

In recent years, the use of 3D virtual worlds has been continuously increased, and adopting virtual worlds for educational settings is becoming more and more widespread. As it is stressed in (de Freitas, 2008), in the future all kinds of virtual worlds will offer different opportunities for learning. In (Ekaterina Prasolova-Førland & Divitini, 2003) we have argued that virtual worlds have promising potential for supporting learning communities, providing students and teachers with a place where they can perform overcoming the barriers of the physical world. According to (Kelton, 2007), virtual worlds allow people to interact in a way that conveys a sense of presence lacking in other media.

3D virtual worlds can be defined as “networked desktop virtual reality in which users move and interact in simulated 3D spaces” (Dickey, 2005). Within such environments, users are represented by avatars – 3D animated characters that allow users to convey their identity, presence, location and activities and interact with other users, agents or virtual objects. Communication possibilities are usually presented in the form of a limited choice of gestures and text-based chat tools, in some cases also a voice chat. Examples of successful 3D virtual world applications include Second Life (www.secondlife.com), Active Worlds (www.activeworlds.com), Wonderland (https://lg3d-wonderland.dev.java.net) and others.

The design of educational virtual worlds is often based on the social constructivist approach (Vygotsky, 1978), allowing learners to co-construct their environment and understanding together with their peers (Bryceson, 2007). In this way, the virtual space provides a dynamic and flexible environment where distributed learners can share information and form the environment according to their needs. Virtual worlds provide possibilities for serendipity that is usually defined as a fluke, but in fact an environment should be created to support it. As it is stressed in (Waters, 2009), a special value of virtual worlds for education is that they have more opportunities for accidental interactions than any other media.

This paper is concentrated upon one type of educational virtual worlds, *virtual campuses*. More specifically we suggest an idea of placing a virtual campus in the context of a virtual city. A virtual campus can be defined as an environment that uses the metaphor of a university and provides users with a range of different tools for learning. A growing number of universities have introduced virtual representations of themselves in the form of virtual campuses for supporting a wide range of educational activities. But we argue, referring to (Vygotsky, 1978), that socializing is of essential importance for learning and needs to be maintained. Using a city context can extend a campus not only spatially, but also add more possibilities for learning, gaming and socializing. While virtual campuses often focus on collaboration among people that are geographically distributed, the metaphor of "virtual city" brings local issues back into the distributed virtual environment, recognizing the critical role of place and local communities in learning. This not only supports interactions with "others around the world, but also – and, perhaps more importantly, with people nearby" (Rheingold, 2003).

Previously we argued that a virtual campus can benefit the learning process in many ways. In (Fominykh, Prasolova-Førland, Morozov, & Gerasimov, 2008), based on the survey and case studies made, we derived an initial set of requirements for a 3D virtual campus and presented the start-up of NTNU's campus design. We consider a virtual campus as a special *place* to perform learning activities and with a *set of tools* to benefit educational process (Clark & Maher, 2001).

A virtual city can supplement a virtual campus by providing additional arenas for their social activities, such as places for clubs, concerts, parties and so on. Moreover, a virtual city around the campus can be an additional place for dissemination and sharing of educational content, educational simulations and demonstrations, as well as a place where students, using special tools, can collaboratively create and share their own content, including 3D constructions. While virtual campuses have substantial potential in terms of attracting new students (Fominykh, et al., 2008), a virtual city is probably best suited for these purposes. It can provide an atmosphere of a real city and information in the form of different media, allowing prospective foreign students and any other users to learn about the local culture, architecture, history, etc.

In the next section an overview of existing virtual campuses and cities discussing their features and current weaknesses is presented and the concept of a virtual campus in the context of a virtual city is suggested. The third section an empirical case study that was performed to test and develop our initial ideas. Further the case study results are presented and discussed in the fourth section. As an outcome of the discussion, we propose a set of guidelines for designing a virtual campus in the city context. Finally, the fifth section concludes the paper, outlining directions for future work.

## RELATED WORK

Many different educational projects that define themselves as 'Virtual Universities' or 'Virtual Campuses' have been developed. Such projects started as online multimedia services for distance learning in the early 90s. Today providing online educational services for time and space separated users is one of the most important roles of virtual campuses. Generally, virtual campuses provide users with different sets of possibilities, ranging from web-based systems (e.g. http://vu.org/) to immersive 3D worlds. This paper primarily focuses on the latter category as well as considering 'Virtual Cities' as another type of 3D virtual worlds.

3D virtual campuses are created based on different types of platforms and technological solutions. For example, Virtual Campus of Nanyang Technological University in Singapore (Ekaterina Prasolova-Førland, Sourin, & Sourina, 2006) is based on blaxxun technology (www.blaxxun.com). This virtual campus provides a very realistic, 'photographic' resemblance of the corresponding physical campus, with offices and students' rooms. There are also different tools available there for students for getting consultations, following lectures and doing practical exercises, especially in computer graphics. There are also numerous examples of virtual representations of real educational institutions in Active Worlds, such as iUni (http://iuni.slis.indiana.edu). However, the most widely used platform at the moment is Second Life (SL), although it has certain disadvantages as a learning environment (Helmer, 2007). Over 500 universities and colleges have a presence in Second Life, a 3D virtual world opened to the public in 2003, which today is inhabited by millions of 'residents' from around the globe. Major universities already using SL include California State University, Harvard University, Ohio State University, University of Hertfordshire and University of Sussex, just to mention a few. The presence of institutions working in Second Life varies broadly, from full-scale, highly realistic campuses, less realistic 'digital interpretations' to individual classes taught in common areas. For example, Northern Illinois University is supplementing both credit and non-credit courses with Second Life classes in art, computer science, education, and communication (Kelton, 2007). In Ohio State University's virtual campus visitors can take several courses, get access to learning materials, visit art installation, music center and other places. Harvard Law School offered a course in Second Life called "CyberOne: Law in the Court of Public Opinion" (Jennings & Collins, 2008). It is common for many of virtual campuses that they attempt to create a 'familiar' atmosphere for the students. Virtual campuses often provide a clear association with the real educational institutions they represent, conveying their 'spirit' and atmosphere by different means. These means may include a realistic outlook, informational resources, possibilities to contact the representatives of the educational institutions, etc.

Virtual campuses and cities are often created within bigger virtual worlds, using their advantages, but also being restricted by their limitations. 'Social virtual worlds', such as Second Life, that are often used for virtual campuses resemble only little parts of real world or sometimes do not even have anything in common with the reality. Whereas virtual worlds that represent the physical world in a very direct and realistic way, known as 'mirror worlds', do not have satisfactory support of learning and socializing (de Freitas, 2008). Examples of mirror worlds include *virtual cities* that nowadays often have detailed and attractive models and advanced functionality. The most known virtual cities are made for Geo-navigation, such as in Google Earth (http://earth.google.com), heritage preservation, such as Rome Reborn (http://www.romereborn.virginia.edu) and Forbidden City (http://www.beyondspaceandtime.org). There also exist virtual cities that are made for gaming and socializing, for example Cybertown (http://www.cybertown.com) and Citypixel (http://www.citypixel.com). However, virtual city designers focus even less on education and training (de Freitas, 2008; Dickey, 2005; and E. Prasolova-Førland, 2005).

It is supported in (Dokonal, Martens, & Plösch, 2004), emphasizing that in the virtual city design the most important questions are probably for what purposes and how virtual cities can be used. Although the level of detail is often of high importance, it is not only an issue of creating a realistic 3D model of the city. A virtual city can not only be a space, but a place which is invested with social meaning (Harrison & Dourish, 1996). In such a way, provided functionality of a virtual campus as well as a virtual city acquire significant importance, because the system should allow users to *do* something in the environment. These may include facilities for communicating and exploring the environment, collaborative work, learning and socializing, tools for creating and sharing the content and other resources.

Based on the discussion in the Introduction and the presented literature overview, we suggest the concept of a virtual campus integrated into a virtual city. The city context can extend the possibilities of a virtual campus to support learning and socializing. At the same time, a campus can enrich a virtual city with social meaning and educational content. Together, the integration of a virtual city and a campus may connect local and distributed communities of learners. We have performed an explorative case study to identify to what extent a virtual world of a city and a campus can enhance educational process and what functionality is required. In our work we develop further a systematic approach to virtual campus design (Fominykh, et al., 2008) and consider this empirical study as a view in a broader perspective and a source of up-to-date feedback.

## CASE STUDY

The case study presented in the paper had several goals, including providing the target group of students with an experience in collaboration and improving the developed concept of a virtual campus. The main research objectives of the case study were:

- Identifying the requirements (in terms of appearance, functionality, content and so on) for an educational virtual city as well as for a virtual campus in the context of a virtual city;
- Evaluating an original 3D virtual environment, where the case study took place;
- Identifying expectations that present-day Norwegian students have of a virtual campus of their university and of a virtual city representing their home city;

The case study was conducted mostly among the students at the Norwegian University of Science and Technology (NTNU). The students performed a number of educational activities in the Virtual City of Yoshkar-Ola (VCYO).

### System Description

This section presents a short description of the Virtual City of Yoshkar-Ola (VCYO) system. In reality Yoshkar-Ola is a city in the Volga region in Russia, where Multimedia Systems Laboratory (VCYO developer) is located. VCYO is a multiuser virtual environment representing the central part of the real city in exact manner with buildings (with examples of interiors), streets, yards, trees and other elements (Fig. 1 and 2).


**Figure 1.** The main square in the Virtual City of Yoshkar-Ola

The model of the city contains also the main building of NTNU as a symbol of collaboration between universities and as a fun element (Fig. 2). The system is a Research and Development project, which is freeware and available on the web (http://virtyola.ru/index.php?lang=english).

The system's functionality includes representing users by realistic customizable avatars. A user can explore the world, moving his/her avatar by using simple interface. A big and a mini-map as well as teleportation are available to facilitate navigation in the virtual city. Users can communicate to each other by text chatting (private, local-group and global chats); voice chatting is being tested. The system also supports social software (Owen, Grant, Sayers, & Facer, 2006) functionality. It is possible to examine descriptions of places and buildings in the city, users' notes and photos in the virtual world (Fig. 2). A user can also add their own comments to existing notes or photos, to leave their own notes and put their own pictures around the world. Such user-generated content often shows users' opinions of the virtual and the corresponding real places that can be useful and interesting for other users.

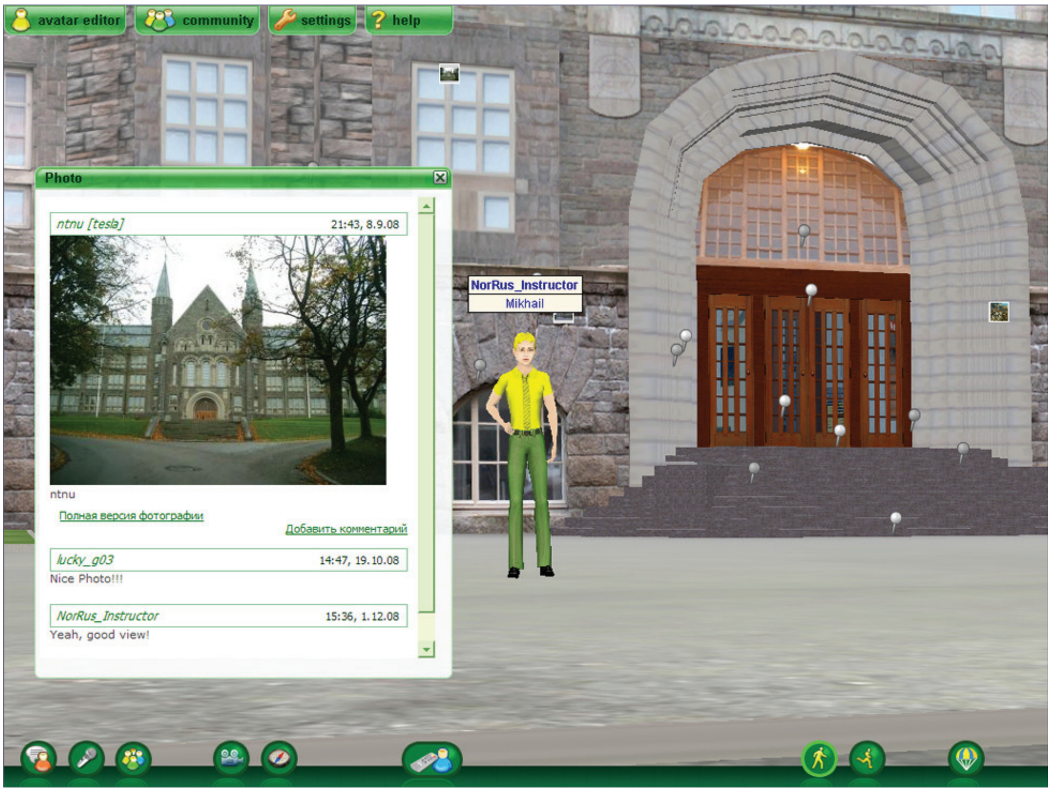


**Figure 2.** Photo-sharing in the Virtual City of Yoshkar-Ola

A citizen of the virtual city can also create a social network with other users, filling a profile, adding friends to a friend list, keeping a blog and commenting others' blogs. VCYO also contains some educational tools to enable live virtual lectures such as facilities for slide show, video and web.

## Case study settings

The research goal of the case study was investigating how a 3D virtual city can better support collaborative learning and socializing among students as well as identifying users' expectations of a virtual campus and its integration into the virtual city context. As the system used in the case study was still in a "beta" version, the feedbacks from the students were useful for identifying existing problems and suggesting improvements and new features.

34 students divided into 8 groups participated in the case study, most of them in their 4th year of study. The students included both ethnical Norwegian and exchange students from other cultural backgrounds as well as a small group of Russian students. The students were given an exercise where

during the preparatory phase they were supposed to explore a virtual world VCYO, aiming to analyze the different design features used and to discuss the usage of virtual worlds for learning and socializing. The students were also asked to make suggestions how they would have designed a virtual campus representing NTNU and a virtual city of Trondheim (the city where NTNU is situated) in the most appropriate way.

As a practical part of the exercise students first had to customize their avatars and explore the world, different places and objects in it. Next, they had to try different communication functionalities and contact other online users. Furthermore, students were supposed to explore the social network of the virtual city's community and use social software functionality to build their own social network. A central task was participation in a virtual lecture. The lecture took place in the open-air auditorium (Fig. 3) in VCYO, where several tools for learning are situated. Lecture theatre with slide show, web browser and video screens with a pointer, as well as chat were used during the lecture. The event lasted about 2 hours that included the lecture itself and the associated discussion. Due to technical problems and server overload, the originally planned lecture had to be interrupted and finished 9 days later. After the lecture, the students had a discussion on virtual worlds and virtual cities in educational settings.


**Figure 3.** Virtual lecture in the open-air auditorium in the Virtual City of Yoshkar-Ola

The students also delivered essays answering a number of questions regarding their experience in the virtual city and their opinions about the future design of NTNU's virtual campus and the virtual city of Trondheim.

All the data in this explorative case study was gathered from the following sources of evidence:

- direct observation of students' activities online
- archival records (visiting statistics, chat log as well as notes, pictures and comments recording)
- users' feedback (essays and questionnaires)

Respecting the main objectives of the case study, the data have been analyzed to define the following:

- The overall impression from VCYO, how to improve it and what functionality is missing
- How navigation tools were used in the system, how to improve them and what other tools are needed
- How social software and communication tools were used in the system and how helpful these tools were for social navigation and for building a social network
- What places in VCYO were the most sought-for, what roles they played and what other places are needed in a virtual campus/city
- What educational experience the students got and how it can be improved in any virtual campus
- How Norwegian students would design a virtual campus of NTNU and a virtual representation of their home city

Two questionnaires were conducted during the case study: one at the planning phase and another after the case study. The first questionnaire was performed before the case study among students taking a different course. Questionnaires were distributed with short descriptions of a virtual city and a virtual campus, since these students were not necessarily familiar with virtual worlds and virtual cities.

The approach has a number of limitations. First, the degree of participation of the participants varied to a certain extent, from logging on regularly, exploring almost all the environment and trying to use all the available tools to participating only in the virtual lecture. Also there have been variations in previous experience in virtual worlds the students had before they started to use VCYO. Student experience in the system was on some occasions limited by technical problems. All this might have influenced the quality and accuracy of the feedback provided in the essays.

When conducting questionnaires we were mostly interested in the overall trends. We are also aware that with the given data foundation and response rate makes it rather complicated to arrive at statistically significant results. For example, for different reasons (e.g. obtaining response from a wider student population) it was not feasible to distribute the 1st and the 2nd questionnaire to the same student group. Therefore in our analysis we generally focus on identifying the major tendencies rather than arriving at concrete conclusions.

## RESULTS AND DISCUSSION

In this section the results from the case study are summarized and discussed. Afterwards a set of guidelines for designing a virtual campus in the context of an educational virtual city is outlined.

### Results from in-world observations

This sub-section presents the empirical data that were gathered during the case study that is mostly how the students used communication and social software tools, path recording data, the results of two questionnaires as well as some examples. From the 34 students participating in the study, 27 communicated by chat and posted text-notes and pictures. 28 discussions, in which students took part, were selected in the chat-log (excluding the lecture). Most commonly during these discussions the students helped each other to understand the system's functionality details and navigate in the virtual city, shared their impressions generally about the VCYO, as well as about particular places and objects, etc. Some of the observed students also met other visitors of VCYO and had some informal conversations. In general, we observed a number of examples of 'social navigation', where the students were guided by peers (for example, how to enter buildings or to get to the lecture place) or invited friends to see some places (for example, to take a walk on the city's roofs)Students posted 135 notes in the virtual city; some of them were commented by their peers or other virtual citizens. Notes were tagged to particular places so that students from the observed group used them mostly to ask about interesting places, buildings and objects, while local virtual citizens often answered by commenting on those notes. For example, there were discussions around the virtual gallery in VCYO replicating the one available in reality in the city of Yoshkar-Ola (Fig. 4). Some of the Norwegian students expressed their interest in the exposition, wishing to learn more about Russian art.

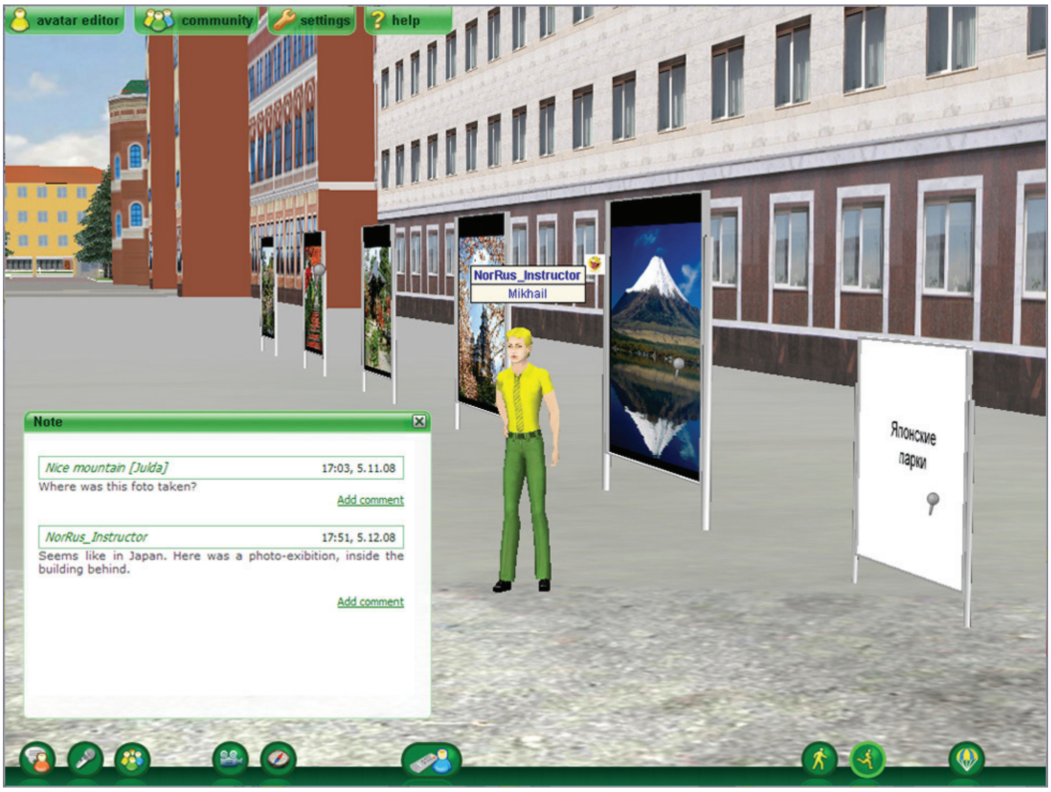


**Figure 4.** Example of note with comments in a gallery in the Virtual City of Yoshkar-Ola

The students from the observed group were interested in the photos of the real city posted in appropriate places in the virtual one; however, they uploaded relatively few pictures of their own. But there was one exception – the main building of NTNU that was created and placed in the outskirts of the VCYO. All of Norwegian students could easily recognize this building and some of them posted photos of it, also leaving a lot of notes discussing the building, the university and other issues (Fig. 2).

Concerning profiles, friend lists and personal blogs functionality, it should be said that it was used to a smaller degree, due to technical problems and the relatively small size of the community and a short trial period.

Path recording was performed during the whole case study time (Fig. 5) and during the lecture event alone (Fig. 6). These data were also used to analyze how much time students spent in the virtual city and what places they visited. Students used different 'movement patterns', but most of them spent most of time in interesting or fun places and run or teleported through other ones. In addition, the authors discovered a trend among the students to go towards known places and explore mostly the space on the way.

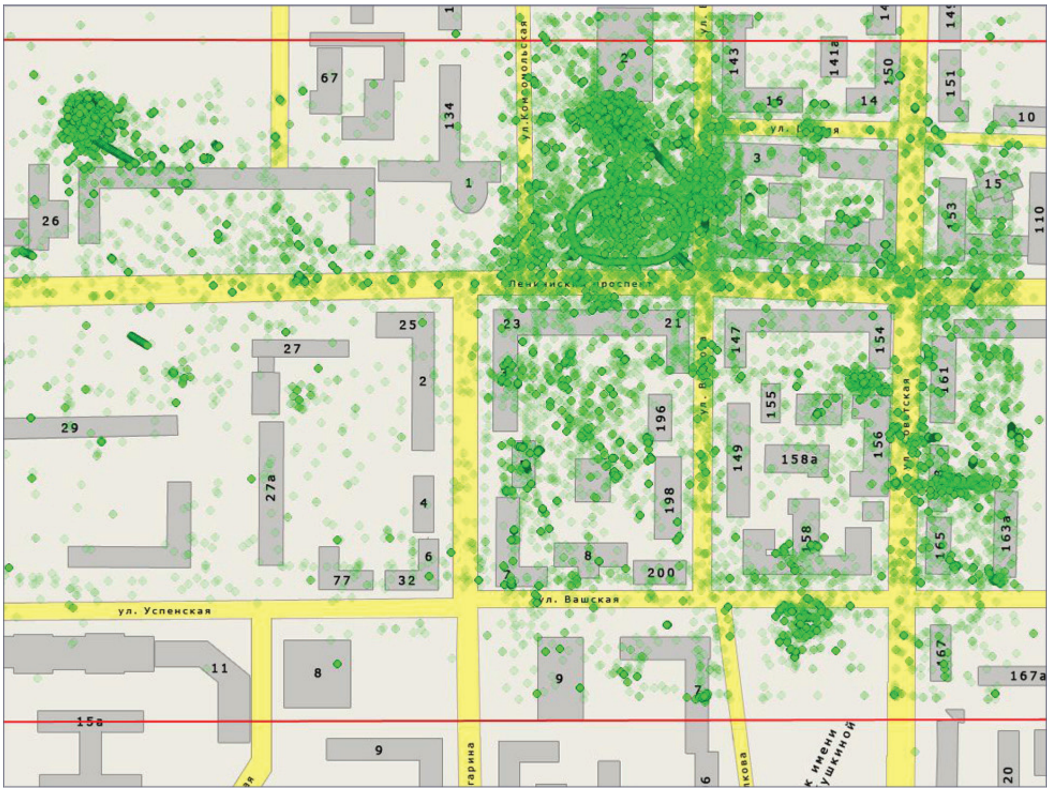


**Figure 5.** Visiting statistics in the Virtual City of Yoshkar-Ola during the case study

During the lecture in the VCYO and the associated discussion students expressed a lot of suggestions as to how to improve the system's functionality, as well as debated advantages and limitation of learning in virtual worlds.

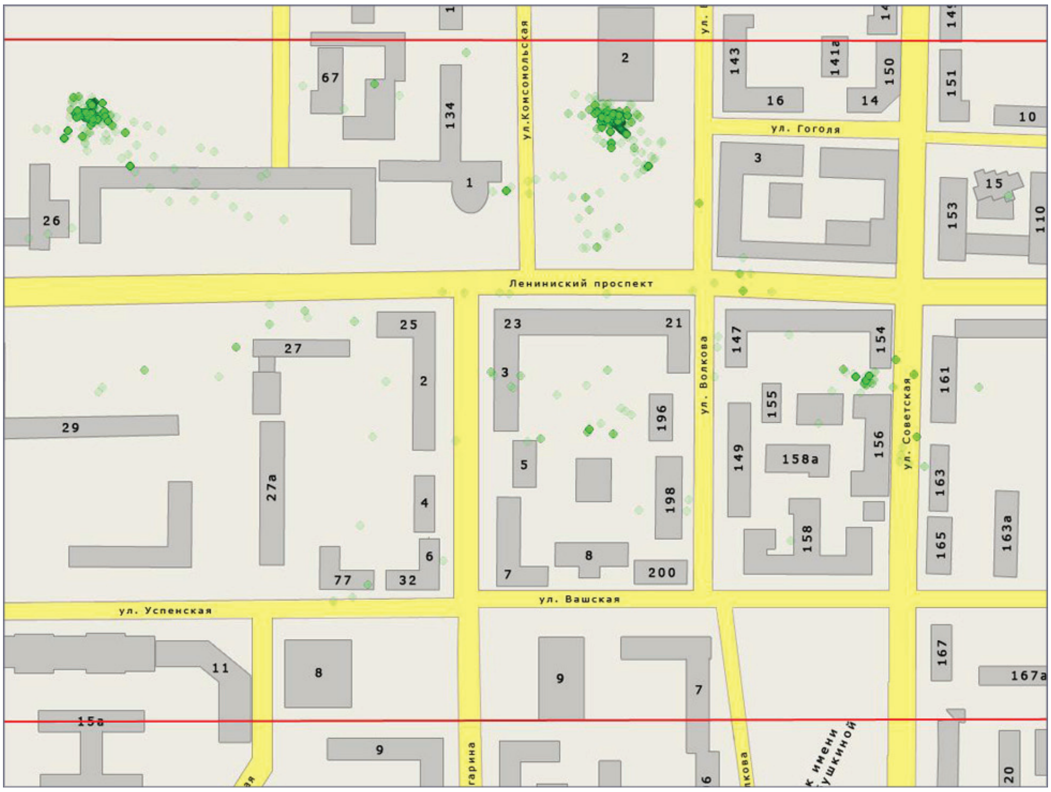


**Figure 6.** Visiting statistics in the Virtual City of Yoshkar-Ola during the virtual lecture

## Results from questionnaires

Two questionnaires were conducted during the case study: one at the planning phase and another after the case study. The first pre-questionnaire was performed before the case study among students taking a different course. Questionnaires were distributed with short descriptions of a virtual city and a virtual campus, since these students were not necessarily familiar with virtual worlds and virtual cities.

Both questionnaires had the same set of questions:

- Q1. What virtual city would you like to visit/participate in its life?
- Q2. What tools and facilities would you need in a virtual city?
- Q3. If a virtual city of Trondheim (where NTNU is situated) will be created, would you visit it/participate in its life?
- Q4. To what extent would you engage in the following activities at the Virtual Campus of NTNU?
- Q5. What tools and facilities would you need at the Virtual Campus of NTNU?
- Q6. What experience do you have with 3D virtual worlds?

Questions Q1, Q2, Q4 and Q5 had sub-questions stressing specific issues such as different activities and facilities/tools are suitable or not for a virtual campus and a virtual city. The students were asked to position their answer on a Likert scale.

The first questionnaire was performed among a group of students taking a different course (not working with the system). The goal of this questionnaire was obtaining feedbacks from a broader student audience. The results from the first questionnaire were analysed and major implications are discussed below. Generally the respond was positive: from totally 24 sub-questions and 26 responses for each, 60 most negative (9,6%), 88 negative (14,1%), 166 neutral (26,6%), 189 positive (30,3%) and 121 most positive answers (19,4%) were received. However several issues were prioritized. The students generally expressed interest in visiting a virtual city: a city where they live, where they are going to live and going to visit for tourism (Fig. 7). In such a city they mostly expect to see high quality models of buildings, often with media content, showing city's culture and history. Additionally the students showed interest in the "interactive quizzes and games" possibility. Tools for social and educational activities were considered less important. Generally, all mentioned means that a virtual city is seen as a game and/or educational environment with advanced graphics and possibilities for learning from realistic 3D buildings as well as from other media (Fig. 8).

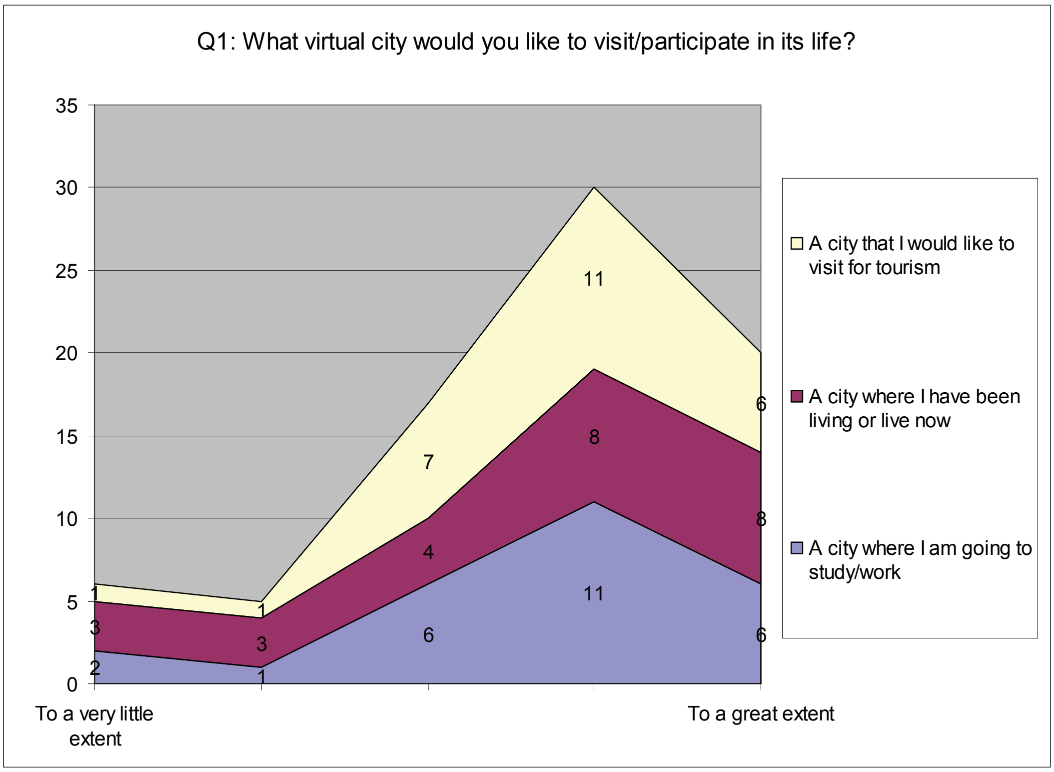


**Figure 7.** First questionnaire results: Virtual city, question 1

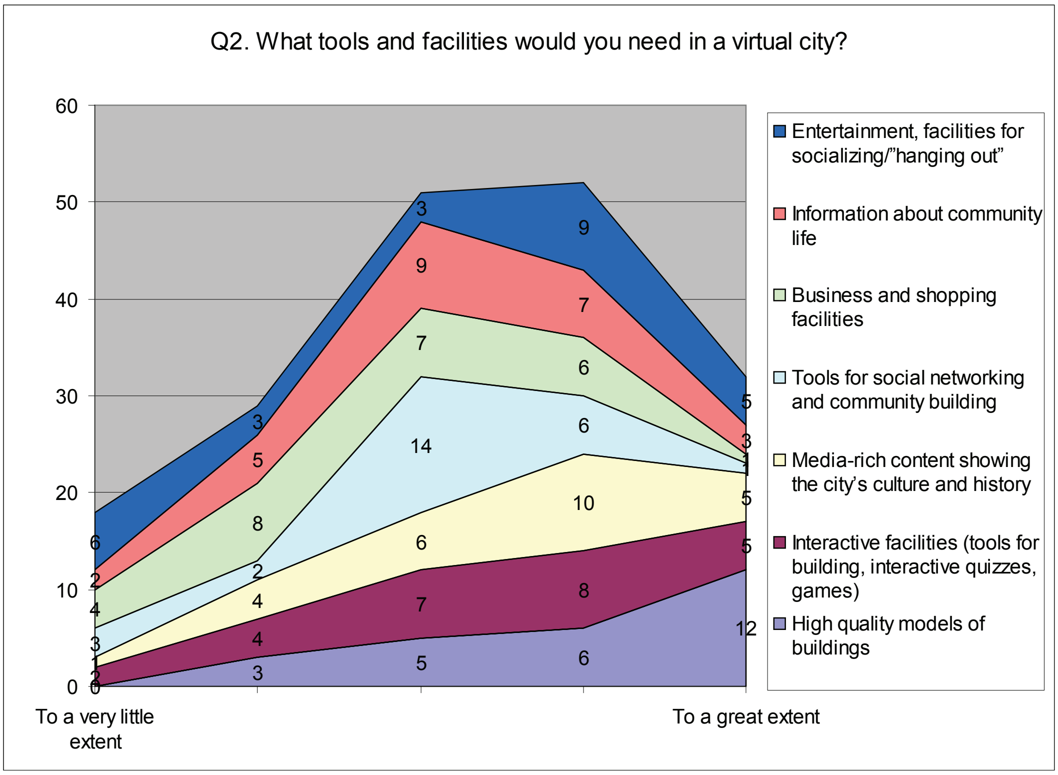


**Figure 8.** First questionnaire results: Virtual city, question 2

According to the results of the same questionnaire, in a virtual campus the students would engage in many activities such as virtual lectures, practical exercises, accessing and sharing resources and group work. However the respondents considered educational games, community building and socializing less suitable for a virtual campus (Fig. 9). For mediating their activities in a virtual campus the students would mostly prefer "traditional" tools, such as slide sharing, text, images and video presentation. As for a virtual city the students consider a high quality of 3D models important. Interactive facilities such as lab simulations and experiments were found potentially useful. Tools for socializing and community building were again recognized as less necessary as well as tools for 3D constructing and presenting 3D content (Fig. 10).

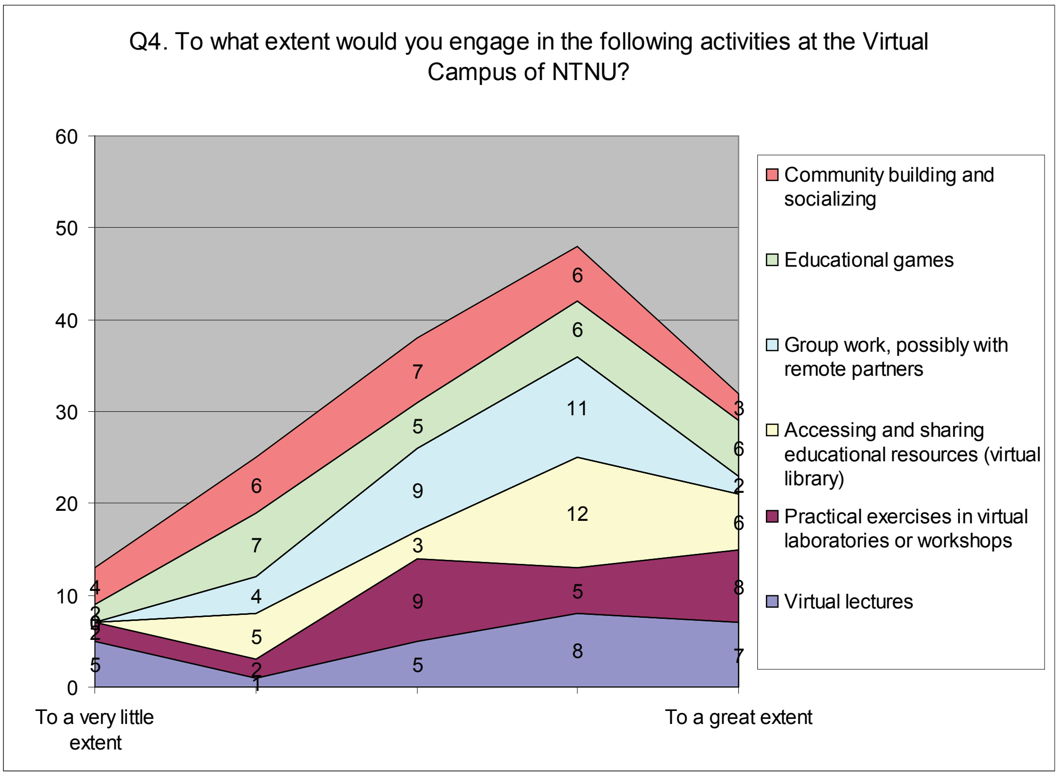


**Figure 9.** First questionnaire results: Virtual campus, question 4

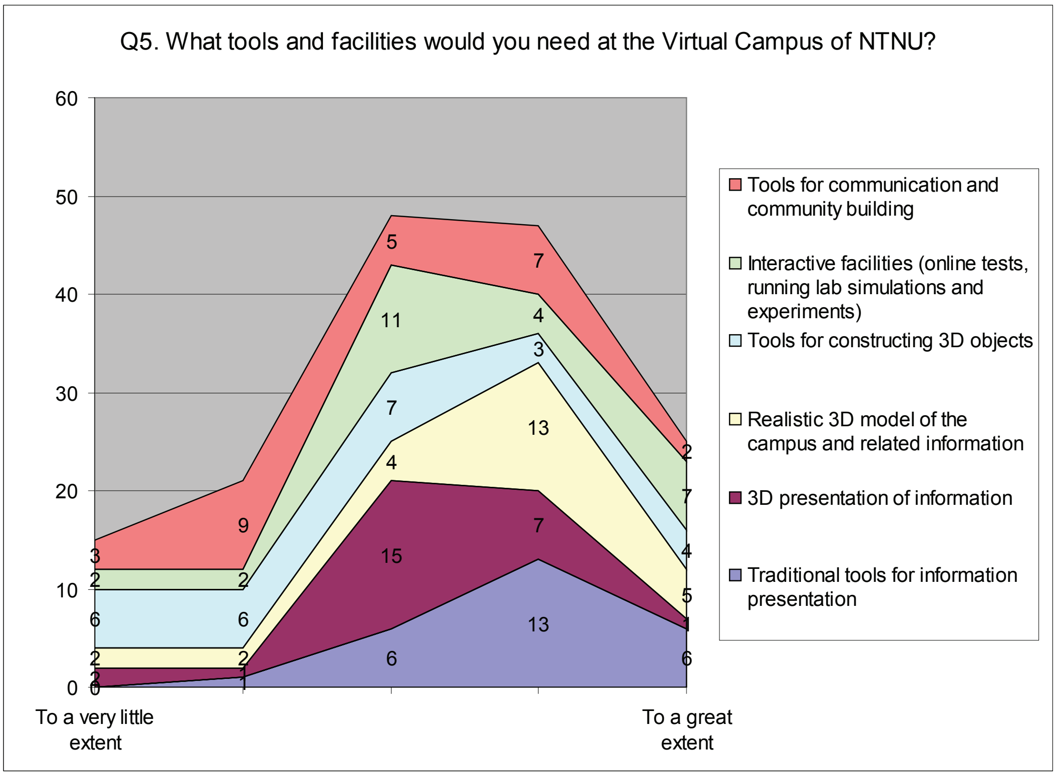


**Figure 10.** First questionnaire results: Virtual campus, question 5

The second questionnaire was performed among the students that participated in the case study. The respond was also rather positive: from totally 24 sub-questions and 12 responses for each, 33 most negative (11,5%), 55 negative (19,1%), 89 neutral (30,9%), 69 positive (20,4%) and 42 most positive answers (14,6%) were received. However, the results show a difference in the priorities compared to the first questionnaire. In addition, two groups of students: one from Norway and one from Russia had different opinions on several issues. The results for these two groups were compared, with major implications are outlined below.

In a virtual city the students mostly prioritized interactive facilities (quizzes and games), media content, showing city's culture and history, socializing tools and tools for community building, while high quality of building paled into insignificance. This resonated with the ideas students expressed during the discussions in the virtual city and in their essays: virtual city contained only models of building, even very accurate ones, has a very limited value (Fig. 12). Answering what virtual city they would like to visit, Norwegian students prioritized the option "A city that I would like to visit for tourism", while Russian students supported the option "A city where I live now". This means that user preferences to a significant degree depend on their existing experience, since VCYO represents the home city of Russian students, while for Norwegians the case study was similar to a virtual tourist trip (Fig. 11).

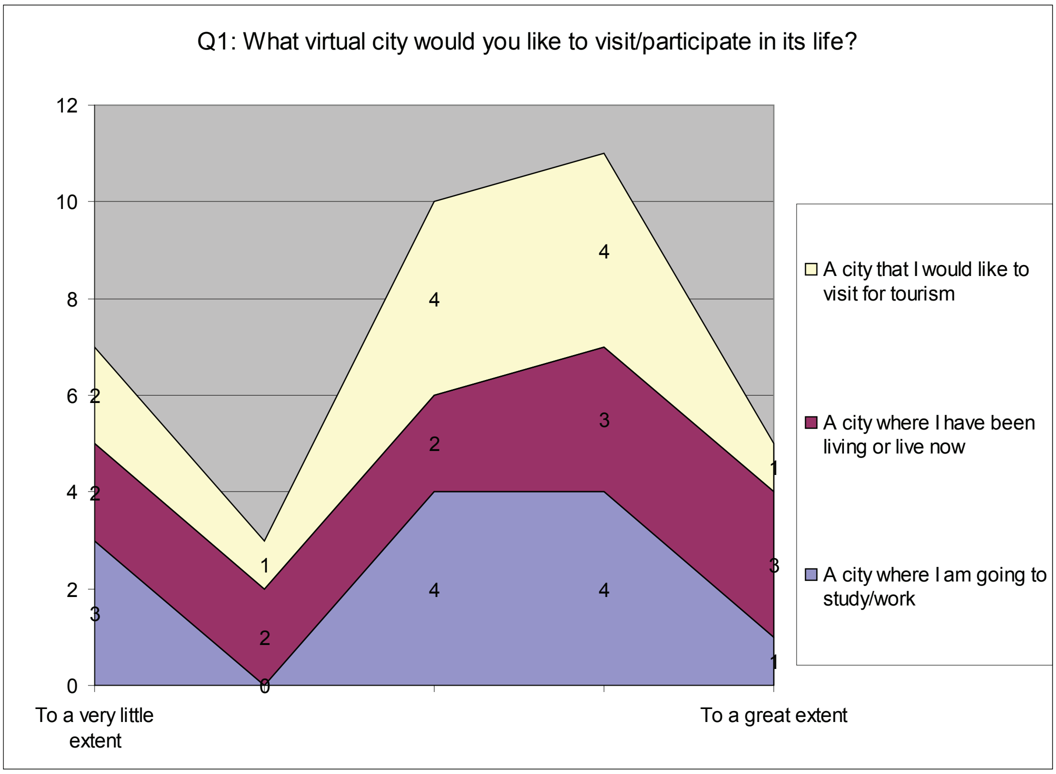


**Figure 11.** Second questionnaire results: Virtual city, question 1

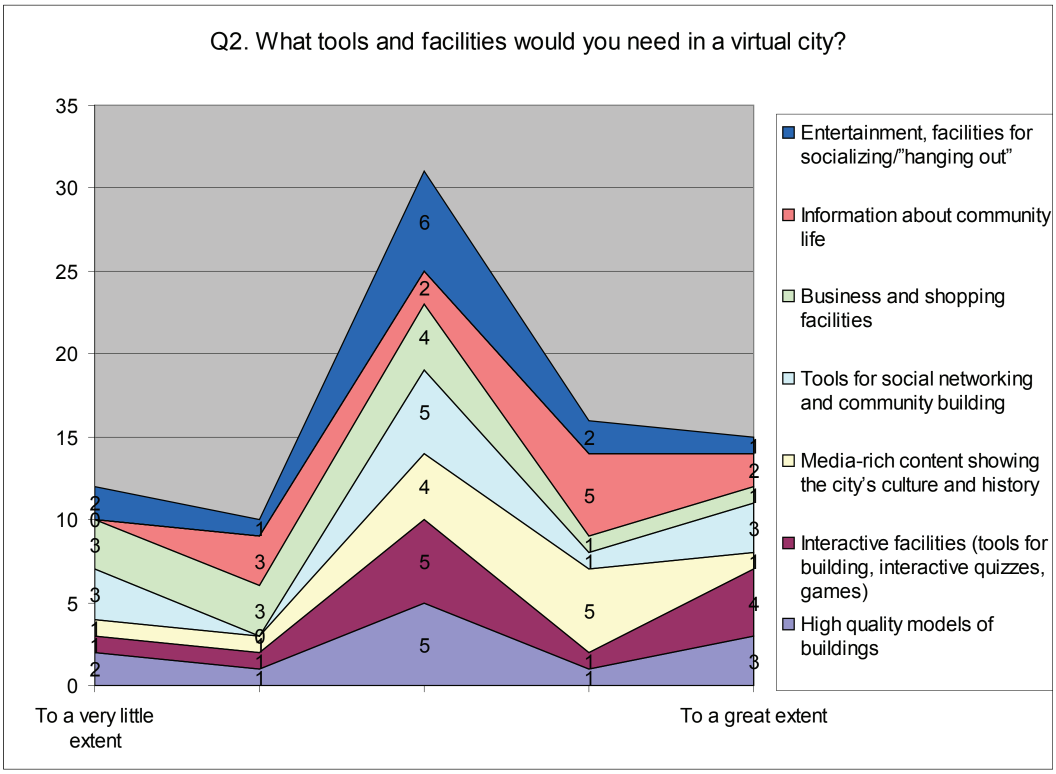


**Figure 12.** Second questionnaire results: Virtual city, question 2

During the case study the students have got an educational experience in a 3D virtual world that, though containing a number of educational tools, could not be called a virtual campus. It appears that the difference in the results of the two questionnaires could be attributed to this experience. Participating in virtual lectures and accessing resources were less attractive for these students in comparison with those answering the first questionnaire, while practical exercises in virtual laboratories, group work and educational games were more attractive (Fig. 13). Realistic models of building in the campus receded into the background, while tools for presenting 3D content got more support than tools for presenting text, graphics and video in the 2nd questionnaire. Tools for socializing and community building tools were slightly more supported than in the 1st questionnaire (Fig. 14).

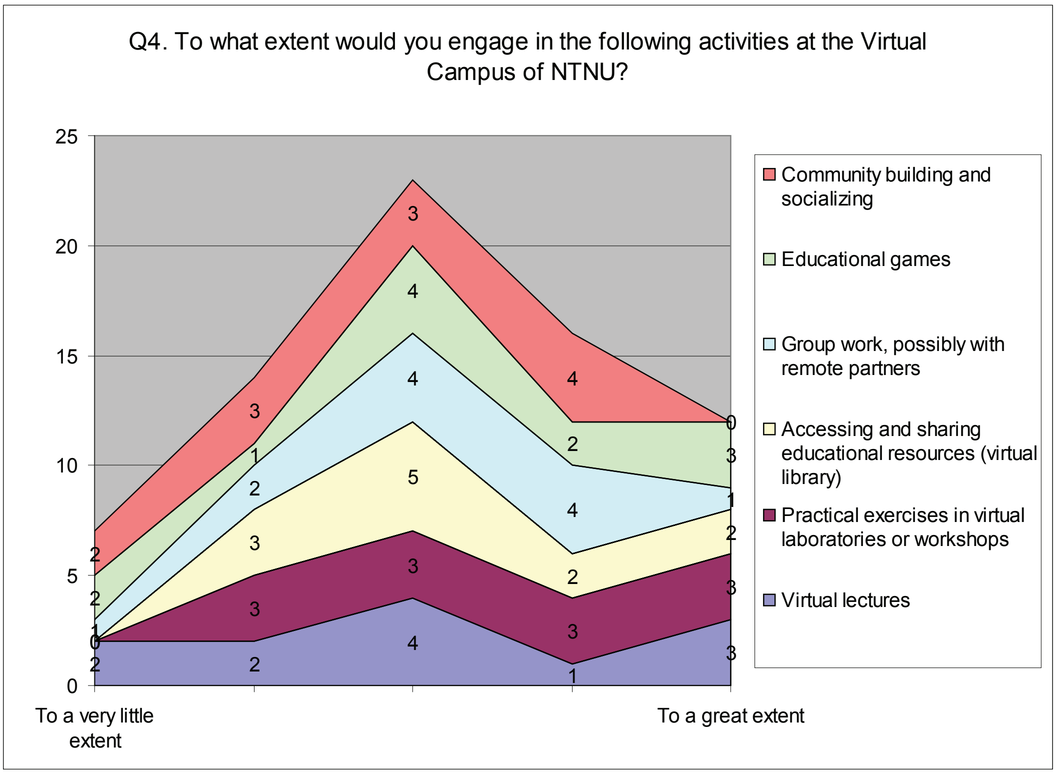


**Figure 13.** Second questionnaire results: Virtual campus, question 4

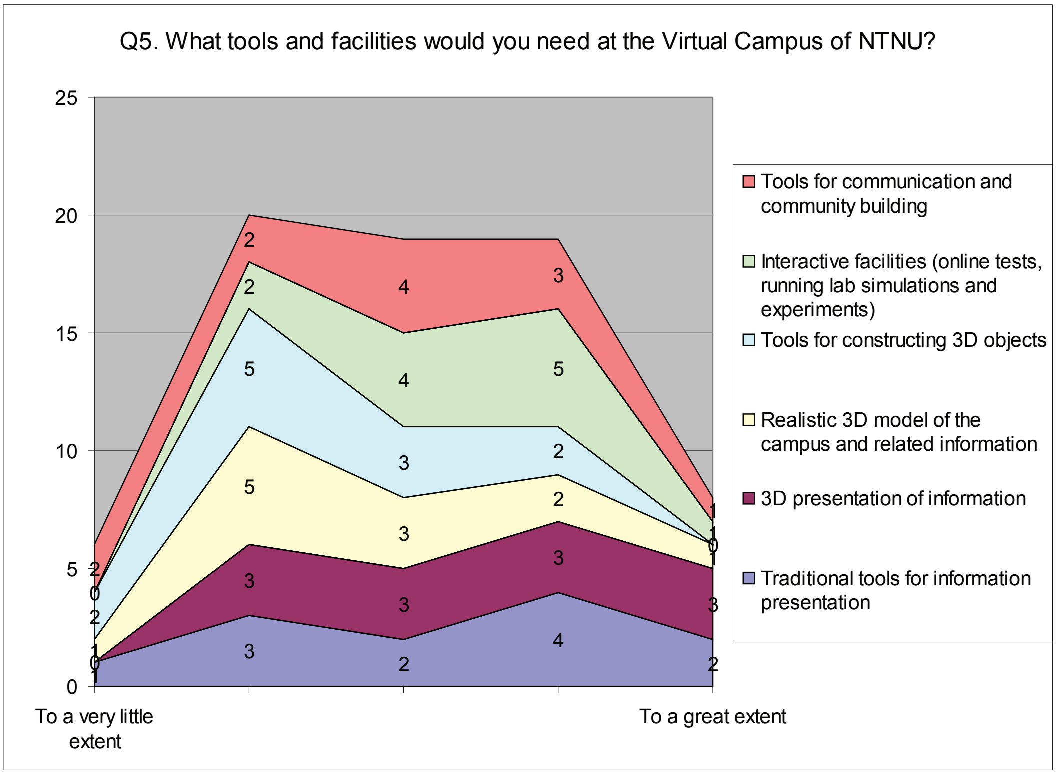


**Figure 14.** Second questionnaire results: Virtual campus, question 5

## Discussion

In this section the case study results are analysed in terms of navigation, community network, educational experience and virtual places, noting how the system's existing functionalities support or limit users' experience in the VCYO. We also discuss the results of two questionnaires that were performed during the case study, investigating what activities, facilities and tools are suitable for a virtual campus and a virtual city.

The *navigation* and exploration of the city was mostly concentrated around the entry and a few other areas of interest such as the main square, the main building of NTNU and the lecture place as the navigation patterns in Figs. 5, 6 and direct students' feedbacks showed. One of the reasons for that was that the students did not get sufficient information upon log-in about the different places in the city that might be interesting to visit, plus at this stage of development not all constructions had enough informational content to motivate in-depth exploration. However, students noted that they had some accidental interactions with local virtual citizens. Despite of the locals did not speak English well enough, they encouraged Norwegians to explore the environment, guiding them and showing different places. The environment therefore supports random serendipity meetings that are useful in a virtual city context, as students' feedback shows. Still, the navigation patterns showed that the existing support for social navigation (by chat and posting notes) was not fully efficient and that additional facilities are needed.

The *community network* development allowed us to analyze the efficiency and limitations of the different tools in the virtual city context. Considering the small quantity of virtual citizens in this case study, the limited time-span and some technical problems, the resulting community network (in terms of blogs and friend-lists) was moderate but satisfactory.

One of the most useful tools was the one allowing to see 'who is online' and teleporting to any user from the list. User notes were used quite a lot, allowing students to discuss asynchronously particular places or objects and enriching the environment with user-generated content. Notes with comments often contained quite meaningful discussions and were usually attached to the places related to the discussion topic. For example, there were a lot of notes with questions about buildings and places, highlighting the need for 'marking the buildings', explaining their purpose. The functionality allowing posting photos was mostly useful in relation to places familiar from reality, showing the importance of the connection between the real and the virtual.

The total amount of notes was less, but comparable to the amount of chat messages – the main communication tool. The findings above suggest that the notes functionality was easy to use and helpful, but most importantly, they highlight the importance of 'situatedness' and context for community development in the virtual city. The students used the virtual city as a discussion board, connecting together the content and virtual places. Moreover, posting notes and photos the students together with local citizens enriched the environment with new user-generated content.

The *educational experience* included taking part in the virtual lecture. Tools for live lecturing available in the open air auditorium (shared displays for slide show, video and co-browsing) proved to be useful for the lecture joining 2 cities, Trondheim and Yoshkar-Ola. Still, there were some problems. For example, visibility problems: it was difficult to see all 3 displays simultaneously, because of the narrow view angle and other avatars, blocking parts of screens. This highlighted the necessity to work further on the organizational settings for virtual lectures. In addition, there were some technical problems due to the server overload. Web and video displays played some movie clips with sounds during the lecture, making it more alive and interesting, though it was inaudible for students using public computers in the lab. The students strongly recommended using voice chat in the future since text chat appeared to be useful, but not sufficient.

*Virtual places* within virtual environments can play a number of different roles in an educational context, such as information spaces, meeting and work places, virtual stages, demonstration and exhibitions (E. Prasolova-Førland, 2005). Our experience and direct students' feedbacks showed that a virtual city itself can provide a number of such places as well as supplement a virtual campus. For example, the streets and squares could serve as natural meeting places, with prominent landmarks such as 'street corners', famous buildings and so on serving as navigation aids. The same landmarks (such as the main building of NTNU in our example) as well as designated places (libraries, campus, boards at teleportation hubs) where community members can store resources and leave their notes, announcements and comments, function as an information place set in a rich context. In our case, it allowed Norwegian students to learn about a foreign city by posting their questions on the buildings of interest and receiving answers from the locals.

A virtual city can also function as an exhibition, attracting public interest to the corresponding exhibition in reality and allowing the community members to post comments and questions, as shown in the gallery example (Fig. 4). The city itself could be seen as a gallery with buildings and virtual citizens acting as exhibits. Navigating through high quality 3D models and communicating with virtual citizens provide an impression of being in the city, of cause, not as bright as in real life, but much closer to reality than with other media. As our experience with the virtual lecture shows, a virtual city can function as a workplace. Still this requires that corresponding facilities are in place as discussed earlier. An important aspect here, as noted in almost all students' essays, is the 'disturbance' factor while having a lecture in an open space (a square) with other users wondering around and other visual impressions diverting attention from the lecture itself. It was suggested to keep such 'serious' educational events 'indoors' in settings close to real-life auditoriums, to create a better focus on the educational content. Such open places in the city are better suited to serve as 'virtual stages' for concerts, city events and gatherings, promoting a feeling of 'togetherness' and presence among distributed users.

Conducting *questionnaires* during the case study we were interested mostly in what activities the students would be engaged and what tools and features they would need. In addition comparing first and second questionnaire allowed investigating how getting experience changes students' preferences.

The results of the first-questionnaire shows that students without much experience in virtual cities and virtual campuses support more traditional and conservative approaches. They support advanced graphics – a well known advantage of virtual worlds, but almost reject social activities. They support an idea of integrating traditional educational activities, such as virtual lectures, and traditional tools, such as shared whiteboards, in a virtual campus, but doubt of more advanced tools. This trend was supported especially by the students, who answered that they have experience in 3D virtual worlds (including games, social virtual worlds and other virtual reality applications). This could be explained that experienced users are influenced by current technical limitations of virtual reality applications. At the same time another part of the target group – non-experienced users – was more positive and more open: they prioritized also entertainment facilities and information about community life in a virtual city, as well as supported community building tools and tools for presenting 3D content in a virtual campus. The results of the first questionnaire show that 3D virtual environments should be further studied, since even users who consider themselves as experienced are not fully able to see the range of possibilities and implications offered by this technology.

Moreover, the results of the questionnaires indicate that even a brief experience is important for forming an opinion about a virtual city and a virtual campus. Using advanced graphics and adopting traditional learning methods (such slide show and so on) at first sight seems to be most suitable strategy in virtual campuses and cities. The practice shows that these features are rather necessary, but not as a central part of virtual city and campus. Other specific tools that use unique advantages of 3D collaborative environment would most probably play the most important role.

To conclude, our case study in VCYO educed some limitations of the system, but at the same time it showed that a virtual city can successfully be used in a wide range of educational activities and in particular as a context for a virtual campus.

### Guidelines for designing a virtual campus in the context of a virtual city

Based on the case study results and the discussion in the previous subsection, we propose a set of guidelines for designing a virtual campus in the context of a virtual city. Since in (Fominykh, et al., 2008) we have already presented an initial set of requirements for a virtual campus, in the following guidelines we will focus more on the aspects of a virtual campus as an integral part of a virtual city, creating together an arena where students can learn and socialize (Fig. 15).

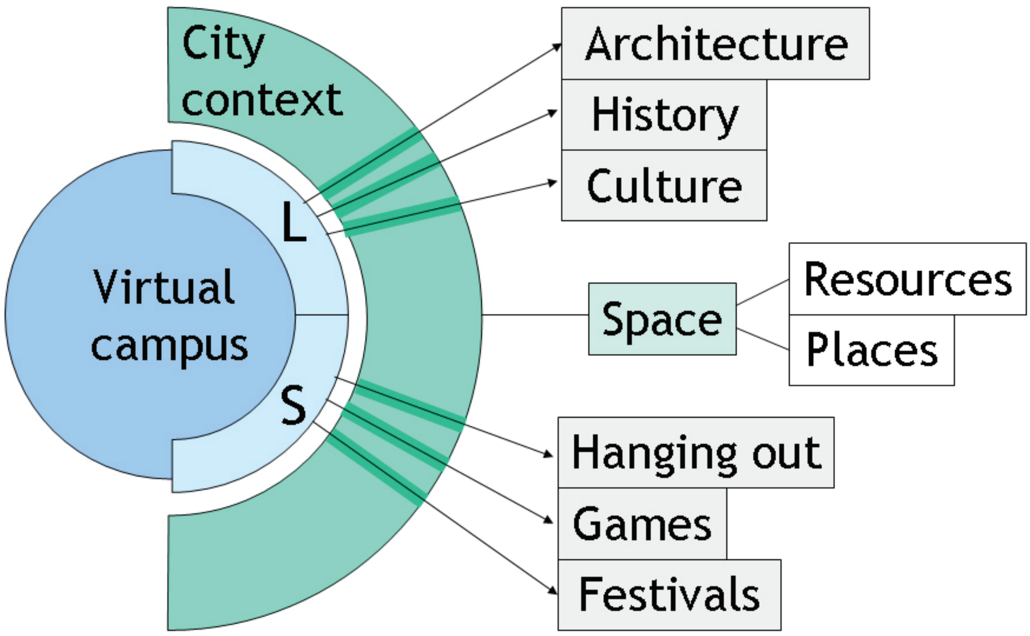


**Figure 15.** Learning "L" and Socializing "S" in a virtual campus are extended by city context

We can think of a scenario where the city's cafes, clubs, squares, museums and libraries constitute a network connected to the infrastructure of the campus. We made these guidelines focusing primarily on the city of Trondheim (that is often called a “nr. 1 student city in Norway”) and on the Virtual Campus of NTNU. Trondheim is actively used by the students for festivals, parties and educational activities, containing a number of dedicated buildings and businesses offering student-targeted services. Still we believe that these findings and guidelines can also be applicable in other similar contexts:

The *appearance* of a virtual campus as well as a virtual city should be as authentic as possible to create a familiar atmosphere and aid navigation. The overall structure of a campus and a city should be presented in a maximally realistic way, while special attention should be paid to the major and most significant buildings, such as main campus buildings and city’s points of interest. Both the campus and the city should contain places for students’ socializing such as cafes, coffee bars, squares and other open places for gatherings, student clubs, places for sports activities (such as tennis and football) and stores selling commodities that students might need. The design of certain places for various educational, social, fun or other activities could have a limited reality resemblance to serve the specific goals in a best possible way, such as auditoriums, buildings representing courses and faculties, but also private houses and educational spaces that can be built by the students and teachers within the major structure of the campus/city. Also, the outside of certain buildings might be scaled down to make it easier for users to move around while the inside could be scaled up to give more space for activities.

*Informational resources* should be an essential part of a virtual campus and a virtual city. It was generally agreed that only models of buildings without corresponding information have a very limited value and meaning, especially for the users not familiar with the city and the campus. Therefore, there should be a strong correspondence between the constructions in the virtual city/campus and the associated informational resources and facilities. For example, the city hall should contain information about local government; the doctors’ offices should contain information about the medical services. The faculty buildings should contain information about the corresponding study programs and research projects, the different auditoriums and course rooms in the campus should display information on lecture schedules and contain resources such as video recordings of the lectures. Informational resources should also be contained in the offices of university teachers and city officials. In some cases, these could be represented by virtual humans, being able to answer a certain set of ‘frequently asked questions'. According to the students, this approach would lead to a lower threshold for asking for help. Such informational resources are especially relevant for foreign students who need to get acquainted with the city and local customs as quickly as possible. The students also emphasized the need for library resources with appropriate search facilities. For better efficiency and availability, such resources in the campus and the city should be interconnected, giving the students access to contextualized information, such as what political events took place in the city during a certain historical period studied in a history class.

The city should in general contain multimedia resources such as sound, pictures, video, 3D resources and 'enactments' with virtual agents associated with relevant important buildings and landmarks, allowing the users to learn about the city, its history and culture. The same applies to campus as on several occasions the students expressed the need for animations to be used as a learning aid in different courses. The possibility to work with 3D content is one of the main advantages of many environments that can benefit learning. Therefore a virtual campus should provide support for presenting, storing, reusing and especially – creating new 3D content. Referring to the feedback from students, we can conclude that the system should provide a special toolkit for working on the media content in order not to overload the system's interface. This toolkit should include easy to use instruments to create and modify any content, including 3D objects, and should be available for all users.

A wide array of *community resources and tools* reflecting and supporting the life of the student community should be integrated in a virtual world of a campus and a city, in a situated and contextualized manner. For example, there should be established some virtual places for social activities (imaginary ones or representations of real places) such as squares, parks, art galleries, museums, student clubs, open-air auditoriums. Other examples include bulletin boards with announcements, blogs and virtual houses for community members, discussion forums and tools for supporting social networks with extensive possibilities for the users to share, annotate and modify the content. There should be clear connections between the community resources and the related virtual places. Moreover, there should be possibilities for automatic recording of the events happening in certain places such as lectures in the lecture halls. A basic support for commercial activities targeting students' needs should be provided to ensure better integration of local businesses into the student community. The students specifically emphasized the importance of 'friends' networks, maintaining the awareness of the activities and whereabouts of ones' friends, as well as their social and educational calendars. In this way a student will have the possibility to teleport to a place in the city or on the campus where his/her friends have a party or a working meeting. There should be search possibilities for locating community members with the needed characteristics (e.g. potential collaboration partners).

Various *navigation facilities* should be available for users to access the content in a virtual campus and a city in the most efficient way. For the campus it could be, for example, teleportation links between buildings and faculties, including different geographically distributed sub-campuses, areas for meetings and research environments. The system should allow advanced searches to get an overview of both social structures (such as the positions of friends and their virtual 'offices') and course and research-related structures. The city environment should provide for example 'city tours' led by agents, 'tourist offices' with information and links to the major points of interest plus searchable maps with filters where one can look for shops, local businesses, historical places and so on. There should be bookmarks and 'transportation routes' marked clearly between different places. In order to support social navigation, there should be possibilities for sharing information on paths taken and places visited by other users. The navigation systems for the campus and the city should be integrated to allow free movement within the overall social and educational space. Such integrated system would be especially useful for new students, serving as a virtual 'helpmate' and supplementing the physical helpmates who according to tradition are assigned at the beginning of the academic year to all newcomers to show them around the area.

*Atmosphere* plays an important role, according to students' feedbacks. Appropriate music and sounds, moving objects, mystery elements such as "hidden doors and secret passages," presence of other users, real or artificial, will contribute to make the virtual world more 'alive' and appealing. The students repeatedly suggested adding gaming elements to the virtual campus and the city. This includes both games as a part of different courses, different types of quests and social games similar to those available on MSN Messenger. Another unexpected elements suggested by the students are places for sports that are not always straightforward to practice in a virtual environment, suggesting that the atmosphere created by such places is more important than the actual functionality.

## CONCLUSIONS AND FUTURE WORK

This paper proposes and discusses the concept of a virtual campus integrated into a virtual city. The settings and the results of the case study that took place in the Virtual City of Yoshkar-Ola are also presented. Gathered empirical data and the students' direct feedbacks allowed analysing and discussing the effectiveness of different tools supporting educational and social activities and make suggestions for their development and improvement. As a result of this discussion, the paper presents a set of the major guidelines for designing a virtual campus in the context of a virtual city. These guidelines will be used for designing a virtual city representing Trondheim, where a virtual campus of NTNU is supposed to be the main feature.

Future work will include the development of the theoretical framework for designing 3D immersive virtual worlds for learning, focusing on the integration of the virtual campus and virtual city concepts. As a result, the authors plan further development of the Virtual City of Yoshkar-Ola as well as the design of the NTNU's Virtual Campus integrated in the city of Trondheim context.

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# Paper 3

**Authors:** Ekaterina Prasolova-Førland, Mikhail Fominykh and Theodor G. Wyeld

**Title:** Virtual Campus of NTNU as a place for 3D Educational Visualizations

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# Virtual Campus of NTNU as a place for 3D Educational Visualizations

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**Abstract:** This paper focuses on two case studies conducted in a Virtual Campus of Norwegian University of Science and Technology (NTNU). In these case studies the Virtual Campus acted as a venue for guest lectures and as a place for collaborative 3D educational visualizations and cross-cultural interaction. The data collected during the studies is analyzed to explore the technological, social and other issues using virtual worlds in educational settings, focusing on visualization of educational content. The paper concludes with some recommendations for future development of the Virtual Campus.

## Introduction

3D virtual worlds support a variety of activities and their use has increased in recent years. The design of educational virtual worlds often follows Vygotsky's social constructivist approach (Vygotsky, 1978), allowing learners to co-construct their environment and understanding together with their peers (Bryceson, 2007). There are a number of reasons for choosing 3D virtual worlds for educational activities. 3D virtual worlds offer new opportunities for learning (de Freitas, 2008) and allow people to interact in a way that conveys a sense of presence lacking in other media (Kelton, 2007). In addition, 3D visualization is a powerful tool for supporting understanding and memorization of complex concepts as well as information retrieval and is widely used in educational contexts (Czerwinski, van Dantzich, Robertson, & Hoffman, 1999). Another important motivation behind the choice of this technology is its potential for supporting cross-cultural understandings and collaboration (Wyeld & Prasolova-Førland, 2006). This suggests that 3D virtual worlds can create a stimulating atmosphere around a collaborative creative learning process, also building on a pre-existing common interest by students in the international multi-user 3D computer game culture. Examples of successful 3D virtual world applications include Second Life (www.secondlife.com), Active Worlds (www.activeworlds.com) and Wonderland (https://lg3d-wonderland.dev.java.net).

A growing number of universities have introduced virtual representations in the form of virtual campuses for supporting a wide range of educational activities. 3D virtual campuses are created using different types of platforms and technological solutions, the most widely used one at the moment is Second Life (SL). Education is one of the major application domains in Second Life and, despite some criticism, it is a good example of this type of platforms. Educational projects in Second Life vary broadly, from full-scale, highly realistic campuses to individual classes taught in common areas. Over 500 universities and colleges have a presence in Second Life since it opened to the public in 2003. Major universities already using SL include California State University, Harvard University, Ohio State University, University of Hertfordshire and University of Sussex, just to mention a few. Other educational organizations that have a presence in Second Life include research organizations (for example, Biomedicine Research Labs), libraries (Alliance Library System), and museums (International Spaceflight Museum). There are also numerous examples of virtual representations of educational institutions in Active Worlds, such as iUni (http://iuni.slis.indiana.edu).

Another popular category of virtual worlds is virtual museums. This metaphor is popular because it is well-known from everyday life. A modern age virtual museum is a complex system with a wide range of possibilities for learners. They are used to facilitate educational process in different ways, such as presenting their exhibitions online and serving as a place for educational activities. Virtual museums have proved effective in a number of educational projects (Hawkey, 2004). As emphasized in (Tanikawa, Ando, Yoshida, Kuzuoka, & Hirose, 2004), in a virtual museum we can provide users with the same opportunities as they would have during a guided tour in a real exhibition, including communication and collaboration with peers.

It is common for both virtual campuses and virtual museums to attempt creating a 'familiar' atmosphere for their users. However, a virtual campus is not only a 3D realistic model of the physical campus. In our previous work we discussed the idea of a virtual campus as a framework around educational and social activities and a set of tools and resources to support those activities (Fominykh, Prasolova-Førland, Morozov, & Gerasimov, 2008). One of these tools was Collaborative Virtual Workshop (CVW) that was introduced as an innovative resource in the context of a virtual campus, supporting collaborative work on 3D educational content as well as sharing and reusing such content. In CVW we seek to combine features from both virtual campuses and virtual museums, taking advantages from both approaches.

NTNU is now in the process of building a virtual campus in Second Life. The Second Life platform was chosen as it is the most common technology of choice for such educational projects, including other pre-existing Norwegian Second Life projects, such as Second Norway. The paper is structured as follows: the next section outlines the two case studies that were conducted in the Virtual Campus of Norwegian University of Science and Technology (NTNU). The following section presents a discussion on the case study results and implications for developing the Virtual Campus and CVW as an integral part of it. The last section concludes the paper and outlines future work.

## Two case studies in the Virtual Campus of NTNU

The Virtual Campus of NTNU is a joint project created in cooperation between the Program for learning with ICT (LIKT), NTNU Library (UBIT) and the Department of Computer and Information Science (IDI). The work on the Virtual Campus of NTNU is based on previous work on creative visualization of educational content and cross-cultural collaborative work in 3D virtual environments (Fominykh, Prasolova-Førland, Morozov, et al., 2008; Ekaterina Prasolova-Førland, 2007). In the following, 2 case studies of using the Virtual Campus for educational activities are presented.

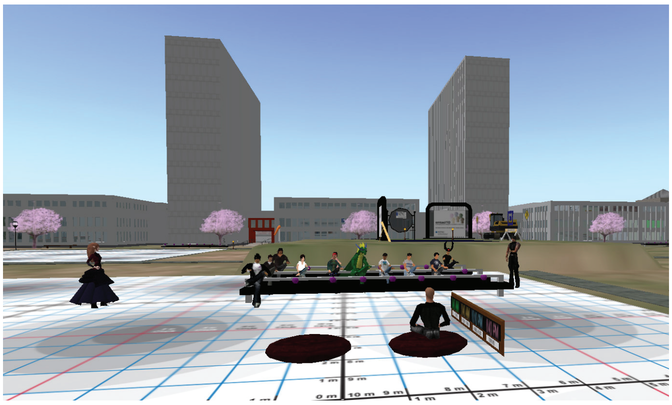

**Fig. 1.** Virtual Campus of NTNU in Second Life

### Case study I: Virtual Campus constructing and a virtual lecture

The development of the NTNU Virtual Campus began in Second Life during the spring semester of 2009. A group of 4 students created an interpreted model of one of the university's buildings – Sentralbygget (Fig. 1) as part of a project course (IT2901 – Informatics Project II). The building has a set of rooms and auditoriums, informational resources and other tools. The students were given a significant degree of freedom in developing the requirements for the project in order to create a design that was as much as possible in the accordance with their needs as NTNU students.

The students decided to focus mostly on the representative function of the Virtual Campus. They have generally achieved two main goals of the project: making the construction recognizable and providing informational resources about the university. The students noted in their report that they learned a lot about both project work and modeling buildings in a 3D virtual world.

When the construction was finished, the NTNU Virtual Campus was used as a venue for a lecture for students from Flinders University, Adelaide, Australia. About 15 students (the amount varied during the session) attended a lecture on educational use of 3D educational worlds. The lecture took place in a virtual auditorium using voice-feed and an in-world slide-show. To avoid some technical problems and due to the fact that not all the students had access to sound, everybody except the lecturer used text chat for communication. In addition to attending the lecture, the Australian students evaluated and discussed the work of the Norwegian group (who also attended the session and presented their project) on the Virtual Campus. They provided feedback and discussed in general the possibilities and potential for using the Virtual Campus for educational activities.

The session and associated discussion allowed us to highlight a number of issues related to the use of the Virtual Campus for education. The Australian students pointed out the opportunities it presented, such as the possibility to attend lectures from different parts of the world and learn from other cultures. The students mentioned a number of areas where they believed a Virtual Campus would be useful. These included: “group work and social activities”, “networking with students and industry people”, “learning and making contacts with people and hearing what they are doing”, etc.

The Australian students also pointed out some drawbacks such as anonymity issues. For example, saying that people can “use avatars to distance themselves from responsibility for their actions”, which is a known problem of online open spaces. The students have also mentioned possible difficulties recognizing people and grading class participation in particular. They also pointed out that it was rather chaotic during the lecture and sometimes difficult to understand who said what (using online chat).

When asked for improvement suggestions, the students mentioned that the campus needed a private discussion place and more efficient virtual classrooms. Another suggestion was to provide better support for 3D content manipulation. At the end of the session, one of the Australian students proposed that “…we could create a campus together”.

**Case study II: Collaborative 3D educational visualizations and cross-cultural interaction**

In the autumn of 2009, the Virtual Campus of NTNU was used for one of the practical exercises in a course TDT4245 – Cooperation Technology. The exercise was carried out in 6 groups, 3-4 students in each. In this exercise, the students were asked to build a visualization/construction representing one of the research areas or a course taught at NTNU. The students were asked to consider how their constructions could be used in educational activities on the Virtual Campus and for promotion of NTNU.

Students had a tutorial on Second Life (in classroom). Following this they met online in Second Life. Students presented their project proposals, were assigned a building area and received additional training in Second Life building. The total building period was approximately 6-7 weeks. One week before the deadline, a joint session with students from Flinders University was organized, Australia (7 students + 1 teacher), Mari State Technical University, Russia (5 students + 1 teacher), and 1 teacher from Molde, Norway. The visitors were guided through the building sites and asked to give their comments and feedback to the Norwegian students’ work-in-progress. The meeting was delayed as the Australians had some technical problems with updating Second Life to a new version since the last time they had visited SL; they also had some bandwidth problems during the session. In their presentations, the students used different elements: pre-made and specially designed buildings, text ‘notecards’ with information, 2D pictures and 3D models, videos, sounds, and other elements.

Assessment was based on participation in the construction effort and on a group essay where the students were asked to discuss different aspects of collaborative work and learning in the context of a virtual campus, collaborative work on 3D educational content as well as future trends and possibilities. The students were also asked to discuss potential use of their constructions and possible directions for development and improvements for the Virtual Campus as a whole. Students evaluated each other’s constructions and received evaluations from the visitors. The following provides an overview of the session.

*Group 1* decided to present the history of NTNU as the university turns 100 in 2010. Using a museum metaphor, the group showed a timeline of the history, including information in the form of text, images and video. The presentation was conducted as a guided tour. The presenters sometimes became silent and as coordinators we had to supplement. This however unexpectedly led to some confusion among the guests, doubting who was saying what. During the presentation, students got suggestions for improvement (mostly how to make the construction more interactive and fun).

*Group 2* developed a presentation of the student project of making the most fuel efficient vehicle "DNV Fuel Fighter" that received first place in an annual competition for European high schools and universities. The group had an exhibition with posters, pictures, video and a 3D model of the car, allowing visitors to drive it themselves (Fig. 2). Before the group started the presentation it took about 4 minutes to gather people at the right place. The confusion about who was saying what had increased as the presenters had also changed. Several people missed some messages and were still at the previous construction hence out of the next presenters' chat range. During this presentation some lag problems also appeared that made some people unable to move and speak. An important suggestion was made – to start 'rezing' and 'de-rezing' buildings. 'Rezing' means making 3D objects appear in the world. During the case study navigating from one student project to another was a problem even if constructions were in close proximity. In our case 'rezing' constructions when needed and 'de-rezing' not needed ones can matter since it can solve navigation problems during presentations and clear more space on the island.

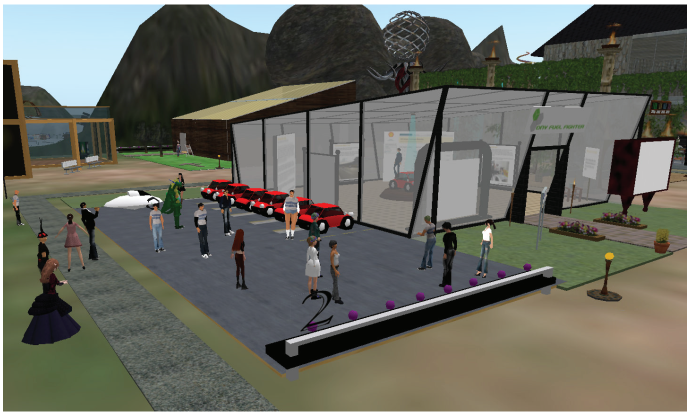

**Figure 2.** DNV Fuel Fighter construction

*Group 3* created a virtual "Health Care Division", responsible for training and creating awareness related to the medical field. The project was at a very early stage and not presented by the students.

*Groups 4 and 5* decided to go with the areas of Architecture and Design and Fine Arts and Music. Group 5 recreated one of the major landmarks in the city of Trondheim – Studentersamfundet. This building houses various student organizations and is an important social meeting place for students in Trondheim, where one could go dancing, attend concerts and participate in debates. Group 4 presented different forms of art, music and dancing inside Studentersamfundet, with videos, pictures and interactive elements such as musical instruments. During the presentation an importance of both real and unreal in 3D virtual environments was stressed. Since the construction was a recreation of a real building, several people suggested showing what is going on in real life in Studentersamfundet, placing announcements and links to various events. There was also a suggestion to show a Twitter feed in this place to keep people up to date. Additionally, several suggestions on building were expressed by the visitors. The Norwegian authors of the project expressed a need for more constructing support.

*Group 6* created a virtual museum of Arts and Music. Students had the idea of allowing talented people, especially NTNU students, share their fine arts learning with each other, as well as displaying their work and attracting potential sponsors (Fig. 3). During the presentation, it was agreed that such a virtual museum can exhibit not only images, but sculptures, installations and other forms of art. Students should be able to contribute with their art works and university project works.


**Figure 3.** NTNU Museum of Modern Art

After the project presentations, the visitors and NTNU students took a tour of the central building of the university – Sentralbygget that was constructed during the first case study (Fig. 1). Towards the end of the session we had some suggestions for improvements, mostly from the visiting teacher, such as providing facilities for easy storing and retrieving of student projects, information in virtual rooms about their real counterparts and more interactivity. Several visitors mentioned the difficulty in navigating in such a large building and the need for an additional map with teleports. One of the NTNU students was critical that the Virtual Campus of NTNU was not commonly known to its students and employees and suggested advertizing on the university's website to make the Campus more available for teaching, student projects and social activities. Finally it was proposed to link the Virtual Campus in Second Life and the local LMS "It's learning".

All visitors were also asked to take a short survey. The survey provided general feedback on the Virtual Campus and vote for the best students' project. The survey showed that the campus was relatively suitable for social activities, while the support for educational activities was minimal and the campus in general needed improvement. The negative evaluation of the educational facilities at the campus by the visitors could be partly explained by the fact that no existing facilities (such as the lecturing ones) were explicitly demonstrated during the session.

After the Norwegian students completed the course they were asked to answer a questionnaire. The questionnaire had totally 4 questions with a set of sub-questions stressing specific issues, such as which activities and facilities/tools are suitable or not for a virtual campus (Figs. 4-5). In addition, the questionnaire contained a short description and 2 questions concerning a new tool/framework with a tentative name "Project gallery" (Figs 6-7). This was initially defined as simple as "a special tool/framework for constructing, storing and presenting content in a 3D environment". In particular, the Project gallery is intended for assisting constructing, presenting and storing student projects, similar to those that were created in the case study. The idea of such a tool/framework originally appeared in one of the authors' earlier works (Fominykh, Prasolova-Førland, & Morozov, 2008) and was reinforced during the case study in response to several problems (as reported by the students during the online sessions in Second life and their essays). For example, participants needed more support for the constructing process. Many students noted that a library of pre-made 3D objects and university related textures could allow them to concentrate more on the creativity. Case study constructions took a lot of space in the Virtual Campus. This space should be cleaned for future projects and the constructions themselves could be saved for later use. Presentation of constructions proved to be not an easy task and also needed support. Therefore, to find solutions to these problems, we introduced the concept of a Project gallery and included corresponding questions into the questionnaire.

When answering the questionnaire, the students were asked to position their answer on a Likert scale, with 5 alternatives varying from "to a very little extent" to "to a great extent". During the subsequent analysis, 5 different alternatives were assigned the following weights: -2, -1, 0, 1 and 2, correspondingly. For each question, the weighted answers were summed up. The results are presented in Figs. 4-7 below.

Among the suggested activities in the Virtual Campus, the students prioritized virtual lectures. An activity that students were involved in – 3D visualization, constructing installations and sharing content – received an equal amount of positive and negative votes. Other activities were less popular (Fig. 4). Among the tools and facilities in the Virtual Campus a library with educational resources was considered the most necessary. Recreation of the main university building – a major landmark – was considered less important than recreation of departments with administrative information and tools. Private and group rooms were considered not important. Socializing place was almost equally supported. Realistic auditoriums were supported less than abstract auditoriums with unrealistic features (Fig. 5).

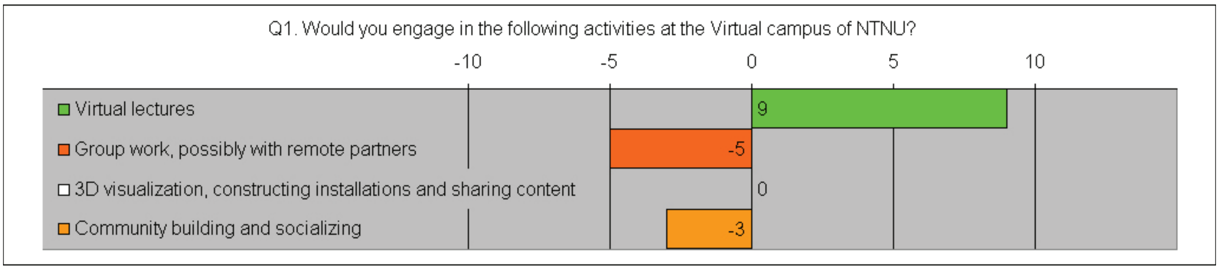


**Figure 4.** Questionnaire results. Question 1: Activities at the Virtual Campus

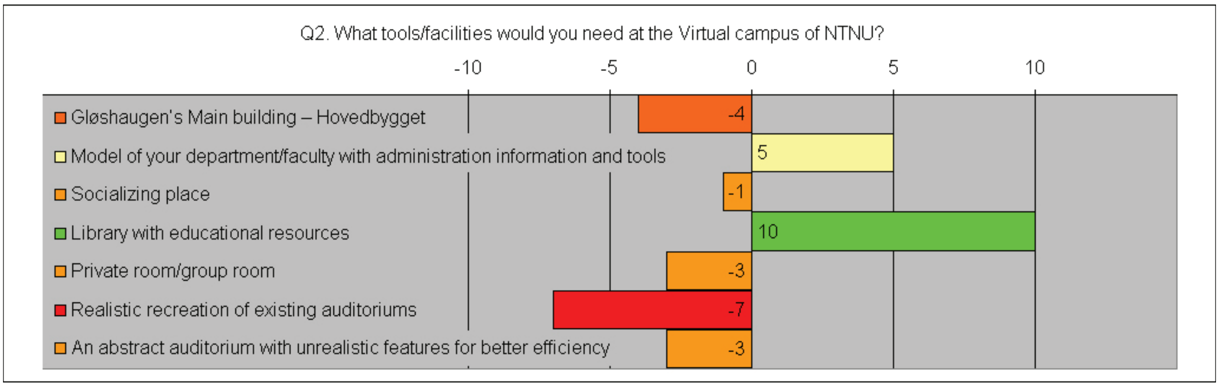


**Figure 5.** Questionnaire results. Question 2: Tools/facilities at the Virtual Campus

According to the results of the questionnaire the Project gallery was mostly seen as an information place, with the library of resources a main feature. Generally, the proposal was considered useful and almost all the points got more positive votes than negative. In addition to an information place, the project gallery should combine a meeting place, elements of a museum and a workshop as well as being a social place. The responses show that all the proposed roles of the Project gallery should be supported (Fig. 6). The students supported all the facilities and tools that were offered as a part of the Project gallery. Besides the library of university related 3D objects, textures and templates for constructing, there should be a creative and fun atmosphere, possibilities for learning more about projects and a stage for presenting. The idea of creating the Project gallery in any recognizable building was also supported by most students (Fig. 7).

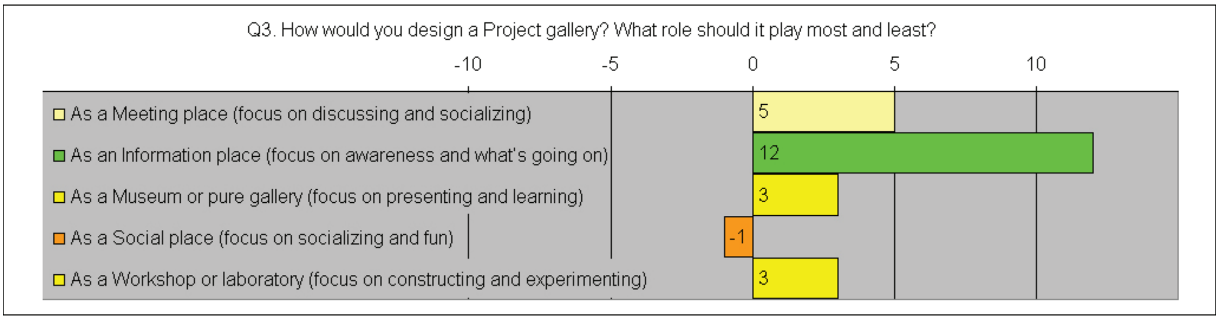


**Figure 6.** Questionnaire results. Question 3: Designing Project gallery

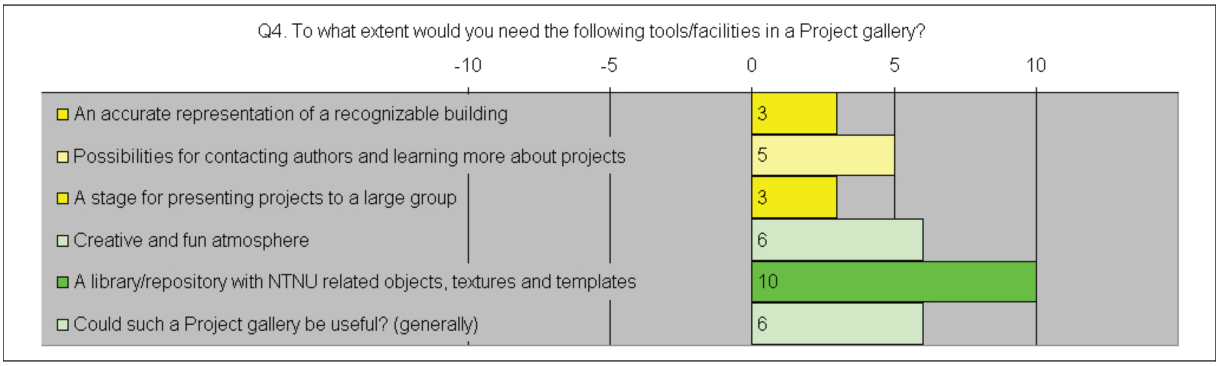


**Figure 7.** Questionnaire results. Question 4: Tools/facilities at the Project gallery

## Discussion

This section summarizes the major implications for further design and development of the NTNU Virtual Campus based on feedback from the case studies and previous research. Among other things, the Virtual Campus will be improved by developing a special tool supporting collaborative work on 3d educational content – Creative Virtual Workshop (CVW). The initial idea of such a tool was presented in our previous work (Fominykh, Prasolova-Førland, & Morozov, 2008). CVW was introduced as an innovative resource in the context of a virtual campus, supporting collaborative learning, creativity expression and resource sharing for a wide range of educational contexts. The recent case studies allowed us to specify its design for the support of creation, demonstration, storing and retrieval of student projects. According to the questionnaire results, case study participants supported the idea of a Project gallery that we now consider as a part of the CVW.

As we have already mentioned in the Introduction, a virtual campus is not only a space, but most importantly a framework around educational content, learning activities and associated tools and resources. In this context, based on the students' feedbacks, the CVW is meant to be one of the main tools of the NTNU Virtual Campus. The following provides the major requirements for the Creative Virtual Workshop in the context of the Virtual Campus.

*Appearance:* The Virtual Campus of NTNU should have some realistic buildings to convey the spirit of NTNU, but at the same time it should be engaging, user-friendly and have unrealistic features/designs where it is necessary for an enhanced and more efficient educational experience. Similarly, while discussing the proposal of the Project gallery/CVW and how it should appear, the students mentioned support for information sharing and meetings as well as a creative and fun atmosphere as important. Since some realistic designs (such as small rooms and auditoriums) were criticized as being not very user friendly, the CVW's exterior should preferably resemble an existing university building, while the interior may have an unrealistic appearance for best possible performance.

*Structure:* The overall structure of the NTNU Virtual Campus should be well-organized and to a certain degree resemble the structure of the physical campus. The structure should have a varying degree of flexibility to allow modifications form the users, but at the same time keeping the overall structure consistent. Realistic buildings and places should be better used for social activities and as representative areas holding various informational resources about the university and its life. At the same time, there should be workplaces where educational activities can be conducted. The CVW is considered a tool in a virtual campus context with a complex structure, integrating several places in one framework. The design of the CVW is based on the previous research and on three main suggestions from the participants of the case studies: firstly, more support for constructing processes, secondly, support for presenting projects and awareness and finally, provision of a library of resources. Accordingly, the CVW will have a virtual workplace equipped with building tutorials and tools. This workplace must also be linked to a library with ready to use objects, textures and scripts as well as university related resources. To provide support for presenting projects, there should be a virtual stage, equipped with corresponding facilities, such as a slide-show screen, a place for presenting 3D constructions and seats for the public. This stage should be surrounded with a virtual gallery that must be able to store and exhibit student constructions (such as those were made in the second case study). Gallery exhibits can be implemented as posters with the possibility for extracting any project to the virtual stage.

*Role:* The Virtual Campus of NTNU in general should be an arena for working and learning in a 3D virtual environment. Various virtual places in the campus should play a number of secondary roles, such as providing support for specific educational or social activities, providing information about the university, attracting prospective students and so on. In the context of the Virtual Campus, the CVW will play several different roles, since it has several functions. These roles are: providing support for constructing (via workplace and library), providing support for presenting (via stage) and providing awareness (via gallery). Among these roles, the CVW can also be used as a meeting place and as a socializing place.

## Conclusions and future work

In this paper we present and describe two case studies that were conducted in the Virtual Campus of NTNU. The paper describes the settings and the initial results of these case studies. Gathered empirical data and the students' direct feedback allowed us to analyze how effective virtual worlds are for supporting educational and social activities. Participants' comments and suggestions were discussed in light of how to develop and improve the campus. Future work will include further development and extension of the Virtual Campus of NTNU. The major directions of the development will be recreation of several recognizable buildings of the physical campus and setting up facilities for lecturing and other educational activities. This includes in particular designing a Project gallery/CVW for supporting creation, demonstration, storing and retrieval of student projects as well as for supporting collaborative work on 3D educational content in general. In addition to using the Virtual Campus for exercises and lectures for students at NTNU and cooperating universities, we plan to use the Campus as a venue for an international Summer School as a part of EU FP7 TARGET project.

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# Paper 4

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# WORKING ON EDUCATIONAL CONTENT IN 3D COLLABORATIVE VIRTUAL ENVIRONMENTS: CHALLENGES AND IMPLICATIONS

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**ABSTRACT**
Collaborative construction and exploration of educational content is an important part of a learning process. In this paper, we focus on collaborative construction of educational visualizations in 3D Collaborative Virtual Environments (CVEs), analyzing results from our earlier case studies in Active Worlds and Second Life. We discuss various aspects of presenting educational content in a 3D environment, such as aesthetics, functionality and expressed meaning, various design solutions adopted by students in their constructions and the challenges they faced. Furthermore, we outline the implications for using 3D CVEs for working on educational content as a part of everyday classroom activities.

**KEY WORDS**
3D collaborative virtual environments, educational visualizations, Active Worlds, Second Life

## 1. Introduction

In recent years, 3D collaborative virtual environments have become increasingly popular in educational settings. One of the reasons is the potential and possibility such environments provide for collaborative work with educational content, as discussed in several studies [1, 2, 3, 4]. According to [5], virtual environments also offer an opportunity for participants to interact in a way that conveys a sense of presence lacking in other media.

Based on several sources [6, 7], 3D Collaborative Virtual Environments (CVEs) can be defined as three dimensional, multiuser, synchronous, persistent environments, facilitated by networked computers. In such environments, users are represented by avatars. Communication is usually presented in the form of gestures, text-based chat and in-voice chat. Some CVEs allow creating and/or uploading 3D objects and other media, such as text, graphics, sound and video.

When talking of ‘educational content’ and ’3D content’, it is necessary to be aware of the ambiguity of these terms. In general, content is something contained, as in a receptacle. However, as for example noted in [8], it can be ‘objects, places, activities’ or any valuable information or experience. 3D collaborative virtual environments allow various types of content, from single media objects to ‘3D cartoons’/enactments and interactive elements as elaborated further in the paper. Some 3D CVEs allow learning communities to create content and leave traces of their activities that become part of the shared repertoire of the community during the process of reification [9].

These possibilities can be exploited for supporting learning process in a number of ways. First, 3D CVEs may allow educators to create educational content that supports better understanding and memorization of complex concepts as well as information retrieval [10]. Second, 3D CVEs provide learners an environment for active and collaborative work with content. This approach is based on ‘constructionism’ [11]. This educational philosophy implies that learning is more effective through the design and building of personally meaningful artifacts than consuming information alone [8, 11]. Constructionism is related to the social constructivist approach [12], where the main idea is that learners co-construct their environment and understanding together with their peers [13]. It is extended to “the idea that learning is most effective when part of an activity the learner experiences is constructing a meaningful product” [14]. As stressed in [15], learning by doing is considered “the most effective way to learn”. Therefore, the technology behind 3D collaborative virtual environments can enable rich authentic learning experiences.

In this paper, we discuss how students can collaboratively work on educational content in 3D CVEs in a number of ways: elaborating on a course curriculum, presenting projects, recreating university environment and so on. By discussing the possibilities and challenges of working with 3D visualizations we outline some implications for using this approach in educational settings. The goal of this paper is therefore twofold. First, to guide educators in adopting educational visualizations in 3D CVEs as a supplement to their everyday classroom activities. This includes among other things choosing the right course design, content and medium. Second, to identify future research directions for using 3D visualizations in a wide range of educational settings.

The paper is structured as follows: the next section presents the major 4 categories of visualizations the students created during our earlier case studies in Active Worlds and Second Life. In Section 3 we discuss these constructions, exploring how various aspects of content presentation affected the collaborative construction process and learning outcomes. In Section 4 we present the major implications for supporting learning through 3D visualizations and active co-constructing of the learning environment in 3D CVEs. Section 5 concludes the paper and outlines directions for future work.

## 2. Educational Visualizations: Case Studies

In this section we present 4 major categories of educational visualizations the students worked on based on data from 5 case studies conducted by the authors in the period from 2005 to 2009. These case studies were conducted among the students of Norwegian University of Science and Technology (NTNU) in cooperation with University of Queensland (UQ) and Flinders University (FU), Australia, and National Yunlin University of Science and Technology (NYUST), Taiwan. Various numbers of students participated in case studies ranging from 1 to 9 groups of 3 to 10 people each. The studies were conducted within different courses and had different purposes, while collaborative work on 3D content and educational visualizations were the common topics. Three of them we conducted in Active Worlds (AW) and other two in Second Life (SL). Neither of these two platforms was designed specifically for learning. Nonetheless, they both have possibilities for collaborative work with content and are used for educational activities (see e.g. [16, 17]).

Active Worlds offers “a comprehensive platform for efficiently delivering real-time interactive 3D content over the web” (http://activeworlds.com/). Active Worlds also has a library of objects to be used as building blocks, such as walls, signs etc. The library can be extended by objects designed by 3rd party tools, such as Autodesk Maya, 3ds Max, Caligari Truespace, and so on. Second Life (SL) is defined by its developers as “a free online virtual world imagined and created by its residents” (http://secondlife.com/). The platform has an “open-ended architecture and collaborative, user-driven character” [17]. Second Life supports various types of content and media, such as text in a form of ‘notecards’, uploading graphics, creating 3D objects in a form of primitives and streaming sound and video. Moreover, it allows creating constructions combining different types of content, programming animations and behavior through scripts written in Linden Scripting Language and performing complex interactions using avatars.

The constructions created by the students during the presented case studies can be divided into 4 major categories: information spaces, abstract concepts, crystallized activities and student environments. The borderlines between these categories are not distinct, but they are representative of constructions created by the students in 3D CVEs as a part of course work. Next, we discuss these categories, focusing on the specific challenges that students had working with various types of content, information and activities. The citations in the rest of the paper are taken from students’ essays following the case studies.

### 2.1 Constructing Information Spaces

Creating and maintaining a shared information space is an integral part of a learning community’s development. In the case study *Collaborative Creation of Common Information Space*, we explored the potential of 3D CVEs in this context [18, 19]. The students were required to build a representation of a FAQ in a Cooperation Technology course (which was originally a wiki-based web forum) in Active Worlds. The students used different metaphors in their constructions to represent the FAQ and visualize distinctions between topics. Examples include: a pier with links to topics on ‘floating platforms’, a park with ‘gardens’-topics and different types of buildings (Fig. 1).

Topics were usually represented as separate buildings, rooms, terraces, and walls with links to 2D resources and billboards. In the constructions, the information was presented with objects, mostly text signs with links to entries on the original wiki-based forum, and additional questions/answers and links to extra materials.


**Fig. 1. FAQ as a building with rooms**

Student constructions highlight different ways of presenting and structuring information in a 3D virtual environment. They also show some limitations of the technology. 3D CVEs provide a greater “freedom of construction” [18, 19] and more possibilities for organization than a web-based information space alone. However, it is more difficult to navigate and to search for information in a 3D environment than using a typical search string in a web-based system. Scaling up is another problem for information spaces in 3D CVEs, as extensions to buildings and rooms lead to lag in loading times and to an overall shortage of available information space. Furthermore, constructing in a 3D CVE often requires significant effort that makes presenting information difficult especially if the choice of ready to use 3D objects is limited.

### 2.2 Displaying Abstract Concepts

Improving students' understanding of the curriculum is one of the most important tasks for the use of technology in educational. In case study *Creative Curriculum Visualization*, we asked students to build a creative visualized presentation of one of the topics covered in the Cooperation Technology course in Active Worlds [20]. The solutions chosen by the students tended to follow the categories:

- '3D shell' – a house or another construction with no apparent connection to the topic and with a content presented by 'traditional' methods such as posters with text and images;
- '3D cartoon' – a 'dramatization/enactment/diorama' with avatars and 3D objects, in some cases with animations (Fig. 2);
- 'virtual museum' – a presentation of the topic in a gallery of images or 3D objects illustrating the major concepts (Fig. 3).

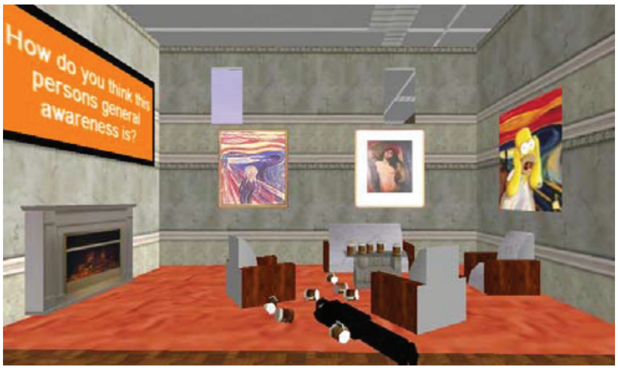


**Fig. 2. 'Awareness' as a '3D cartoon'**


**Fig. 3. Museum of communication means**

Constructing visualizations of the major curriculum concepts in a 3D collaborative virtual environment, the students spent a significant effort on elaborating on educational content and their understanding was on several occasions improved, as followed from the students' feedbacks. However the students experienced a number of problems working on this task. It was rather time-consuming and required much more effort than simply reading a textbook. The students also experienced some misunderstandings with the ambiguity of visualizing abstract concepts in a 3D environment.

### 2.3 Student Constructions as Crystallized Activities

According to [9], continuous negotiation of meaning is the core of social learning and involves two processes: participation and reification. Participation is the complex process that combines doing, talking, thinking, feeling, and belonging. Reification is the process of giving form to one's experience by producing objects that congeal this experience into 'thingness'. In the case study *Constructing a Virtual Tower of Babel*, the students with different cultural backgrounds (Norway, Australia, Taiwan, etc) were working in groups to construct a virtual Tower of Babel in Active Worlds [21]. The students incorporated and 'crystallized' different aspects of their intercultural collaborative activities, experiences and communication into 'thingness' by adopting various construction solutions for their towers and leaving traces of their activities and identity there. A lot of work was done during the preparatory phase, including finding a common language and discussing the details of tower design. The building process itself involved a number of both technological and social challenges. Some of the towers followed a 'modern' design approach, while there were also examples of a more 'authentic' style (Fig. 4).

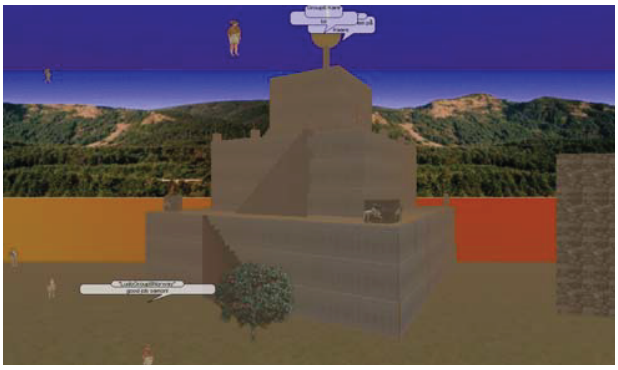

**Fig. 4. A Babel tower in an 'authentic' ancient style**

This case study showed that the experience the students got working in a 3D CVE helped them to overcome their cultural and language differences. A new 'virtual culture' was created in a 3D world, where all the presented cultures were combined in a shared time and space. The students' activities and experiences of being a part of this 'new culture' were 'crystallized'/'reified' into virtually tangible content as a part of the resulting constructions. At the same time, the students had technological problems, such as the small number of building objects to choose from, limited awareness of each other's actions and limited coordination of collaborative activities. In addition, the students had some social challenges during the case study, such as finding a compromise in a group about the construction design. These problems and challenges were 'crystallized' in the Babel constructions as well, for example members of one group started building in two different locations due to a misunderstanding but later united the resulting 'Babel towers' with a teleportation bridge.

### 2.4 Constructing a Student Environment

Environment is an important part of the educational process, not only in real life, but also in a virtual world. Its function is to provide access to information resources and tools as well as creating an appropriate educational atmosphere. In the context of a virtual campus, the environment should provide a clear association with the real educational institution, conveying its 'spirit' and atmosphere.

In the case study *NTNU Virtual Campus Construction*, a group of 4 students created an interpreted model of one of the NTNU's buildings – Sentralbygget (Fig. 5) in Second Life, as part of the Informatics Project II course [22]. The students were given a significant degree of freedom in developing the requirements for the project in order to create a design that was as much as possible in the accordance with their needs as NTNU students. The students decided to focus mostly on the representative function of the Virtual Campus. They achieved two main goals for the project: making the construction recognizable and providing informational resources about the university.

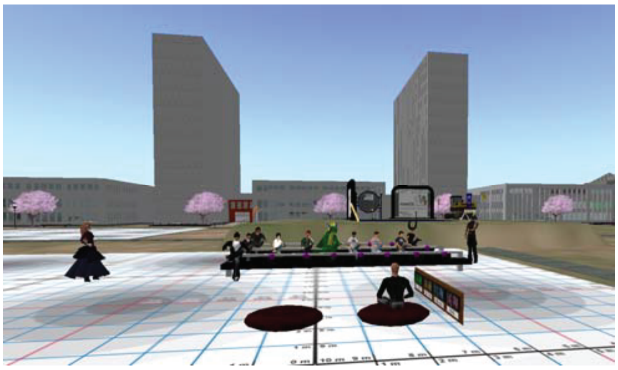

**Fig. 5. Virtual Campus of NTNU in Second Life**

In the case study *Visualizing NTNU Research Areas and Projects*, the students were asked to build in Second Life a construction representing one of the research areas, a project or a course taught at NTNU as a part of the Cooperation Technology course [22]. Six groups of 3-4 students each built 5 constructions: Museum of NTNU History, Medical Center, Student House Studentersamfundet (2 groups), Museum of Modern Art and DNV Fuel Fighter, an award-winning student research project showing a 3D model of a fuel-efficient car with corresponding information (Fig. 6).

All these constructions supplement the environment of the virtual campus, but at the same time, working on these constructions, the students visualized abstract concepts, activities and created information spaces as well.

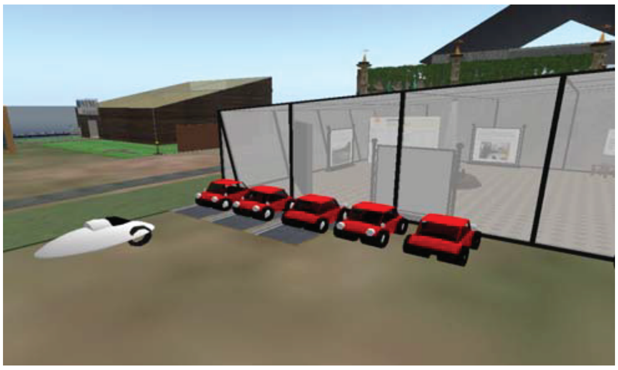

**Fig. 6. DNV Fuel Fighter project with car models**

Constructing their environment, Norwegian students aspired to resemble reality where possible. However, they found, realism designs have both positive and negative aspects. Visiting groups of foreign students, invited to comment on their constructions, suggested the introduction of less 'realistic' elements into the virtual campus. The visitors paid more attention to user-friendliness of the constructions than to their 'realness'.

This case study reinforced some of our earlier results [23]: that a student environment should be well-organized and to a certain degree resemble the structure of its physical corollary. At the same time, it should be flexible to allow modifications from the users and include abstract features, where it is necessary to enhance a more efficient educational experience.

All the constructions imposed certain space demands, filling the area allocated to the Virtual Campus. This needs to be considered during the planning phase and the construction process.

## 3. Discussion

Though the presented case studies had different goals and settings, they all considered educational visualizations in some way or another. Based on the results of these case studies, we investigated how educational visualizations can be used more efficiently in 3D virtual environments. In this section we discuss aesthetics, functionality and the expressed meaning of 'visual shells' that students used in their visualizations. We also explore how the students filled these shells with different types of content. We conclude with consideration of the role of the 3D CVE platform in the constructive work.

### 3.1 Visual Shells

By *visual shell* in a 3D CVE we mean a way of organizing, presenting and structuring content, for example in the form of a virtual museum. 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. Shells are especially important in 3D virtual environments, considering their plentiful visualization opportunities. A 3D CVE can itself be considered as a special kind of shell for presenting content in comparison with other technologies.

*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). On many occasions, the students spent a significant amount of time and put a lot of effort into making their constructions as elaborate as possible, in order to impress their peers that were voting for them at the end of the construction period. A lot of attention was paid to detail, such as interior decoration, furniture, lighting effects, art displays on the virtual walls and other items supporting a special atmosphere, such as 'torches' inside a construction resembling a medieval castle, and so on.

On many occasions, these elaborate constructions had very little or nothing to do with the topic of presentation (such as a medieval castle hosting an exhibition dedicated to the 'awareness' concept). In some cases, the choice of the design was governed by the availability of other peoples' constructions that could be copied and reused. In Active Worlds, we had cases of copying or getting inspired by designs used by neighbors. In Second Life, students to a significant degree used pre-made building stones and constructions that they obtained for free or bought for 'Linden dollars at various 'marketplaces' within the Second Life universe.

On the other hand, *Functionality* was in some cases in conflict with the aesthetics aspect of student constructions. This included elements such as furniture, doors, stairs, lighting, sound and various 'fancy' items serving as obstacles, complicating navigation and diverting attention from the actual content being displayed. Apart from diverting attention, when the overall design was not consistent with the presented content this made navigation within the construction and accessing the content less intuitive.

It is interesting to note that the constructions that were voted highly by their peers were those that provided a simple structure (such as separate virtual houses for different subtopics), often at the expense of less 'aesthetic' constructions. Another category appreciated by their peers were those constructions that followed well-known metaphors such as the 'museum' (Fig. 3), with clearly structured exhibitions and navigational paths (e.g. with arrows) through them, as well as a 'traditional' way of displaying exhibits.

*Expressed meaning* was another aspect of the visual shells. Apart from aesthetics and functionality, the appearance of the constructions symbolized something. For example, the different designs of Babel towers symbolized cross-cultural understandings between students from the different participant nations (Fig. 4). Here, the students could mediate the symbolic in different ways, not only as an 'authentic' tower, but also more schematically like a set of endless stairs to reflect the 'reaching heaven' idea of the parable.

The aspect of meaning might on certain occasions be in conflict with its aesthetics and functionality. Creating realistic and meaningful constructions or shells often required a significant amount of effort and planning. Meaningful constructions often had a rigid structure, but the expressed meaning contributed to a better understanding of the content that was inside. At the same time, shells with simple structures were more flexible, but did not necessarily add any meaning to the content.

Realism resemblance, such as the case with the NTNU Virtual Campus, could also be considered an *expressed meaning*, symbolizing the spirit of the university (Fig. 5). In this context, the existing structures of the campus that are built in real life years ago might not be ideal for the current educational needs. Also, the affordances of navigation and observation in a virtual world (e.g. flying) are often not very compatible with the realistic structures such as stairs and doors. Therefore, the visitors of the campus in the *NTNU Virtual Campus Construction* case predominantly recommended more functional, 'open' spaces, not necessarily realistic ones.

### 3.2 Filling Visual Shells with Content

*Visual shells* are filled with different kinds of content, like museums are filled with exhibits and decorative elements such as furniture. In the presented case studies, information was presented inside the shells in different modes: text, multimedia and 3D symbols. Continuing the parallel with museums – besides exhibits in the form of 2D text posters and graphical images, simple or complex 3D objects – the students created 3D 'installations', 'dioramas' or '3D cartoons' (Fig. 2). These represent different scenes for easy-to-understand 'enactment' of the chosen concepts. Exhibits had different degrees of interactivity, including: sound, quizzes, video and animations.

It is necessary to consider the duality and, in some cases, antagonism between 2D and 3D content. Text is straightforward, while the meaning of 2D graphics and especially 3D symbols might often be unclear and ambiguous without proper explanation (e.g. representing a cross-cultural process in the form of a Babel tower). At the same time, 3D is, in many cases, more vivid and appealing than text, while graphics is somewhere in between. From the student feedback, we found students acknowledge the ability of 3D CVEs to visualize ideas and make associations in different ways than in an 'ordinary' 2D workspace or reality. For example, "CVEs offer a more creative approach to the representation of information that most other easy-to-use media do. One can more easily find different ways to express information and by this offer more different perspectives on one topic" [20].

As opposed to a museum where an exhibition may be mostly static and prepared in advance by the staff, the virtual constructions and exhibits constructed by the students were dynamic, carrying traces/'crystallizations' of their activities in terms of notes left, annotations, created objects, chat records, and so on.

### 3.3 Platform Issues

The case studies show that the availability of appropriate building blocks is important for facilitating a successful construction and visualization process. Active Worlds (AWs) includes a predefined library of building blocks that can be extended by objects designed by 3rd party tools and added to the 'object path' by the administrator (after conversion into the AW-compatible format). This process can be cumbersome. Though it is relatively straightforward to start building with a minimal amount of instruction needed, the limited, standard choice of building blocks included in AWs may present a hindrance to creative expression. For example, the group that created the 'Communication museum' (Fig. 3) noted that they had to "put the pictures of what we missed into frames. Therefore we missed some of the usefulness of 3D, but still got our thoughts and ideas illustrated". Students also complained that the available building blocks mostly included objects of a Western aesthetic (e.g. models of castles but not pagodas). Generally, students were quite inventive in terms of finding substitutes. In addition to the 3D objects for image substitution, they used metaphors such as 'a lot of PCs' as a visualization of chat. Furthermore, due to the specific way of building new objects in AW (by copying objects and converting them into other ones), students had to copy the work of other students while working on their assignments. The consequences of this were both positive and negative: from cross-pollination of ideas, collaboration, sharing and development of content to passivity and plagiarism.

In Second Life (SL), the platform also has several restrictions [24]. These include working with 3D objects, such as size, importing objects, the total amount of objects per island and others. However, the advantage of Second Life compared to Active Worlds is that every user is able to create their own objects without having to use external tools. In addition, vast libraries of user-created objects are available for free and for sale in virtual shops in the Second Life universe. Such pre-made objects were extensively used by the students during the *NTNU Virtual Campus Construction* case study.

Nonetheless, the limitation of Second Life compared to Active Worlds is higher resource demand and a steeper learning curve for users. It is difficult to import 3D objects from 3rd party tools into SL that some students might prefer from their previous experience. SL's inbuilt editor has a number of limitations as stressed in [22]. Also, as opposed to AW, displaying text and images in SL is not straightforward and requires importing 'textures', something one needs to pay for. The vast availability of pre-made objects (such as whole houses) in one way makes building faster, as whole houses might be raised quickly once the students have them in their inventories. On the other hand, this method of building often required much less elaboration than the one used in AW. As students spent less time and effort on planning, designing and actually raising the construction, the corresponding educational gain from the collaborative elaboration of content may be less than that in AWs.

## 4. Implications

In this section we present the major implications for using 3D CVEs for working on educational content and for educational visualization, and provide some recommendations for educators that may consider adopting this technology as a part of their own everyday classroom activities. These recommendations concern the choice of technologies, the content to work on and ways of presenting the chosen content. It is important to realize that all these choices are highly dependent on the chosen educational contexts and situations and therefore need to be considered carefully in individual cases.

### 4.1 Choosing Suitable Technology

As discussed earlier, the technology behind 3D CVEs has a number of limitations. Therefore, in some educational situations, using of 3D CVEs might not be the best choice. Other collaborative tools may be more suitable. For example, in cases where students predominantly work on text documents and know each other well, document sharing facilities such as Google Docs and IM tools such as MSN and Skype may be more appropriate. In addition, one has to keep in mind the existing tools used at the educational institution in question (e.g. Learning Management Systems) and tools used already by the students in their daily life (such a mobile phones). If the use of a 3D CVE appears too disruptive for established practices, the usefulness of this approach will be limited. As for creating content in 3D CVEs, this demands more effort than when using other technologies. Hence, careful planning is required beforehand.

The choice of 3D CVE is justified when one is working on predominantly 3D content (visualizations, 3D modeling, recreating objects from reality, simulations). Such technology is also relevant when learners are geographically distributed, are not well acquainted with each other and when a sense of presence and immersion is important (e.g. in roleplay as a part of history and theater classes). When choosing technology from existing platforms, one has to keep in mind the following aspects:

- Available bandwidth and computational resources

- Available resources for user training
- The required variety of 'building blocks'
- Dependability on external 3D modeling tools
- The need to collaborate with existing projects (and therefore choosing the same platform)

### 4.2 Choosing Suitable Content

The presented cases showed that sharing and 'storing' ideas in a 3D environment has many different aspects, depending on the type of message. For example, it is relatively easy to make a good overview in 3D CVE of a small topic with posters and objects, while a large amount of information is difficult to store due to the long time it takes to 'walk' through it in the 3D world. The commonly chosen solutions, such as putting in a lot of links to online resources, were evaluated as too cumbersome. Also, it was generally agreed that abstract concepts and pure theory is difficult to present in a creative way, compared to e.g. a demo on "building a boat".

One of the groups in the *Displaying Abstract Concepts* study mentioned that in a 3D CVE "it may be easier to create associations than explaining thoughts." However, when the choice of the visualization objects is limited and ambiguous, the associations intended by the designers may not correspond to the ones of the audience. This is especially relevant when representing visually certain non-concrete concepts such as awareness and cross-cultural understanding as opposed to e.g. chemical molecules, car models and models of existing buildings (e.g. campus buildings). Even if the observer has a good imagination it does not always follow that he or she will interpret it in the way intended. On the opposite, the constructions where the theoretical concepts are explained with concrete, unambiguous examples, such as 'Communication museum' (Fig. 3) and '3D cartoons' from everyday life illustrating awareness (Fig. 2), were highly appreciated by the peer students.

To conclude, it is easier and more straightforward to work on and visualize concrete educational content such as 3D models of existing entities in reality or (e.g. fuel-efficient car, as in Fig. 6). However, educators may in many cases benefit from visualizing abstract concepts as well if planned carefully. Necessary measures might include preparing a visual 'glossary' or a set of building blocks and introducing certain rules (visual 'grammar') for using these building elements.

### 4.3 Choosing Suitable Presentation Form

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: text, images, 3D objects and '3D cartoons' and 'dioramas'.

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. making the meaning of the visual shell in accordance with the displayed content. One of the groups in the *Displaying Abstract Concepts* study 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". If too much attention is paid to the meaning expressed in the construction, flexibility is reduced and a significant amount of advance planning is required. For example, if students design a thematic exhibition dedicated to ancient Egypt with the *visual shell* in the form of a pyramid, it would be difficult to extend such an exhibition or reuse it for a different theme. The same applies to using models of existing campus buildings for housing students' exhibitions.

This is especially relevant for platforms like AW as opposed to SL where the use of an inventory of building blocks makes changes in the constructions more straightforward. This is one of the reasons why many groups in the *Displaying Abstract Concepts* and *Visualizing NTNU Research Areas and Projects* case studies chose to simplify their constructions and designed a *visual shell* or theme (such as a castle or a house) where the content presentation was unconnected to the former, such as placing signs or images in the rooms, resulting in "symptomatically too little creativity and originality" [20]. When filling the constructions with exhibits, in many cases, students tended to oversimplify – using pictures and text instead of 3D objects. A related aspect was the possibility to connect information, often as links to external resources, to the visual objects. The usefulness of this depended, however, on how "good the user is to make intuitive connections between the information and the object" [20].

To overcome the problems outlined above, we recommend creating an extended library of standardized building blocks, preferably adjusted for the particular educational situation (where, for example, object dimensions are standardized, allowing students to easily and flexibly exchange 'visual shells' according to the theme of their virtual exhibition). In this way, it is possible to find a balance between aesthetics, functionality and meaning without sacrificing flexibility of construction.

## 5. Conclusion and Future Work

In this paper, we focused on collaborative construction of educational visualizations and elaboration of 3D educational content in 3D Collaborative Virtual Environments (CVEs), analyzing results from a number of earlier case studies in Active Worlds and Second Life. Based on the results from these case studies, we discussed various aspects of presenting educational content in a 3D environment, such as aesthetics, functionality and expressed meaning, various design solutions adopted by students in their constructions and the challenges they faced. We outlined the implications for using 3D CVEs for working on educational content and visualizations, providing some recommendations for educators.

Future research will include further investigations on the educational use of 3D CVEs. To resolve some of the identified problems that students experienced during collaborative construction activities, we are currently developing a Creative Virtual Workshop (CVW), a special tool/framework for constructing, storing and presenting 3D educational content in CVEs.

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# Paper 5

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# Paper 6

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| **Authors:** | Mikhail Fominykh and Ekaterina Prasolova-Førland |
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# Virtual Research Arena: Presenting Research in 3D Virtual Environments

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**Abstract:** The paper presents Virtual Research Arena – a framework for creating awareness about educational and research activities, promoting cross-fertilization between different environments and engaging the general public. In the paper, we present initial results of an explorative case study where we apply the framework. The study includes a practical exercise in cooperation technology course and the first Virtual Science Fair in Trondheim, Norway. The data collected during the study are analyzed to explore the technological, educational, social and other issues of using 3D Collaborative Virtual Environments for visualizing research projects and promoting research to the general public. We also present how the current studies fit into our previous research on supporting learning communities in 3D collaborative virtual environments. The paper concludes with outlining future development of the Virtual Research Arena.

## 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, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2009).

One of the reasons is the potential and possibility of such environments for supporting collaborative work with various types of content, as discussed in several studies (Arreguin, 2007; Atkins, 2008; Hwang, Park, Cha, & Shin, 2008; Nederveen, 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 have discussed in (Prasolova-Førland, Fominykh, & Wyeld, 2010b). As it is noted in (Bessière, Ellis, & Kellogg, 2009), content can be 'objects, places, activities' or any valuable information or experience. CVEs allow creating complex interactive content and use it collaboratively for various purposes. 3D CVEs allow learning communities to create content and leave traces of their activities that become part of the shared repertoire of the community through the process of reification (Wenger, 1998).

Another important reason is an opportunity for participants to interact in a way that conveys a sense of presence (Park, Hwang, & Choi, 2009), lacking in other media (Kelton, 2007). Users are represented by avatars and act in a shared 3D space that gives them awareness of each other's actions. Communication is usually presented in the form of gestures, text-based chat and in-voice chat and allows using CVEs for meetings, performances and role-playing (Sant, 2009). These opportunities result in a number of benefits for establishing and supporting learning communities (Bronack et al., 2008) and in the potential for supporting cross-cultural understanding and collaboration (Wyeld & Prasolova-Førland, 2006).

A growing number of education- and research-intensive institutions have started using CVEs for presentations and promotions, conferencing, sketching, training and other purposes. For example, promotion of the organization is one of the primary reasons for nonprofits establishing their presence in CVEs (Bettger, 2008). Conducting presentations in CVEs is becoming more popular and common and although the technology has some limitations, the potential is apparent and highlighted for example in (Yankelovich & Kaplan, 2008). Advanced universities are building full-scale, highly realistic virtual campuses with various functionality (Prasolova-Førland, Sourin, & Sourina, 2006). Other organizations that are using CVEs include research centers, libraries and museums. In the industry, many companies, such as IBM, Sun and Cisco, are using 3D CVEs and investing in research and development of new environments.

The virtual world Second Life is one of the most successful CVEs at the moment (www.secondlife.com). It remains one of the most stable, developed and populated, though it has certain limitations, as stressed for example in (Crowther & Cox, 2008) and (Bowers, Ragas, & Neely, 2009).

In this paper, we investigate the possibilities of CVEs for learning communities and continue exploring how to support interconnected aspects of city life in an integral virtual environment, experimenting with the area of education and research. In particular, we focus on visualizing and promoting research projects and engaging general public. We present a qualitative analysis of data from an exploratory case study that involved students from a graduate cooperation technology course, researchers and general public.

Despite the great opportunities of CVEs for visualization and the importance of presenting and promoting research, there are few studies in this area (Djorgovski et al., 2010) and the body of knowledge on educational studies in CVEs has not developed enough (Campbell & Jones, 2008). Therefore, the main goals of this paper are: first – to demonstrate that CVEs can be successfully used for presenting and promoting research projects and guide education- and research-intensive institutions in this area and second – to present an improved framework of the Virtual Research Arena (VRA) that is designed to integrate research community into society with its different aspects.

The paper is organized in four sections. In the next section we present the concept of Virtual Research Arena and outline its initial use in Norwegian Science Fair and in the practical exercise of cooperation technology course. In the following section we discuss the results of the studies, showing the impact, value and possible application of the VRA and the ideas behind it. In the last section, we outline directions for the future development of the Virtual Research Arena and conclude the paper.

## Visualizing research projects

The work presented in this paper was conducted in the Virtual Campus of Norwegian University of Science and Technology (NTNU) in Second Life. Despite the criticism we mentioned, Second Life platform was chosen as it is the most common technology of choice for such educational projects, including other pre-existing Norwegian projects, such as Second Norway. The campus and previous studies there were described in (Prasolova-Førland, Fominykh, & Wyeld, 2010a; Prasolova-Førland, et al., 2010b).

### Virtual Research Arena overview

In this paper, we present initial results of implementing and using Virtual Research Arena – a framework for creating awareness about educational and research activities, promoting cross-fertilization between different environments and engaging the general public. The idea of the Virtual Research Arena emerged after we were invited to participate in an annual scientific festival and present our work there. Our goal was to attract scientists who wanted to demonstrate their work on the festival in a virtual mode and to build visualizations of their projects (Fig. 1).

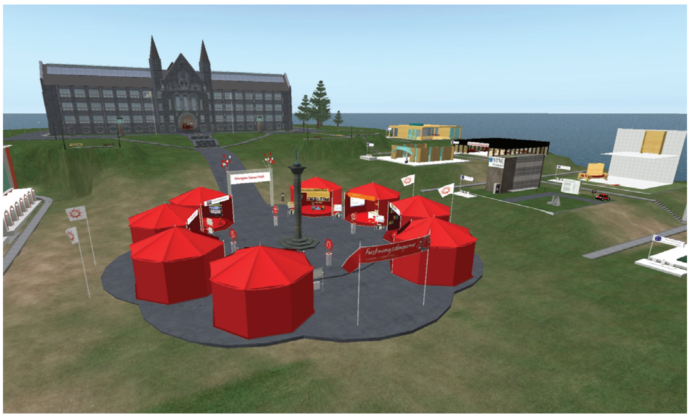

**Figure 1:** Virtual Research Arena in the Virtual Campus of NTNU

In the previous research, we were exploring collaborative work on 3D content in a virtual campus and virtual city context. The VRA contributes to the conceptual framework 'Universcity', in which we seek to integrate different aspects of city life, such as culture, society, education and entertainment (Fominykh et al., 2010). We consider 'Universcity' as an integral/holistic organism, since in reality all these aspects are interconnected. The 'Universcity' framework has 4 layers that correspond to the aspects of city life. Each layer has its own specifics and major infrastructure elements or facilities (Fig. 2). These elements of the environment are designed using a tool called Creative Virtual Workshop or CVW that we previously proposed and described in (Fominykh, et al., 2010). In the core of CVW lies collaboration around 3D content that includes creating, sharing, exhibiting, annotating and other manipulations. CVW functions as a pattern for creating infrastructure elements/facilities of the 'Universcity' in such a way that they are connected to all the layers. The VRA functionality was designed based on the basic ideas of CVW.

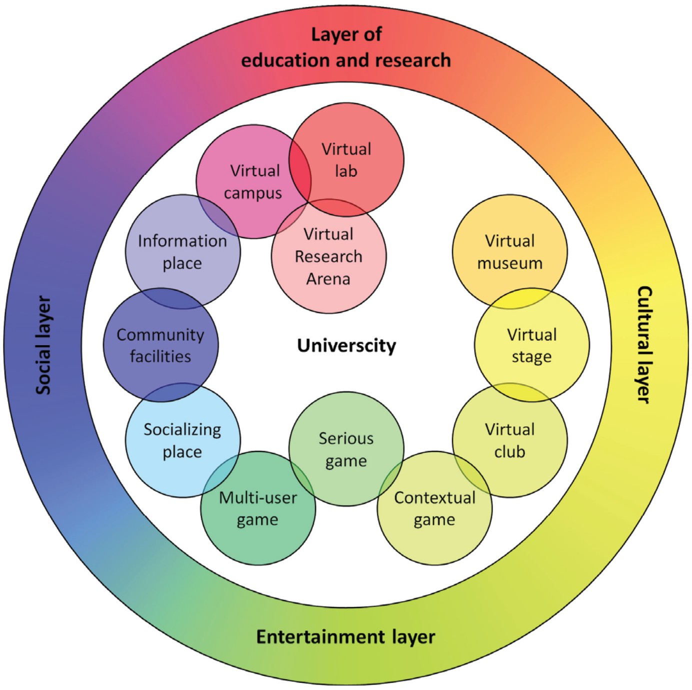


**Figure 2:** Virtual Research Arena in the 'Universcity' context

In the following, we present the use of VRA in Norwegian Science Fair and in the cooperation technology student exercise.

**Presenting research projects at Norwegian Science Fair**

Norwegian Science Fair in the city of Trondheim is a part of Norwegian Science Week, an annual festival. The goal of this event is to present science projects to the general public. In Trondheim, which is recognized as a 'student city' and a 'technological capital', the festival is organized in pavilions on the central city square. At this science fair, a number of researchers present their work in appealing yet simple ways.

In September 2010, a virtual science fair was erected in Second Life to mirror the one in reality. One of the major city landmarks – King Olav Tower, was reconstructed in the virtual science fair on the virtual 'central square', in the same place where the fair was organized in reality, to create a familiar atmosphere for the local visitors. At the same time, the Virtual Science Fair could be visited from around the globe through Second Life. In this way, it contributed to creating a meeting place for researchers, students and public. Moreover, while the physical pavilions at the fair were deconstructed at the end of the event after two days, the virtual pavilions have been preserved and available for future use.

Furthermore, the Virtual Science Fair was presented at the fair in real life as one of the projects. The visitors in the real life could come to the pavilion and immerse themselves into the virtual extension of the fair, exploring a number of projects (Fig. 3). Such a mix of real and virtual is especially interesting and should be further improved, according to the feedback.


**Figure 3:** Real-life pavilion of the Virtual Science Fair in Second Life

The Virtual Science Fair in Second Life has 8 pavilions, each presenting a research project from NTNU and other research environments. Most pavilions presented major ideas of projects with posters, slides, video clips and links to web pages. Also, some interactive elements were used, such as teleports to other regions in Second Life, interactive models and feedback boxes. The following virtual pavilions were presented:

- “Virtual Eidsvoll” – an educational region in Second Life for studying Norwegian history;
- “ArTe New Media Art” – research and dissemination activities at the intersection of art and technology;
- “Middelalderens Nidaros i virtuell virkelighet” – a reconstruction of medieval city in virtual reality;
- EU project “TARGET” – a 3D virtual serious game;
- “WAVE” – Women Academics in Virtual Environments;
- “Multi-lingual text annotator Typecraft” – a free online tool for language experts and anthropologists;
- “Digital stil” – a project advertizing social networking and mobile technologies;
- “vAcademia” – an educational virtual world.

The number of people who visited the real-life pavilion of the Virtual Science Fair shows that this topic is interesting for the general public. An article dedicated to the Virtual Science Fair published in a national newspaper “VG” is also a sign of interest.

**Visualizing research projects at cooperation technology course**

In the autumn of 2010, we conducted a practical exercise in a course TDT4245 – cooperation technology in the Virtual Campus of NTNU. This is a regular exercise and we applied most of the lessons learned from the earlier work, especially from the previous case study conducted in 2009 and described in (Prasolova-Førland, et al., 2010a).

The data in the recent study was gathered from three sources of evidence: direct observation of students’ activities online, virtual artifacts, such as chat log and 3D constructions, and users’ feedback in a form of group essays. After the study, the data were qualitatively analyzed.

The recent study was carried out with 25 students in 7 groups, 2-4 students in each, both regular NTNU students (master and PhD level) and international students, participating in the NTNU international master program. The students were asked to build a visualization representing any research project and present it at a joint session by role-playing. This method is based on ‘constructionism’ (Harel & Papert, 1991) – an educational philosophy, which implies that learning is more effective through the design and building of personally meaningful artifacts than consuming information alone (Bessière, et al., 2009; Harel & Papert, 1991). 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 behavior in accordance with a specific role (Craciun, 2010; McSharry & Jones, 2000).

Prior to the competition, the students had a tutorial on Second Life in a classroom (for those who were located in Trondheim). Following this, they came online into Second Life, presented their project proposals, identified building spots and received additional training. The total building period was about 1 month. During this time we were available for questions and assistance both in a real-life computer-room and online in Second Life. Assessment was based on participation in the construction effort and on a group essay where the students reflected on their experience.

This year the exercise was conducted in conjunction with an "International Summer School on Collaborative Technologies, Serious Games and Educational Visualizations", organized by the EU TARGET project (http://www.reachyourtarget.org/). The summer school provided 2 virtual events: a seminar "Using Virtual Worlds to Improve Business Presentation Skills" by Judith Molka Danielsen and a seminar "TARGET EEU – A step toward new e-learning technologies", by Albena Antonova. Each of the seminars attracted 20-30 participants from different countries (China, United States, UK, Russia, Bulgaria etc.). TARGET announced a prize for the best student project, which was later divided between two groups that got an equal amount of votes. Almost finished student constructions were available in the Virtual Campus of NTNU during the Norwegian Science Week and demonstrated on the Virtual Science Fair.

During the joint session the students presented their projects in the form of role-plays, evaluated each other's constructions and received feedbacks from the visitors. The following provides an overview of the session.

*Group 1* created a programming history museum. The group constructed 4 floating platforms symbolizing eras of programming and presenting important concepts. Each platform has interactive schemes or challenging quests (for example reconstruction of a motherboard and if-then loops) as well as slides explaining the topic. For a role-play presentation group members appeared as robot-like avatars, guiding the visitors through the museum and explaining the central concepts.

*Group 2* visualized the effect of Kung-Fu training on health. The group created a very realistic and authentic Chinese-inspired environment that impressed the public, including Chinese visitors. The building was decorated with traditional Chinese furniture, an animated statue of Buddha, an authentic fireplace, a gong and other elements. Posters and slides on the walls provided information about the martial art and its influence on the human health. The leader of the group has an authentic avatar.

*Group 3* created and presented a research project "BP Solar Energy" – the biggest solar skin in Norway. The solar skin is located at the NTNU campus south wall and provides an additional energy supply. The students constructed a piece of wall with an interactive virtual solar skin that could be switched on and off, emanating light and thus visualizing conversion of the solar energy. The construction also included posters and slides providing more information about the project and presenting group members. The students also prepared a scenario and performed a role play highlighting the importance of solar energy and presenting the project in an informal yet informative way (Fig. 4).

*Groups 4* presented the work of the designer Enzo Mari called "Autoprogettazione" and who was known by using simple pieces of wood for constructing furniture. The group built several pieces of furniture and placed them in a workshop. The construction also included a presentation area showing a video clip and posters, providing additional information. During the performance, one of the group members impersonated Enzo Mari.

*Group 5* tried to visualize the idea of proposing prototypes and selecting the best solution. The construction included a room with a set of random interactive objects, and a half-working voting system. The presentation was done by simply naming "the prototypes" and soon became a discussion on the CVE technology.

*Group 6* created a visualization of a concurrent design methodology by constructing a "Concurrent Design Facility". The students sought to re-create real-life design facilities and built a room with a few tables and large screens on the walls for different expert groups. An additional screen displayed the central aspects of the presented methodology. During the presentation the group members played the key roles of facilitator, session secretary and customer, while the public was invited to be members of the expert groups. In such a manner, a demonstrative session "How to make a good project presentation in a virtual environment" was played.

*Group 7* visualized a project called "ArTeNTNU" that aimed at increasing knowledge about the interdisciplinary intersection between digital art and software technology. The students built a simple 2-floor building, filling it with posters, slides and web links with information about the artifacts created within the projects.

One of the *TARGET seminars* was held between the presentations. Most of the students and a number of international visitors participated in the event.

During the discussion in the end of the session, the central question debated was usefulness of 3D virtual environments for presenting projects. A group of students argued that using tools like Second Life requires too much time and effort, even though the presentation is more vivid and appealing. Another group was less critical and proposed that there is a number of cases where using a 3D environment is feasible and the effort spent is rewarding. Analyzing the chat log showed that the students learnt a lot about advantages and limitations of using CVE technology for collaboration and moreover they understand more clearly the roles of other tools and technologies.

**Figure 4.** BP Solar Energy project: role-play project presentation

After the sessions, the students had 2 weeks for reflecting on their activities in group essays. We provided a guideline for this task in the form of a set of points to discuss. According to the guideline, the students had to talk over potential use of their constructions, a number of aspects related to collaborative work and learning and other topics. In this paper, however, we explore the one related to the VRA design.

Evaluating general usefulness and the potential of the Virtual Research Arena in group essays, the students provided different opinions. Positive feedbacks were related to conceptual opportunities of the VRA, while the criticism was mostly focused on some imperfections of the current design and limitations of the technology. The potential of the VRA was mostly seen in promoting presented research environments by creating a socializing and gathering place around project presentations. Increased awareness among researchers, students, university departments, research groups, institutions and general public was emphasized as a way for promoting collaboration and an important opportunity. In the current VRA design, the students appreciated appealing reconstructions of real-life places.

[Essay citations]:
*VRA is a cost efficient, social place to meet researcher colleagues, and discuss with them in a natural setting.*
*It's easy to create a small interesting taste of a topic in VRA, and then link further to external information on the web.*
*We like that there are some physical and design similarities with the real "Norwegian Research Week" event.*

Many students expressed their appreciation for the global nature of the VRA and potential for supporting collaboration between researchers, students and general public.

[Essay citations]:
*People from other cities can take a look of what NTNU and Trondheim has to offer. VRA can be a source to trigger the willingness to visit Trondheim and NTNU.*
*This is an extraordinary way to promote collaborations among different projects. Using this approach new cross boundary projects may come out.*
*Visitors/Students from other places can also find it useful to discover the inner working of the university, visit some of the buildings and know the activities developed in the university by students and teachers.*

The negative impression was based on a general frustration about the early stage of the VRA development. Some were disappointed that proposed functionality is not yet implemented.

[Essay citations]:
*VRA does not provide any support for research activities, but it does provide the users with an interactive experience*

*The problems in this kind of technology are time required to make a presentation and a lot of system resources to use it smoothly.*
*The quality of objects is too undeveloped to fairly illustrate all types of research projects.*

Several technical comments were related to navigation problems, overage of objects and complexity for inexperienced users.

## Discussion

In this section, we discuss how the development of the Virtual Research Arena changed the students' experience. Furthermore, we discuss the context the VRA and summarize the major implications for presenting research projects in CVEs.

### Virtual Research Arena impact

Analyzing the studies presented in the paper, we noticed a change in how the participants reflected on their experience. In comparison to the previous study in the undeveloped campus (Prasolova-Førland, et al., 2010a), we observed several trends that were related to the development of the VRA and improvement of the study settings.

According to the observations and feedbacks, the students were inspired by the other constructions in the Virtual Campus, intentionally or not. They could explore existing project visualizations both from the previous year cooperation technology course and the Virtual Science Fair. There was no plagiarism since the topics were different, but the students could grasp some interesting and effective solutions and estimate approximate effort required. Reconstruction of several real places in the Virtual Campus helped the students to adapt to the environment and feel comfortable, as almost all the groups noted in the essays. According to the feedbacks, attracting attention to the neighborhood of the Second Norway region in Second Life encouraged some of the students to explore the region and expect visitors to their own projects.

Within TARGET summer school 2 virtual seminars were organized, which provided the students with an outlook of the latest trends in the area of CVEs. On the seminars, some recent and current projects were presented, from which the students could learn more about the practical use of the technology. Besides that, the students could experience how the virtual lecturing works in general, its benefits and limitations. Moreover, the summer school attracted some international participants, which resulted in a bigger and more independent audience. Another difference of the study this year was initiation of a prize for the best project.

The introduction of role-playing as a presentation method had also influenced the students' experience, according to their feedbacks. First of all, calling this activity "role-playing" placed more emphasis and improved the general attitude of the students. Although not all the groups did really play roles, the overall quality of the presentations increased. As distinct from last year's presentation, this time none of the groups reported the problem identifying who is presenting. The students prepared scenarios, some wore authentic avatars and many used voice chat in addition to the text. Moreover, the audience was expecting a play and therefore more focused. In many plays, the presenters engaged the audience into the play, which was appreciated both by the visitors and the students.

The VRA helped the students to extend their understanding of cooperation with the CVE technology. Discussing the possibilities and the future of the CVEs in essays, most of the groups mentioned their potential for supporting social networks and collaboration among various groups of people, institutions and countries. Describing scenarios of use for their own constructions, the students often considered them as a part of the Virtual Science Fair that is closely connected to the university and local community.

The study demonstrated the range of possible topics that can be visualized and also the variety of presentation methods. The topics included research projects or concepts from both technical disciplines and humanities. A number of different metaphors were used, including a museum, a gallery, a meeting room and a workshop. Construction presentations revealed the possibilities for immersing visitors into the project environment or process, live discussions and demonstrations.

Our observation of the students' work and their feedbacks can be summarized as a set of recommendations for presenting research projects in CVEs. The following recommendations are developed for teachers, instructors and technicians working with the CVE technology.

- Demonstrate the possibilities of the technology, including interactive elements, various types of content and ways of presenting information.

- Provide tutorials introducing technology basics and building resources for composing structures from ready-to use blocks.
- Involve presenters and visitors from different social groups, such as researchers, students and general public.
- Support activities in a virtual environment with real-life events or places to attract more visitors for both virtual and real-life environments.

**Conceptualizing Virtual Research Arena**

The results of the presented study contribute to 3 major areas that are connected by the VRA: first, collaborative work on 3D content; second, virtual campus as an environment for learning, researching and socializing; and third, virtual city as an environment integrating different aspects of city life. In the following, we attempt to form a concept of VRA out of our observations, experience and case study data.

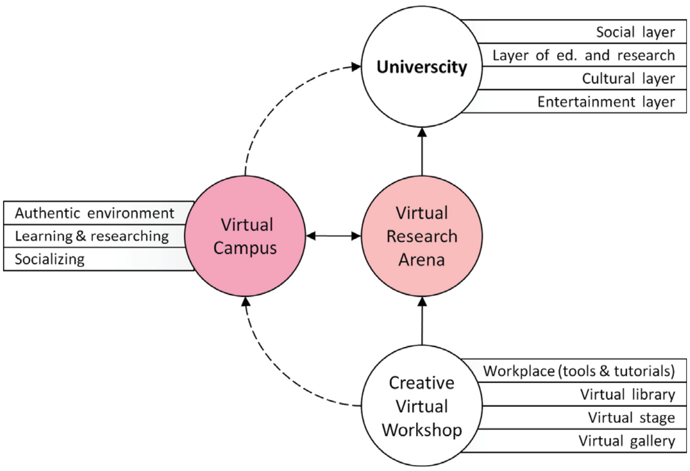


**Figure 5.** Virtual Research Arena context

*Collaborative work on 3D content* is the major activity that Virtual Research Arena supports. Tools and features that provide this support within the VRA are designed based on the basic ideas of CVW. The VRA has a virtual workplace equipped with tutorials and tools, providing assistance for control and navigation, communication and work with content. The workplace is linked to a library with ready-to-use 3D objects, textures, scripts and other resources. To provide support for sharing and presenting content, there is a virtual stage (under development), equipped with corresponding facilities, such as a slide-show screen and a place for presenting 3D constructions. The stage is surrounded by a virtual gallery (under development), which contains and exhibits constructions.

*Virtual Campus* framework was elaborated based on the results of the presented study. The Virtual Campus of NTNU was used as a venue for the study. It provided appealing atmosphere, tools and facilities for seminars, meetings and discussions. Besides that, the campus contains crystallized activities or traces (Wenger, 1998) from past events, creating a cultural component of the environment and a base for further development. In the virtual campus context, the VRA is a place, where students and researchers can try out their ideas, express themselves, create visualizations and exhibit them.

*'Universcity'* framework was improved based on the results of the study. In the 'Universcity' context, Virtual Research Arena and Virtual Campus are infrastructure elements. They represent the layer of education and research, which is considered for supporting educational/research activities and networks. At the same time, the VRA is connected to all other layers: cultural, social and entertainment. The VRA contributes to the cultural layer by attracting international visitors in the virtual environment and after that perhaps in real life as well. In the virtual city, the research arena is embedded into the architectural/cultural environment and replicates a real place. The VRA contributes to the social layer by connecting research environment and the general public. It allows scientists to present their work to the public, facilitates communication and creates awareness about the local and international research. For many people, visiting events within the VRA is an entertainment, since one of the main goals of the

arena is presenting scientific models and projects in an interesting and engaging way. The results of the study can be generalized and used for designing other infrastructure elements in all the layers.

## Conclusions and future work

In this paper we present the results of a case study conducted to evaluate the Virtual Research Arena framework. Conducting events both in the virtual environment and in reality, we collected empirical data and feedbacks from participants, including university students, researchers and general public. The results show the potential and possibilities of the VRA for supporting collaborative work with 3D content in the research area. In addition, the experience with developing and studying the VRA contributed to the Virtual Campus and Virtual City frameworks.

Future work will include more studies in the area of collaborative work and learning in 3D CVEs and further development of the Virtual Research Arena framework. We are planning to use the arena more widely in the city life and connecting it more clearly to other 'Universcity' layers. Furthermore, we have in focus strengthening the link between the virtual environment and reality and attracting more participants from various society groups.

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# Paper 7

**Authors:** Mikhail Fominykh and Ekaterina Prasolova-Førland

**Title:** Collaborative Work on 3D Content in Virtual Environments: a Methodology

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# Educational Visualizations in 3D Collaborative Virtual Environments: a Methodology

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**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.

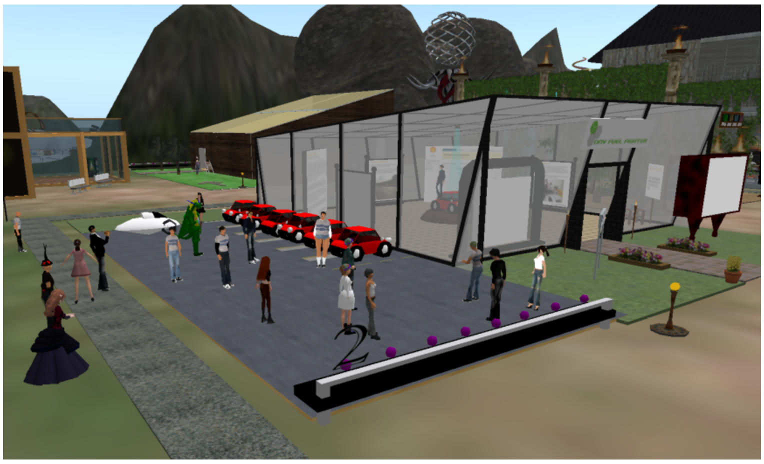

**Figure 1.** Student visualization project Fuel Fighter, 2009

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.

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# Paper 8

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**Title:** Collaborative Virtual Environments for Reflective Community Building at Work: the Case of TARGET

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# Collaborative Virtual Environments for Reflective Community Building at Work: the Case of TARGET

Leif Martin Hokstad * Ekaterina Prasolova-Førland * Mikhail Fominykh

**Abstract** In this article, we present initial results of designing a community, outlined in the TARGET framework. The main aim of the TARGET project is to research, analyze, and develop a new genre of technology enhanced learning environment – a reflective learning community integrated at the workplace that supports rapid access to competence development of individuals, namely knowledge workers within the domains of project management and sustainable manufacturing. The open question was: To what extent can 3D collaborative virtual environments facilitate *reflective dialogue* in communities to support lifelong workplace learning? One possible answer is given in this case. The empirical study is held as a part of the TARGET International Summer School, which acted as a forum for the presentation of innovative approaches, developments, and outcomes of research projects. The results of the study were analyzed to complement the TARGET community, seeding methodology as well as to provide implications for the use of 3D collaborative virtual environments for community building. In addition, TARGET illustrates how learning and working might be well integrated.

**Keywords** Computer support * 3D collaborative virtual environments * Communities of interest * Community seeding methodology * Second Life

## Introduction

TARGET is a large university and industry project, involving seventeen European countries, focused on the creation of a serious game for competence development in the areas of project management and sustainable manufacturing (www.reachyourtarget.org).

In this article, we describe and discuss in detail the merits and results of using the TARGET International Summer School as a means to create a community in the workplace. In addition, we discuss initial results of a community seeding methodology, outlined in the TARGET community framework. We conducted a study in the virtual world of Second Life involving students, partners, and international visitors. The Summer School acted as a forum for the presentation of innovative approaches, developments, and outcomes of research projects in the areas of technology enhanced learning, serious games and collaborative technologies, facilitating the exchange of ideas between students, researchers and practitioners.

## Background

The TARGET project has emerged out of a realization of the need for continuous learning, continuous adaption to changing market needs and the development of new skills and practices. Innovation and organizational development is perceived as intrinsically connected to the ability of an organization to learn. In turn, learning is seen as a collaborative endeavor that needs to transcend or extend the individual aspects of learning. The transfer aspect of learning is seen as limiting, and learning is in this perspective seen as directly connected to the workplace and the challenges and affordances in the working context.

The challenges identified in the TARGET consortium may be identified as gravitating around the following:

1. The in-demand nature of needed knowledge for innovation and development
2. The need to develop knowledge on an collaborative, organizational and not solely individual basis
3. The need to develop *in situ* knowledge, that is, knowledge that emerge from local needs and depends on the solution of the available local resources (i.e. time, human power)
4. The need to develop networks and pathways between clusters of knowledge in ever-changing organizations
5. Developing the "lived curriculum" as a basis for learning
6. Providing mechanisms and affordances for the dissemination of knowledge through reflective practices, and securing means for the flow of knowledge across the organization

The learning efforts thus are both related to the dissemination of existing knowledge, and to developing pathways for knowledge dissemination to parts of the organization where there has been little or no exchange of knowledge. In addition, learning across organizational boundaries and across disciplines is perceived as necessary for the development of new services and products.

The TARGET consortium also sees the need for developing methodologies and practices for developing knowledge that not yet exist in the organization. As such the knowledge perspective adopted here rests on what Gibbons et al. have termed Mode 2 knowledge (Gibbons et al., 1994). Gibbons et al. distinguish between Mode 1 and Mode 2 knowledge production. Whereas Mode 1 represents traditional knowledge, reflecting the classic academic hierarchies, Mode 2 knowledge is developed in an interaction between different actors from science and industry. Typically, this kind of knowledge is developed out of a defined problem or a given context, and is consequently interdisciplinary and rests on both theoretical and practical input. Mode 2 knowledge is also connected to its immediate application, and the interplay between development and application. In a very real sense, learning is not separated from the development of knowledge and its application. Although the individual and social aspects are present in all type of learning and knowledge production, to Gibbons et al. the individual drive is seen as the dominant in Mode 1 knowledge production, and the social or collective drive is seen as dominant in Mode 2 knowledge production (Gibbons, et al., 1994). The topics chosen in the TARGET game scenarios, i.e. topics from project management negotiation and sustainability all have the characteristics of being situated in the organizational context.

To the present context, the most important components of the TARGET project draws upon in the design of the TARGET learning environment are the following:

- Threshold concepts
- Learning communities
- Serous games and 3D collaborative virtual environments

These are discussed in more detail below.

## *Threshold concepts*

The emerging and promising framework of 'threshold concepts' is applied as a means of organizing learning content within knowledge ecosystems across corporate and educational environments (Meyer, Land, & Baillie, 2009; Meyer, Land, & Smith, 2008)[1]. To be brief, threshold concepts are components of the learning content that address the difficulties and challenges from the perspective of the learner, and focuses upon the relation between the learner and the content of learning. Threshold concepts have the following characteristics:

- Transformative – it means changing the way the learner thinks about a given subject
- Irreversible – it means once learnt it cannot be "unlearnt" or forgotten
- Integrative – it means previously hidden interrelations are exposed to the learner

At the same time, threshold concepts represent aspects of knowledge that are troublesome, and may initially be perceived as counterintuitive. Coming to terms with threshold concepts frequently position the learner in a state of liminality or unrest, during which the learner will oscillate between a previous understanding and an emerging, but not yet fully appreciated understanding. The period is characterized by unrest and frustration for most learners, and may be compared a troublesome or painful rite of passage. The nature of a threshold concept is frequently connected to tacit knowledge, and threshold concepts are embedded in the relations between participants and practitioners in communities. Consequently, they are hard to pinpoint for the newcomer, and the participation in a game with supportive community tools may facilitate and ease the transition into this knowledge landscape.

In cross- and interdisciplinary work, threshold concepts are likely to occur to the learners, because they are constantly exposed to and expected to transcend the limits of their own discipline. The desired outcome of the learning process is that new knowledge or new combinations of knowledge from various sources, theoretical or practical, is developed.

Examples of threshold concepts identified in the TARGET consortium, relevant for project management, are connected to negotiation, stakeholder analysis, and sustainability.

## *Learning communities – the community landscape*

Establishing and nurturing vibrant learning communities is seen as a highly complex process (Wenger, McDermott, & Snyder, 2002; Wenger, White, & Smith, 2009). Yet, at the same time, such communities are seen as highly important in developing and spreading new skills, insight and innovation (Johnson, 2010). To the TARGET project, developing a methodology for practical guidelines for the creation of a variety of possible communities is an essential part of the work. Traditionally, Communities of Practice (CoP) have been the most common form of community. Today, a gamut of community realizations may be identified and described. The opposite ends of the gamut the affiliation centers on the metaphors of 'belonging' and of 'connecting'. Whereas communities of practice emphasize the static state of belonging and homogeneity, newer collaborative entities are characterized by their emphasis on connections, networks, and heterogeneity. To the latter category Engeström contributes with the notion of mychorrihaze, a biological metaphor for networks that interact with its surroundings (Engeström, 2007). Perceiving the collaborative grouping as an interacting and interdependent entity, Engström describes

[1] The authors would like to recommend Dr. Michael Thomas Flanagan's webpage for an update on the activities and research connected to threshold concepts: http://www.ee.ucl.ac.uk/~mflanaga/thresholds.html

such structures as “both a mental landscape and a material infrastructure” for the participants (Engeström, 2007).

Drawing upon work by Hughes, Jewson and Unwin, Fuller and Engström, one may suggest that the typology above rests on a historical and evolutionary understanding of collaboration patterns (Engeström, 2007; Fuller, 2007; Huges, Jewson, & Unwin, 2007). Each type or realization is situated in a specific historical context, and reflects that context. Yet, rather than representing sharply distinguished types, each type tends to stretch into the next historical period, thereby constituting a continuum of development. Hence, the notion of a Community of Interest (CoI), as introduced by Fischer et al. seems to incorporate the variety and dynamism that is a typical feature of a modern workplace (Fischer, Rohde, & Wulf, 2007).

Describing Communities of Interest, Fischer et al. state that “CoIs bring together stakeholders … and are defined by their collective concern with the resolution of a particular problem” (Fischer, et al., 2007). CoIs can be thought of as “communities of communities” (Brown & Duguid, 1991) or a community of representatives of communities. CoIs are also defined by their shared interest in framing and resolution of a (design) problem, are more temporary than CoPs, come together in the context of a specific project and dissolve after the project has ended. According to (Fischer, 2005; Fischer, et al., 2007), CoIs have potential to be more innovative and transforming that a single CoP if they can exploit “the symmetry of ignorance” for social creativity.

Stakeholders within CoIs, as in the TARGET consortium, are considered as informed participants (Brown, Duguid, & Haviland, 1994; Fischer, et al., 2007), being neither experts nor novices, but both. They are experts in their own domains when they communicate their knowledge and understanding to others. At the same time, they are novices and apprentices when they learn from others’ areas of expertise. Therefore, the major strength of CoIs is their potential for creativity (Fischer, 2000; Rittel, 1984). CoIs have great potential to be more innovative and more transforming than a single CoP (Fischer, 2001, 2005; Fischer, et al., 2007). To the TARGET context, this implies the utilization of the potential in the juxtaposition of different competences to facilitate innovation, and to develop new “across-line-of-service” products and services.

Overcoming distances in social creativity and supporting learning in CoIs requires externalizations (Bruner, 1996; Seymour Papert & I. Harel, 1991) in the form of boundary objects (Star, 1989) that have meaning across the boundaries of the individual knowledge systems, subcommunities or different CoPs that join together in a CoI for some purpose (Fischer, 2001).

Boundary objects serve these different systems or communities in situations where each of them has only partial knowledge (based on the symmetry of ignorance) and partial control over the interpretation of the boundary object (Arias & Fischer, 2000; Fischer, 2001; Star, 1989). In this way, boundary objects allow different knowledge systems and communities to interact by providing a shared reference that is meaningful within both parts. Such objects perform a brokering role involving “translation, coordination, and alignment among the perspectives of different CoPs“ (Fischer, 2001). Boundary objects are typically negotiated, dynamic and have emergent characteristics. Boundary objects, because of their emergent character, are also central in the development of a culture of reflective dialogue. In the TARGET context, based on the material from the industry partners, one example of a boundary object in project management would be ‘living with uncertainty’ (Karlsen, 2011). As a concept in project management, this comes across as a counterintuitive and troublesome part of the tacit nature of knowledge in this domain, where new or less experienced learners would look for methods that give predictability, check lists for actions and the like.

Central in this perspective upon community and the learning attempted in these environments is that boundaries between disciplines and knowledge domains are constantly re-examined, broken down, negotiated, and rebuilt. The boundaries between the disciplines and domains thus may be seen as *trading zones* for interdisciplinary activities (Klein, 1996). Consequently, learning depends on collaboration and co construction in a continuous interplay amongst the participants. These zones are where innovation and development may occur, but simultaneously these zones are difficult to access and grasp.

Since the joint construction of shared knowledge occurs in knowledge domains partly unknown to the participants, a transdisciplinary approach will involve threshold concepts, since the boundary objects typically are troublesome, sometimes counterintuitive, yet they integrate a certain set of beliefs, theories, and concepts.

### *Collaborative virtual environments (CVEs) and serious games*

Recently, there has been a growing interest in innovative forms of collaborative learning, such as serious games, that may be suited to provide memorable and transformational experiences in the workplace. Serious games are digital games that are driven by learning objectives. Such games can be deployed as test beds for Experience Management that are – so is the assumption – highly motivating and emotionally engaging, causing high and long knowledge retention.

Based on several sources (Bell, 2008; de Freitas, 2008), 3D collaborative virtual environments (CVEs) can be defined as three dimensional, multiuser, synchronous, persistent environments, facilitated by networked computers. Second Life is one of the most successful CVEs at the moment (www.secondlife.com). This virtual world remains one of the most stable, developed, and populated, though there are without doubt certain limitations. CVEs have promising potential for supporting learning communities because of their capability to provide a social arena where students, teachers and other stakeholders can meet and interact overcoming distances and different time zones (Chou, 2009; Helmer, 2007). On the longer term, the CVE becomes a container of artifacts used by the users for their daily social and educational activities, and traces left by community members as a result of their participation. These traces become a part of the shared repertoire of the community through the process of reification (Wenger, 1998).

Establishing and supporting learning communities is additionally supported in CVEs by an enhanced sense of presence (Bronack et al., 2008; Park, Hwang, & Choi, 2009) and a possibility for collaborative work with various types of content (Atkins, 2009; van Nederveen, 2007).

## The TARGET Platform – Learning at Work

The components of the TARGET platform consist of a 3D collaborative virtual environment focused on a serious game application where learners may interact and discuss amongst themselves through their avatars, supported by dedicated Web 2.0 tools, leading to the maturing of the associated knowledge ecosystem of the organization(s).

The center of the platform is an engaging story where each learner has their personal experience based on their unique decisions thereby affecting the situated context where their avatar is immersed. Plans of personalized learning are construed from tailored made stories that address the particular needs of the individuals, leveraging the narrative building blocks imbued with the corporate experience of industry such as Siemens and Nokia.

Games scenarios that are being developed are related to stakeholder management, negotiation scenarios, and cases involving sustainability issues. All scenarios are based on empirical material developed in the project consortium together with industry partners.

The purpose of the TARGET project as a whole is to account for and incorporate in the in-service training programs the knowledge in a company that is crucial to the operation of the business, but which at the same time is difficult to capture and to disseminate throughout generations of employees. In this project, learning at the workplace means to activate the 'tacit knowledge' of different employees and stakeholders about 'project management' (e.g., how to organize, coordinate projects).

The data collected from industry partners Siemens and Nokia and university partner Norwegian University of Science and Technology gave the background material for what kinds of scenarios the consortium wanted to develop. In these organizations, project management courses have been offered for a long time, and evaluation material from the courses was made available to the consortium. The material was analyzed within the threshold concept framework to deduct what the most difficult concepts in the development of competence in project management. In turn, these concepts were used to design the game scenarios, and incorporating the accumulated experience in the kind of situations and challenges that the player shall experience. The main point here is that the content and game design is deeply rooted in the experience of the organizations that partake in the consortium. Furthermore, the game will be deployed in the very same organizations as a part of the ordinary in service training programs and teaching. In a very real sense, this is knowledge stemming from the workplace, developed and deployed in the workplace.

## *TARGET International Summer School*

The TARGET International Summer School in Second Life acted as a forum for the presentation of innovative approaches, developments, and outcomes of research projects in the areas of technology-enhanced and workplace learning, serious games and collaborative technologies, facilitating the exchange of ideas between students, researchers and practitioners. The design of the Summer School activities is intended to suggest possibilities as to facilitate *reflective dialogue* in communities.

The virtual format of the Summer School demonstrated the possibilities of modern educational technologies for working and learning. Participants were able to unleash their creativity and express their ideas in a new way, demonstrating research projects to peers, experts and other visitors as well as getting feedbacks. Second Life was chosen as preliminary environment to demonstrate and try out different ideas and concepts within the TARGET framework. It was also used as a 'proof-of-concept' in order to test out community seeding methodology proposed by the authors in the context of organizational learning in a highly diverse consortium. The diversity of this consortium that consisted of several partners from both industry and academia provided yet another motivation for the organization of the Summer School, i.e. creating bridges between these different communities and, correspondingly, different approaches to learning.

During the Summer School, we conducted a number of events and activities, both in a virtual environment and in real life. Virtual Campus of Norwegian University of Science and Technology (NTNU) in Second Life provided a venue for the virtual world part of the Summer School and a number of tools to support all the associated events.

A central part of Summer School has been a student project competition that focused on creating visualizations of research projects and presenting them to the audience through role plays. The goal of these activities has been to explore innovative aspects of the CVE technology, focusing on community building and collaborative construction, and sharing of knowledge. This method is based on 'constructionism' (Seymour Papert & Idit Harel, 1991) – an educational philosophy that implies that learning can happen most effectively through the design and building of personally meaningful artifacts (Papert, 1986; Seymour Papert & Idit Harel, 1991).

These projects were performed in cooperation with a cooperation technology course at NTNU. The participants of the student project competition included 25 students in seven groups, 2-4 students in each, both regular NTNU students (master and PhD level) and international students, participating in the NTNU International Master program. The total building period was five weeks. During the final session, the students presented their projects in the form of role plays (Fig. 1). They also evaluated each other's constructions and received evaluations and feedbacks from the international visitors. In addition, two seminars were conducted: "Using Virtual Worlds to Improve Business Presentation Skills" by Judith Molka Danielsen and "TARGET EEU (Extended EU) – A step toward new e-learning technologies" by Albena Antonova and Ekaterina Prasolova-Førland.

Figure 1. Role-playing presentation of a student project

After the competition, the students delivered a group essay where they reflected on their experience. The students discussed potential use of their constructions, different aspects of collaborative work, role play, 3D visualization, and learning in CVEs.

The Summer School was conducted in conjunction with the Norwegian Science Fair, which is a part of an annual festival Norwegian Science Week. The goal of this event is to present science projects to the public. In Trondheim, which is recognized as a 'student city' and a 'technological capital', the festival is organized in pavilions on the central city square. In the Virtual Campus of NTNU, a Virtual Science Fair was erected in Second Life to mirror and enhance the one in reality. One of the major city landmarks – King Olav Tower, was reconstructed in the virtual science fair on the virtual 'central square', in same place where the fair was organized in reality (Fig. 2).

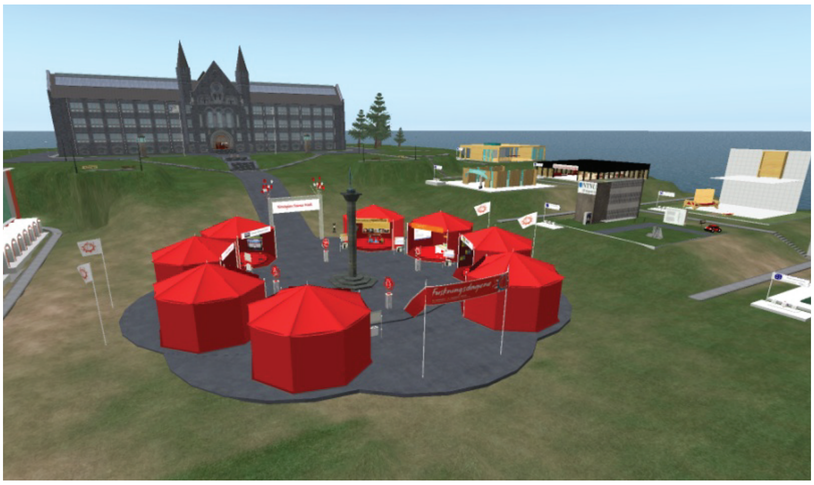

Figure 2. Virtual Science Fair in the Virtual Campus of NTNU

Figure 3. TARGET pavilion at the Virtual Science Fair

Virtual Science Fair was designed based on the principals of the Virtual Research Arena (VRA) – a framework for creating awareness about educational and research activities, promoting cross-fertilization between different environments and engaging general public (Fominykh & Prasolova-Førland, 2011). The Fair consisted of eight pavilions and, together with the Summer School constructions, formed a common environment in the Virtual Campus (Fig. 2). Each pavilion presents a research project from different NTNU departments and other research environments (Fig. 3). Examples of the projects presented (in addition to presentation of the TARGET project itself) included:

1. “Virtual Eidsvoll” – a historical reconstruction project in Second Life for studying Norwegian history;
2. “Multi-lingual text annotator Typecraft” – a free online tool for language experts and anthropologists;
3. “Digital style” – a project advertising social networking and mobile technologies;
4. “vAcademia” – an educational virtual world.

The Virtual Research Arena in this case served as a metaphor and realization of TARGET’s ideas of technology transfer between diverse communities and establishing connections between different disciplines and practices, involving representatives from universities, research institutions, businesses, and the general public. It can also be though as a virtual workplace where learning can take place in many forms as elaborated in the next section.

The potential and usefulness of the Virtual Research Arena were evaluated by the students participating in the Summer School in their essays. There has been some criticism since there was no actual support for doing research, but just for presenting results. Positive feedbacks were related to conceptual opportunities of the VRA.

The Virtual Science Fair was presented at the fair in real life as one of the projects. The visitors in the real life could come to the physical pavilion and immerse themselves into the virtual extension of the fair, exploring a number of projects (Fig. 4).

Figure 4. Virtual Science Fair is demonstrated to the visitors of the 'real-life' Science Fair

## Lessons learnt for CSCL@Work

In the following, we will discuss how we followed some recommendations based on literature review aligned with input from the consortium, and how this was implemented in the TARGET summer school. In addition, we will suggest implications for the learning processes that may be deducted from the cases. We will also suggest possible future work.

In the TARGET learning environment, collaborative learning has been designed as a reflective learning community at the workplace. TARGET will be a reflective community platform for learners who need to have rapid access to develop competencies in the domain of project management using a serious games approach. The game simulates the activities associated with 'planning and executing a project'. Through play, participants develop competencies and expertise in project management.

The first TARGET International Summer School in Second Life proved useful insight in terms of testing out community seeding methodology introduced earlier (Prasolova-Førland & Hokstad, 2009), including the new focus on Communities of Interest, social creativity and community evolution approach, see e.g. (Fischer, 2001; Fischer & Ostwald, 2002).

In the following, we will discuss how Summer School functioned as an example of community seeding in a serious game within the TARGET context. Using the community framework and a set of recommendations for community seeding and sustaining we have introduced earlier (Prasolova-Førland & Hokstad, 2009), the process is elaborated and illustrated along the dimensions of domain, community/network and practice.

## Domain

*Recommendation:* It is necessary to define the domain and engaging issues: issues important to the organization, aspects that are important and motivating for people and can bring in new members. This also includes identifying the ideas, insights and practices that are to be shared in the community at the early phase (Kaulback & Bergtholdt, 2008; Wenger, et al., 2002).

*Realization in the Summer School:* In the Summer School, the focus was on the topics central for the project domain: exploration of the potentials of role plays and simulations in a business/scientific context, alternative means of project presentations. Project visualizations at the Virtual Research Arena have been extensively used for educational purposes in accordance with the constructionist approach (Seymour Papert & Idit Harel, 1991). At the same time, they have been used as a means of knowledge sharing across different communities of interest, in this way supporting social creativity (Fischer, 2005). For example, according to one the student essays, *"The Virtual Research Arena could be quite useful for presenting things like:…enable idea gathering in a more interactive intuitive setting … make visualization extensions for information sources like Wikipedia, where visitors can see things in an interactive 3D setting"*.

In this way, the Virtual Research Arena and its pavilions served as 'boundary objects' between different research communities (Arias & Fischer, 2000; Fischer, 2001) and at the same time contributed to promoting research projects to a broader audience of students, researchers and general public. During the course of the Summer School, a number of boundary objects have been collaboratively created in order to facilitate the exchange of ideas between communities of students, researchers, and practitioners. These boundary objects contributed to establishing a common ground and shared understanding and vocabulary among community members by to a significant degree taking advantage of visual symbols, interactive elements, and aesthetics means. Participants took advantage of the mutual "symmetry of ignorance" (Fischer, 2000; Rittel, 1984), allowing social creativity to be unleashed at the boundaries of different domains, demonstrating research projects to peers, experts and other visitors as well as getting feedbacks. The result of these activities might be what the students called "boundary projects", as appears in one of the essays: *"Virtual Research Arena can be a great opportunity to foster both research activities and collaborative learning. First, it can be used as means for making every researcher aware of other research projects. We believe this is an extraordinary way to promote collaborations among different projects. Using this approach new cross boundary projects may come out"*. In this way, our experience shows the potentials of 3D visualizations for supporting learning and exchange of ideas in a virtual workplace as well as enhancing creativity across boundaries of different communities of interest.

*Implications for TARGET learning process:* Boundary objects seem important in the learning environment. On the one hand, they represent to the individual learners, an exposure to multiple perspectives. On the other hand, they represent common points of reference to the community of learners. Boundary objects may be seen as parts of the trading zone between the various disciplines and the participants of a community that represent theses disciplines.

## Community/network

*Recommendation:* The process of seeding a community should to a substantial degree be based on existing social networks in order to be successful. At the same time, establishing connections across communities is important (Fischer, et al., 2007). Establishing mutual trust and "investing in social capital" is crucial (Bos-Ciussi, Augier, & Rosner, 2008).

*Realization in Summer School:* During the Summer School, we studied how the students collaborated around their creative visualizations, building upon constructions from previous student generations. The Summer School has also demonstrated the ideas of community seeding, evolution and re-seeding model (Fischer & Ostwald, 2002) where the 'seeds' represented by students' projects grew on the 'soil' generated by the evolution of earlier student generations at the Virtual Campus, and were later integrated in the Virtual Research Arena, reseeding the new community of TARGET researchers and early adopters.

A number of events, such as seminars, gatherings and a role-playing session, during the course of the school allowed extending social networks across countries and institutions. The potential of the VRA was mostly seen in promoting presented research environments by creating a socializing and gathering place around project presentations. Increased awareness among researchers, students, university departments, research groups, institutions, and the general public was emphasized as a way for promoting collaboration and an important opportunity for establishing new contacts. In this way, our experience with the Summer School highlighted the importance of informal communication spaces for working, community building and collaborative creative activities.

*Implications for TARGET learning process:* Establishing productive and creative communities rests on a delicate and complex balance between the "symmetry of ignorance" and the symmetry of interests amongst the participants. Both formal and informal means of interaction are needed as well as openness towards other communities and networks. Learning under these affordances requires a highly flexible infrastructure.

## *Practice*

*Recommendations:* a) The first step in terms of establishing a community practice is creating a preliminary design for the community, based on the "Seven principles" (Wenger, et al., 2002), such as launching the community with dedicated community spaces, both private and public and corresponding initial community events (Wenger, et al., 2002).

b) It is recommended to provide initial boundary objects and introducing shared artifacts as catalysts of collaboration (Thompson, 2005; Wenger, 1998) such as "monuments" (symbols strengthening identity within the community, e.g. logos); "instruments" (an infrastructure supporting interactive communication) and "points of focus" around which the interaction and collaboration will be structured.

c) It is necessary to identify early what knowledge to share and how, laying an initial plan for a community repository, identifying ways to capture and store 'soft' knowledge to be embedded into community practice and stored into relationships (Wenger, et al., 2002).

*Realization in Summer School:* In order to create a preliminary 'design' for the community/communities in question, there have been introduced dedicated community spaces (e.g. lecture halls, campus buildings, reconstruction of Trondheim central square with exhibition tents) and associated community events: Summer School seminars and the Virtual Science Fair in conjunction with the real one. According to student feedbacks, these arrangements were suitable for connecting communities of students and researchers: *"We think the Virtual Research Arena (VRA) is highly suitable for research activities. Researchers at university level are often geographically distributed across countries. This is due to the fact that research projects often need top specific knowledge in small domains that is hardly available inside its own country boundary. With limited resources (money)* *available in the project, and bearing in mind the CO2 emissions from flight travels, researchers may like to have a platform to meet that mimics real life meetings."*

As a part of establishing shared practice, we have introduced a number of shared artifacts as catalysts of collaboration such as TARGET stand as a "monument" (Fig. 3), building tools and meeting facilities as "instruments" and "points of focus", such as campus buildings, constructions on the Virtual Science Fair and both previous and recent student constructions (Fig. 2). These focal points were demonstrated to the public facilitating collaboration within and between communities of students, researchers, TARGET partners and the general public (Fig. 4).

In addition, we have explored innovative ways of capturing, storing, and mediating knowledge through 3D creative visualizations and role-plays. The 3D constructions capturing the knowledge and experiences acquired by different generations of students and researchers will be stored in a 'project gallery' constituting the community repository, where they can retrieved and updated/annotated by community members at any time. The work on such a gallery provides one of the directions for future research, i.e. exploring alternative and innovative ways of visualizing, storing, and managing community knowledge.

*Implications for TARGET learning process:* A game scenario that encompasses experiences and challenges that interacts on the balance between the symmetry of ignorance and symmetry of interest, seem fit to be the event or monument that attract participants into these kinds of learning environment.

## Conclusions and Future Work

In this chapter, we describe a sociotechnical platform that fosters workplace learning in the field of project management. We have presented and discussed initial testing results of a community seeding methodology, outlined in the TARGET community framework, and explored different aspects of community building in the context of serious games and 3D CVEs. The purpose was to explore learning environments by inviting participants into practices where knowledge and insight is emergent from the diversity of the contributions.

We asked to what extent a 3D collaborative virtual environment facilitates *reflective dialogue* in communities to support lifelong workplace learning. Our experience demonstrated that 3D collaborative virtual environments *can* support reflective dialog in learning communities in following ways:

- By providing boundary objects to enable dialog between learners from different backgrounds and disciplines
- By providing a flexible infrastructure and both formal and informal meeting and workplaces for members of different "Communities of Interest"
- By providing a set of shared artifacts as catalysts of collaboration and a shared repository for storing and 3D visualization of community knowledge
- By enriching reflective dialog with innovative expression forms, such as role plays and 3D visualization

It is important to understand that attempts to control such communities directly are in most cases destined to fail, according to the principles and understanding suggested by Wenger (Wenger, et al., 2002). In this tradition, the design principles for vibrant and alive communities are not meant to be 'recipes' and are not the same as most organizational designs. They could rather be seen as triggers and catalysts for a community's natural evolution, often based on pre-existing social structures.

Also, communities cannot be measured in conventional ways as traditional methods are not likely "to appreciate the creativity, sharing and self-initiative that are the core how a community creates value" (Wenger, et al., 2002). Following this understanding, we outline a number of implications for TARGET learning process and organizational learning in a serious game context in general:

- The importance of 3D visualizations for supporting learning and exchange of ideas in a virtual workplace as well as enhancing creativity across boundaries of different communities of interest
- The importance of informal social spaces for community building and collaborative creative activities
- The need to explore alternative and innovative ways of visualizing, storing, and managing community knowledge

For the future work, we plan to continue seeding and nurturing reflective and creative TARGET communities according to the principles and guidelines outlined above, contributing to development of associated community social tools and support systems. In addition, a new TARGET Summer School (in collaboration with EU CoCreat project (http://www.cocreat.eu/) was held autumn 2011, with a focus on collaborative virtual workplaces for creativity support. During this process, future work will encompass a number of research issues:

- Further exploration and development of the community methodology in the context of serious games and 3D virtual workplaces
- Providing support for creative communities and communities of interest in 3D virtual worlds in a cross-disciplinary and multi-cultural context
- Exploring the potentials of role playing and serious games for supporting learning at the workplace
- Further experiments of integrating serious games in workplace development programs;
- Further exploration into threshold concepts as content identifiers in complex learning environments
- Further development of methods for community repository building and maintenance

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# Paper 9

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# Constructing a 3D Collaborative Virtual Environment for Creativity Support

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**Abstract:** In this paper, we focus on creativity support for learning in 3D collaborative virtual environments. We propose a set of requirements and a design for a 3D virtual working environment that supports creative collaboration among university students. This 3D working space is to be used in the university course "Designing e-learning" for developing creative solutions for informal and formal learning in virtual places and involving students from different European countries and partner organizations participating in the EU CoCreat project. The main goal of the project is to develop and evaluate collaborative spaces for learners of different ages in order to promote creative collaboration and to explore new and innovative learning models.

## Introduction

Traditional learning practices need to be adapted to the modern society in order to cope with its rapid changes. Innovative solutions that promote problem-solving are required and, in those situations, creativity plays a central role. Creativity can be applied to every domain of knowledge and must be seen as an important competence. There is evidence in the literature that creativity is an effective method, key component and valuable outcome of learning (Eteläpelto & Lahtia, 2008; Kangas, 2010; Lewis, 2006; Livingston, 2010). However creativity is not a spontaneous process and it needs to be promoted with novel solutions. One of the new technologies, known to be very promising in creativity support, is 3D Collaborative Virtual Environments (CVEs). For example, in (Prasolova-Førland, 2007) CVE technology is used for creative educational visualizations, and in (Peppler & Solomou, 2010) creativity and collaborative learning are explored in the context of virtual 3D architectural building. In (Minochaa & Reevesa, 2010) learning spaces in a 3D CVE were successfully utilized to foster creativity and informal learning among students, in contrast to traditional instructional approaches.

CoCreat (http://www.cocreat.eu/) is a project, supported by the European Commission under the Life Long Learning programe (http://eacea.ec.europa.eu/). The project identified a number of problems in the society (e.g. technological environments, learning landscapes (ecosystems) and interaction between different generations) and the need for a range of new learning practices in complex and dynamic learning environments in order to tackle these problems. The aim of this project is to find out how to enhance creative collaboration by applying the theory of collaborative learning. The outcome of the project will be increased competence in acting and learning in complex and dynamic environments where collaboration and creative solutions of problems are required.

The project will bring students from four different universities (University of Oulu – Finland, Tallinn University – Estonia, Valahia University of Targoviste – Romania, Norwegian University of Science and Technology – Norway) in a 3D virtual space. Other social media technologies (e.g. microblogs, wikis, social networking and web mapping) will be applied in implementation of "Designing e-learning" course as well. Study-process will be structured with the ideas of design- and problem-based learning. Through technological solutions and pedagogical structuring students are encouraged to develop creative solutions for informal and formal learning in virtual places.

In this paper, we present the requirements and design for a 3D CVE that will be used in CoCreat project. Collaborative Virtual Environments are very promising for creativity support because of their possibilities for visualization, communication and self-expression, however the area lacks strong methodological frameworks. The purpose of the paper is to outline a general methodology for facilitating collaborative creative activities in 3D CVEs.

Two Second Life locations will be used as a basement for the project's 3D virtual environment: Virtual Campus of Norwegian University of Science and Technology (NTNU) and the island of Kymenlaakso University of Applied Sciences (KUAS). These locations and the platform Second Life were chosen because of being venues for a number of similar projects before and the availability of some of the required infrastructure.

## Background and related work

Different techniques can be used to help students to appropriate the body of knowledge presented in a course. These techniques are often aiming at making students active and triggering their creativity (Eteläpelto & Lahtia, 2008; Kangas, 2010). In this paper, we focus specifically on creativity in a collaborative context. Schneiderman identifies the following main phases in a collaborative creative process (Schneiderman, 2002): collect (searching for material and visualizing it), relate (consulting with peers), create (trying out solutions, creating associations, composing artifacts) and finally donate (disseminating results).

Technology Enhanced Learning (TEL) suggests a number of solutions that can be applied for supporting creativity in educational settings. In this paper, we focus on one of such solutions, 3D Collaborative Virtual Environments (CVEs) that can be defined as three dimensional, multiuser, synchronous, persistent environments, facilitated by networked computers (Bell, 2008; de Freitas, 2008).

The purpose of CoCreat project is to explore creative collaboration among the learners of different ages, and there are a number of reasons for applying 3D CVEs in this context.

First, CVEs provide learners an environment for active and collaborative work with 3D content, which allows to apply 'constructionism' (Harel & Papert, 1991). In addition, 3D visualization is a powerful tool for supporting understanding and memorizing complex concepts already widely used in educational contexts (Börner, 2001). There is some evidence reported in the literature that 3D graphics can be beneficial for memorization and information retrieval (Czerwinski, van Dantzich, Robertson, & Hoffman, 1999). CVEs potential for supporting cross-cultural understandings is another important motivation behind the choice of this technology (Wyeld & Prasolova-Førland, 2006). In an increasingly globalized world, there is an ongoing need for ICT professionals to work in diverse cultural environments. When members of different cultural backgrounds come together to collaborate on a single project they are acculturated to different ways of seeing themselves in relation to others and are able to observe how others behave in the same situations. They come to appreciate different approaches to similar tasks and adjust their own behavior to accommodate these differences (De Blij & Muller, 1986).

Finally, an important reason is an opportunity for participants to interact in a way that conveys a sense of presence, lacking in other media (Kelton, 2007; Park, Hwang, & Choi, 2009). Users are represented by avatars and act in a shared 3D space that gives them awareness of each other's actions. Communication is usually presented in the form of gestures, text-based chat and in-voice chat and allows using CVEs for meetings, performances and role-playing (Sant, 2009). Moreover, the ability of this technology to support informal socialization is also acknowledged by existing research (Börner, 2001; Minochaa & Reevesa, 2010; Prasolova-Førland & Divitini, 2003). These opportunities result in a number of benefits for establishing and supporting learning communities (Bronack et al., 2008).

Establishing and nurturing vibrant learning communities is seen as a highly complex process (Wenger, McDermott, & Snyder, 2002; Wenger, White, & Smith, 2009). Yet, at the same time, such communities are seen as highly important in developing and spreading new skills, insight and innovation (Johnson, 2010). Traditionally, Communities of Practice (CoP) have been the most common form of community.

Describing Communities of Interest (CoI), Fischer et al. state that (Fischer, Rohde, & Wulf, 2007): "CoIs bring together stakeholders … and are defined by their collective concern with the resolution of a particular problem. CoIs can be thought of as "communities of communities" (John Seely Brown & Duguid, 1991) or a community of representatives of communities. Stakeholders within CoIs, as in the CoCreat consortium, are considered informed participants (J. S. Brown, Duguid, & Haviland, 1994; Fischer, et al., 2007), being neither experts nor novices, but both. They are experts in their own domains when they communicate their knowledge and understanding to others. At the same time they are novices and apprentices when they learn from others' areas of expertise. According to (Fischer, 2005; Fischer, et al., 2007). CoIs have potential to be more innovative and transforming that a single CoP if they can exploit "the symmetry of ignorance" for social creativity because different backgrounds and different perspectives can lead to new insights.

Overcoming distances in social creativity and supporting learning in CoIs requires externalizations (Bruner, 1996; Papert & Harel, 1991) in the form of boundary objects (Star, 1989) that have meaning across the boundaries of the individual knowledge systems/ subcommunities/ different CoPs that join together in a CoI for some purpose (Fischer, 2001).

## Creativity support in 3D CVEs

In this section, we present two cases from our own experience in the use of 3D CVEs for educational purposes, which are related to creativity support. In addition, we summarize our experience and provide implications for the CoCreat project environment.

### Creative curriculum visualization

Improving students' understanding of the curriculum is one of the most important tasks for the use of technology in education. In case study *Creative curriculum visualization*, we explored advantages and disadvantages of 3D CVEs for collaborative creative elaboration and visualization of educational content. We asked students to build a creative visualized presentation of one of the topics covered in the Cooperation Technology course in Active Worlds (Prasolova-Førland, 2007). Their work was evaluated based on the analysis of the constructions and on the discussion in group essays. The solutions chosen by the students tended to follow the categories:

- '3D shell' – a house or another construction with no apparent connection to the topic and with a content presented by 'traditional' methods such as posters with text and images;
- '3D cartoon' – a 'dramatization/ enactment/ diorama' with avatars and 3D objects, in some cases with animations (Fig. 1);
- 'virtual museum' – a presentation of the topic in a gallery of images or 3D objects illustrating the major concepts (Fig. 2).

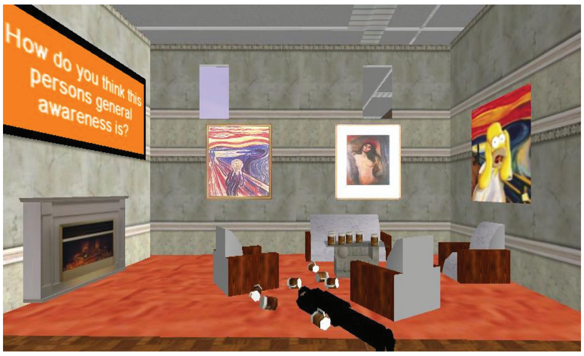


**Figure 1:** 'Awareness' as a '3D cartoon', student project


**Figure 2:** Museum of communication means, student project

Constructing visualizations of the major curriculum concepts in a 3D collaborative virtual environment, the students spent a significant effort on elaborating on educational content and their understanding was on several occasions improved, as followed from their feedbacks. The students acknowledged that the technology provides a creative atmosphere and a set of means for self-expression. However the students experienced a number of problems working on this task. It was rather time-consuming and required much more effort than simply reading a textbook. The students also experienced some misunderstandings with the ambiguity of visualizing abstract concepts in a 3D environment.

During this case study we explored the support for the different phases of the creative collaborative process (Schneiderman, 2002) and also the typology of the 3D content and visualization means in 3D CVEs, which will serve as an input for the CoCreat case study, especially the requirements.

### Research projects visualization

Collaborative virtual environments can be used as an alternative technology for presenting information. In the case study *Research projects visualization*, we asked students to build a creative visualized presentation of a research project and present it at a joint session by role-playing within the Cooperation Technology course in Second Life (Fominykh & Prasolova-Førland, 2011a).

Having a great degree of freedom, the students expressed their creativity in a number of ways, selecting diverse and interesting projects, applying different metaphors and using different types of content presentation technics (Fig. 3).

After the practical part of the exercise, the students reflected on their experience in group essays. The analysis of the data collected during the study showed that the exercise in the 3D environment helped the students to get some practical experience on the cooperative technologies and to gain deeper understanding of the course concepts (Fominykh & Prasolova-Førland, 2011a).

This case study demonstrated the range of possible topics that can be visualized and also the variety of presentation methods. The topics included research projects or concepts from both technical disciplines and humanities. A number of different metaphors were used, including a museum, a gallery, a meeting room and a workshop. Construction presentations revealed the possibilities for immersing visitors into the project environment or process, live discussions and demonstrations.

In addition to the student group work, we studied the possibilities of 3D CVEs for research project visualizations in other settings. Developing a framework called Virtual Research Arena (Fominykh & Prasolova-Førland, 2011b), we constructed a Virtual Science Fair in Second Life to explore an alternative and creative way for presenting research. The Virtual Science Fair has 8 pavilions, each presenting a research project (Fig. 4).

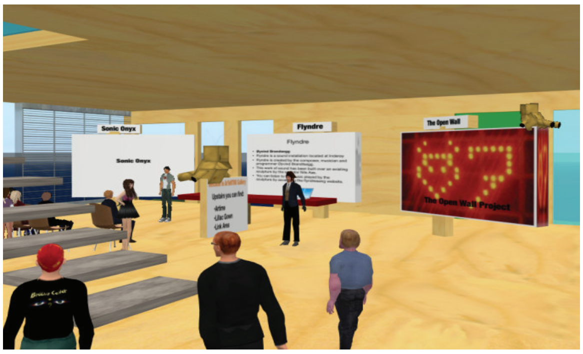


**Figure 3:** Art and technology project, role-play project presentation

**Figure 4:** TARGET EEU project, Virtual science fair pavilion

In this case study, we gain additional experience in conducting creative collaborative activities on 3D content and further developed the typology of the 3D content and visualization means in 3D CVEs. In addition, the structure of the requirements for the CoCreat virtual environment is taken from the results of this study.

**Experience summary**

Based on the several case studies, including the mentioned above examples, we are developing a theoretical framework and a tool called Creative Virtual Workshop or CVW that we previously proposed and described in (Fominykh & Prasolova-Førland, 2011b). In the core of CVW lies creative collaboration around 3D content that includes building, sharing, exhibiting, annotating and other manipulations.

In addition, previously we developed a set of recommendations for collaborative work on 3D content in CVEs, presented in (Fominykh & Prasolova-Førland, 2011a).

All this work served as a background for constructing the CoCreat 3D virtual working environment.

## CoCreat 3D collaborative virtual environment

Based on the results from the case studies presented in the previous section, related work and a series of discussions with CoCreat partners, we propose a set of requirements and the design for the CoCreat 3D collaborative virtual environment to be used in the “Designing e-learning” course as described below.

**Pedagogical model**

"Designing e-learning" course aims at familiarizing students with the key concepts, competing theories and approaches of designing TEL. In collaboration with international students, they will develop practical skills of setting up, implementing and evaluating the use of distributed set of integrated TEL systems and tools, and they will design a prototype of an advanced TEL course.

The course will be taught in the spring semester 2012. However, we will conduct the preparatory study already in the autumn 2011 within the course on Cooperation Technology at NTNU. This preparatory will serve as 'a proof of concept' for the main course, but, at the same time, the result of the students' work will be actively used in the later "Designing e-learning" course as examples of 3D educational visualizations and associated infrastructure. Moreover, the preparatory case study in the autumn will allow us to get additional insights on supporting collaborative creative processes in a 3D CVE.

The main idea of the preparatory study is to give the students some basic information on the "Designing e-learning" course and ask them to come up with a design for the technological infrastructure in the 3D CVE with the focus on supporting cooperation among students (information sharing, coordination, synchronous and asynchronous communication, etc.). Norwegian students will work in groups and create small 'educational modules' or practical tutorials in Second Life, illustrating different concepts within the course such as coordination, information sharing, awareness and so on.

Working on this task, the students will have the following plan:

- Developing a web-based educational module (an extended blog post) on a certain topic/course concept (1 week);
- Writing a plan for a 3D visualization/a 3D CVE infrastructure element on the topic chosen (1 week);
- Creating a group construction in the NTNU Virtual Campus according to the plan (4 weeks);
- Preparing a role-play presentation of the 3D construction (1 week);
- Analyzing and reflecting on their activities by blogging during the whole semester and presenting a summary in an essay by the end of the course;
- Discussing their activities, design ideas and final results as well as receiving feedbacks during a virtual "Summer School". This summer school will include a number of virtual seminars with participation of students, teachers and researchers from European and other countries, including CoCreat partners, partners from other EU-funded projects and visitors from other institutions.

International students in the spring semester will be able to explore visualizations ('educational modules') prepared by the Norwegian students. Any visitor will be able to learn about cooperative technologies in general and get some ideas on how educational content can be presented in a 3D CVE. Blogs of the Norwegian students will be linked to the virtual environment and available to the visitors/CoCreat participants, providing a source for inspiration and discussion.

**Requirements**

Each of the points of the requirements has its grounding in theory and/or based on the results of our previous empirical studies as well as discussions with CoCreat partners. The structure of the requirements is based on our previous research into collaborative work with 3D content (Fominykh & Prasolova-Førland, 2011a) and was evaluated in another educational project – Virtual Research Arena (Fominykh & Prasolova-Førland, 2011b):

- *Content level* (basic methods for facilitating 3D construction process and elaborating on 3D content in CVEs). 3D construction is described along 3 main dimensions: virtual exhibits, visual shells and dynamics (building further on the 3 categories from the "Creative curriculum visualization" study). A successful construction provides a harmony between these dimensions.
    - Virtual exhibits or 'types of content' is the first dimension for describing 3D constructions (Fominykh & Prasolova-Førland, 2011a). Virtual exhibits have 3 main categories: text, 2D graphics and multimedia, and 3D visual symbols.
    - Visual shell or 'content presentation form' is the second dimension for describing 3D constructions (Fominykh & Prasolova-Førland, 2011a). A visual shell can be described using 3 dimensions: aesthetics (appropriate atmosphere and decorations, e.g. in a 'medieval' style), functionality (interactivity and navigation, e.g. a 'museum'-like pre-defined path through an exhibition) and expressed meaning (symbols and metaphors, e.g. an Egyptian history museum in the form of a pyramid).

    - Dynamics of the content considers how the virtual exhibits are presented to the viewer in terms of 'story-telling', e.g. a development of the narrative as the visitor moves along the construction and facilitation of roleplaying.
- *Service level* (tools and facilities for supporting collaborative educational activities in CVEs).
- *Community level* (methods and tools for creating and maintaining learning communities around educational activities in CVEs).

As we focus on collaborative creativity in this work, we focus on the support for the 4 phases of the creative collaborative process (Schneiderman, 2002) in the requirements set for the CoCreat collaborative environment.

Content level:

- To facilitate the *Collect* phase of the creative collaborative process, it is necessary to provide similar projects or examples from previous student generations. A library of pre-made objects and tools will assist learners with searching for material and visualizing it.
- To facilitate the *Create* phase of the creative collaborative process, the environment should provide basic and advanced tutorials and a workplace, allowing the participants to try out different solutions, with minimized time/effort investment and a required degree of flexibility, in collaboration with peers.
- To facilitate creation and appropriate use of *virtual exhibits* of different kinds, the environment should provide explicit examples of their use for presenting different types of information.
- To facilitate elaborating aesthetics, functionality and expressed meaning of the *visual shell,* it is necessary to provide explicit explanation and examples of visual shells for different contexts.
- There should be created a set of tools and aids for supporting development of *dynamic* content.

Service level:

- The environment should provide basic and advanced (specific domain oriented) *tutorials*, always available at hand. Additional materials and links to external resources should also be provided.
- The environment should provide basic *building resources*, allowing the participants to start early composing structures from ready-to-use blocks.

Community level:

- Collaborative facilities, such as seminar rooms, community spaces, and annotation and feedback facilities, should be available to provide support for consultations with peers during the *Relate* phase of the collaborative creative process.
- Community repository (CVW virtual gallery) should be available to allow learners to share and disseminate their projects, supporting the *Donate* phase of the collaborative creative process.
- The environment should support "creative communities", taking advantage of the mutual "symmetry of ignorance" (Fischer, 2000; Rittel, 1984), allowing social creativity to be unleashed at the boundaries of different domains. This can be realized by providing tools for social activities and collaborative work, facilitating interactions between stakeholders from different domains.
- The environment should comprise ideas, insights and practices that are to be shared in the community at the early phase (domain), such as collaborative technologies and educational visualizations.
- Dedicated *community spaces* should be present in the environment, such as group rooms and meeting places with corresponding initial community events (tutorials, discussions and seminars). In these spaces, *connections between different communities* should be supported, such as students and teachers, external experts and the general public by facilitating a series of community events.
- Initial *boundary objects* should be created, providing shared understanding and vocabulary among community members in the situation of "symmetry of ignorance" (Fischer, 2000; Rittel, 1984). Shared artifacts should be introduced as catalysts of collaboration, such as an infrastructure supporting interactive communication and 'points of focus' around which the interaction and collaboration will be structured (Thompson, 2005).
- The environment should have a *Community repository* (Wenger, et al., 2002), such as a virtual gallery, exhibiting the results of the activities of community members (reification).

As a part of the evaluation process, we are planning to investigate to what extent the system designed according to these requirements supports the 4 phases of the creative collaborative process (Schneiderman, 2002). To further validate the proposed set of requirements, we are planning to compare student accomplishments (including 3D constructions) in this study to the previous ones conducted in 3D CVEs.

**Design**

In this sub-section, we present the design of an educational CVE that supports creativity. The environment will be used in the CoCreat pre-study and built in the Virtual Campus of NTNU in Second Life. Later it will be improved and used in the project together with the KUAS island.

Content level:

- Facilitating the *Collect* phase of the creative collaborative process in the environment will be carried out by adding functionality to the library of pre-made objects and the virtual gallery to assist learners with searching for material and visualizing it.
- Facilitating the *Create* phase of the creative collaborative process will be carried out by making tutorials and building resources available at hand, but also by constructing a common working area (an advanced sandbox).
- Facilitating appropriate and creative use of virtual exhibits will be realized by constructing an exhibition, presenting different types of *virtual exhibits*, such as text, posters, videos, interactive elements and visual symbols (Fominykh & Prasolova-Førland, 2011a). The exhibits may provide information on their appropriateness in different situations.
- Facilitating elaboration of *visual shells* will be realized by constructing an exhibition, presenting different aspects of *visual shells*, such as aesthetics, functionality and expressed meaning. The exhibition will provide information on the appropriate use of those aspects in different situations, based on our previous experience with collaborative work on 3D content (Fominykh & Prasolova-Førland, 2011a).
- The *dynamics* component of the content will be supported by constructing a virtual stage for live performances around the content, such as presentations and role-playing.

Service level:

- *Tutorials* for introducing technology basics for participants are already present in the NTNU Virtual Campus, including some references to external resources. These tutorials will be renovated and complemented by the new ones, introducing specific project related issues.
- Basic *building resources and ready-to-use blocks* are also present in the NTNU Virtual Campus. The library of resources will be renovated and extended.

Community level:

- To support the *Relate* phase of the creative collaborative process, a number of facilities available in the NTNU virtual campus (such as seminar rooms, community spaces, and annotation and feedback facilities) will be renovated to provide better support for communication and consultations.
- To support the *Donate* phase of the creative collaborative process, the CVW virtual gallery will be used to serve as a community repository. The virtual gallery will be connected to the library of resources, to the workshop with tutorials and to the common working area.
- Resources related to the community domain (e.g. e-learning course design, project documents, related literature on collaboration and creativity support with 3D CVEs) will be provided in the form of textual, graphical and multimedia artifacts within the virtual environment as well as links to external resources.
- Some of the *community spaces* are already present in the NTNU virtual campus. Group work areas will be allocated to students in advance and provided with navigational infrastructure/collaborative tools. To support *connections between different communities*, a set of designated community spaces will be created. A number of international visitors (including researchers, teachers and students) will be invited to participate in the joint events, taking place in these spaces.
- *Boundary objects* will be realized as a common area with realistic and recognizable reconstructions of landmarks or monuments (later for each university participating in the project), with corresponding information about the partners. This area will serve as a point of focus, around which the interaction and collaboration will be structured, with corresponding informational resources from the partners to address “symmetry of ignorance”.
- *Community repository* will be organized on the basis of the CVW virtual gallery, which is already functioning. The gallery will contain and exhibit any 3D constructions, including previous student projects and contributions from the CoCreat community.

## Evaluation plans and discussion

The collaborative spaces resulting from the design presented in the previous section will be further developed and redesigned by the students as a result of their activities during the planned case studies in autumn 2011 and spring 2012. The participants of these studies will be students from the participating organizations of the CoCreat project, involving several European and non-European countries is planned. The international scope of the studies will make it possible to explore the aspects of diversity, cross-cultural and cross-curriculum interaction in regards to supporting creativity. During these case studies, the collaborative spaces and their support for collaborative creative activities will be evaluated, exploring the possibilities and limitations of 3D Collaborative Virtual Environments in this context.

The *evaluation* of creativity support is rather complicated by objective and qualitative measures. For this reason, we will adopt different techniques for collecting multiple data from different sources. These will include observations of student activities in the virtual environment, analysis of the constructions and interviews.

Different indicators of creativity will be studied. In particular, considering the starting conceptualization of creativity, one important aspect will be to study "symmetry of ignorance" and creativity. In this perspective, we will put particular attention in studying interaction among participants with different backgrounds to observe the impact on creativity. This analysis will be conducted at the group and at the community level. Our hypothesis is that groups with students with varied background will be more creative than homogeneous groups. At the community level, we hypothesize that sessions with the presence of external experts and students from other universities will trigger high level of creativity.

Different resources are provided to make construction easier. Though this is essential to promote usage of the system, it might also hinder creativity. In the study we therefore aim at evaluating the final constructions to identify whether they can be considered as original or simply a re-use of the provided resources. Breakdowns in construction processes will be studied since they might actually lead to creative problem solving.

We also want to investigate whether exploration of the virtual spaces leads to exploration of related learning content. Our hypothesis is that exploration of the space and visits to others' constructions leads to exploration of learning content, with cross-pollination, and learning. In this perspective, it is important to consider the impact on creativity of physical navigation vs. interaction within the community without navigation (e.g. during a meeting in an auditorium).

Relation between learning and creativity is also an important aspect. Though the constructions might be very creative from an esthetic or experiential perspective, this does not necessarily lead to learning. In the analysis, we will therefore evaluate whether the constructions reflect a deep understanding of the syllabus content. Indicators that have been identified are the richness and variety of visualized material, references to external sources, and links across different constructions to visualize deep connections among the topics of the course.

We have identified a number of specific challenges associated with implementing collaborative creative spaces and their evaluation. Technical challenges include the importance of sharing/donating and security issues/limitations imposed by Second Life as well as connectivity issues, stability, complexity and a steep learning curve. Organizational challenges include supporting collaboration between actors with diverse backgrounds (organizational, cultural and geographical) and attitudes to the technology will require finding and optimal balance between different communication modes (e.g. asynchronous vs. synchronous communication across different time zones. In the core of the study lies the complexity and, in certain cases, ambiguity of 3D visualizations. The role of the pre-made resources is twofold since they make the construction process easier, but may be inhibiting for the creative process. Methodological challenges include high complexity of creation, supporting and especially evaluation of creative communities (Fischer, et al., 2007; Wenger, et al., 2002; Wenger, et al., 2009).

## Conclusions

In this paper, we have focused on collaborative spaces for creativity support in a university context. We have presented a set of requirement and a corresponding design for such a space to be used in the university course "Designing e-learning" for developing creative solutions for informal and formal learning, as a part of CoCreat EU project. The initial collaborative spaces will be further developed and redesigned by the students as a result of their activities. The future work will contain an evaluation of the collaborative spaces and their support for creativity during the course of two case studies involving students from different European countries during autumn 2011 and spring 2012. The result of these studies will be lessons learned on supporting creativity in educational context with 3D Collaborative Virtual Environments.

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