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Collaborative Work on 3D Educational Content

Thesis for the degree of Philosophiae Doctor

Trondheim, April 2012

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Science and Technology
Faculty of Information Technology, Mathematics and
Electrical Engineering
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NTNU - Trondheim
Norwegian University of
Science and Technology

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Norwegian University of Science and Technology

Thesis for the degree of Philosophiae Doctor

Faculty of Information Technology, Mathematics and Electrical Engineering
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ISBN 978-82-471-3451-1 (printed ver.)
ISBN 978-82-471-3452-8 (electronic ver.)
ISSN 1503-8181

Doctoral Thesis at NTNU, 2012:88

Printed by NTNU-trykk

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.

Acknowledgements

I would like to thank all the people in all the worlds. Special thanks to the advisors, colleagues, friends, family, and to possible readers.

I would like to express my gratitude to *Ekaterina Prasolova-Førland* for her support and guidance on all the stages of this research work. I am thankful to many of my colleagues at the Department of Computer and Informational Science and at the Program for Learning with ICT who helped me with my research.

I am thankful to *Alf Inge Wang* and *Torbjørn Hallgren* for their co-supervision, to *Monica Divitini*, *Reidar Conradi*, and *Guttorm Sindre* for their wisdom and advice. I would also like to thank *Leif Martin Hokstad* for his forethought and management.

It is a great pleasure to thank my co-supervisor *Mikhail Morozov, Alexey Gerasimov*, and all other people at the Multimedia Systems Laboratory for their great projects and innovative ideas that influenced this research work.

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.

Contents

Abstract ... iii
Preface ... v
Acknowledgements ... vii
Contents ... ix
List of Figures ... xiii
List of Tables ... xv

Part I ... 1

1 Introduction ... 3

1.1 Motivation ... 3
1.2 Research goal ... 5
1.3 Research Context ... 6
1.4 Contributions ... 6
1.5 Thesis Structure ... 8

2 Background ... 11

2.1 Computer-supported cooperative work and learning ... 11
2.2 3D collaborative virtual environments ... 11
2.2.1 Overview of 3D collaborative virtual environments ... 12
2.2.2 Educational use of 3D collaborative virtual environments ... 13
2.2.3 Collaborative work with 3D content ... 14
2.3 Design of educational 3D collaborative virtual environments ... 14
2.3.1 Use of metaphors in educational 3D collaborative virtual environments ... 15
2.3.2 Virtual campuses ... 15
2.3.3 Virtual cities ... 16
2.4 Learning communities in 3D collaborative virtual environments ... 17
2.4.1 Learning communities and communities of interest ... 18

2.4.2 Learning communities support in 3D collaborative virtual environments 18
2.5 Conclusions and challenges 19

3 Research Context and Design 21

3.1 Extended Research Context 21
3.2 Research topics 22
3.2.1 Collaborative work on 3D content 23
3.2.2 Design of tools and environments within 3D CVEs 24
3.2.3 Support for learning communities in 3D CVEs 25
3.3 Research Design 26
3.4 Research process 29
3.4.1 Studies on the collaborative work on 3D content 31
3.4.2 Studies on the design of tools and environments in 3D CVEs 32
3.4.3 Studies on the support for learning communities in 3D CVEs 34

4 Results 37

4.1 Primary papers 37
4.1.1 Paper 1 39
4.1.2 Paper 2 40
4.1.3 Paper 3 41
4.1.4 Paper 4 42
4.1.5 Paper 5 43
4.1.6 Paper 6 44
4.1.7 Paper 7 45
4.1.8 Paper 8 46
4.1.9 Paper 9 47
4.2 Secondary papers 48
4.3 Relations between papers and research topics 50

5 Evaluation 53

5.1 Evaluation of research questions and contributions 53
5.1.1 Typology of 3D Content and Visualization Means 53
5.1.2 Methodology for learning with educational visualizations in 3D CVEs 54
5.1.3 Creative Virtual Workshop framework 55
5.1.4 Guidelines for designing virtual campuses and educational virtual cities 55
5.1.5 Virtual Research Arena framework 56
5.1.6 'Universcity' framework 57
5.2 Validity discussion 57
5.2.1 Construct Validity 57
5.2.2 Internal Validity 58
5.2.3 External Validity 59

6 Conclusions and Future Work 61

6.1 Major conclusions 61
6.2 Summary of contributions 61
6.3 Future Work 63

References 65

Part II 75

Paper 1 79
Paper 2 87
Paper 3 119
Paper 4 129
Paper 5 139
Paper 6 145
Paper 7 157
Paper 8 169
Paper 9 187

List of Figures

Figure 1: General research approach 27
Figure 2: Timeline of research activities and contributions 30
Figure 3: Studies on the collaborative work on 3D content 31
Figure 4: Studies on the design of tools and environments in 3D CVEs 33
Figure 5: Studies on the support for learning communities in 3D CVEs 35
Figure 6: Relations between papers and research topics 51

List of Tables

Table 1: Relations of topics, research questions, contributions, and papers 9

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.

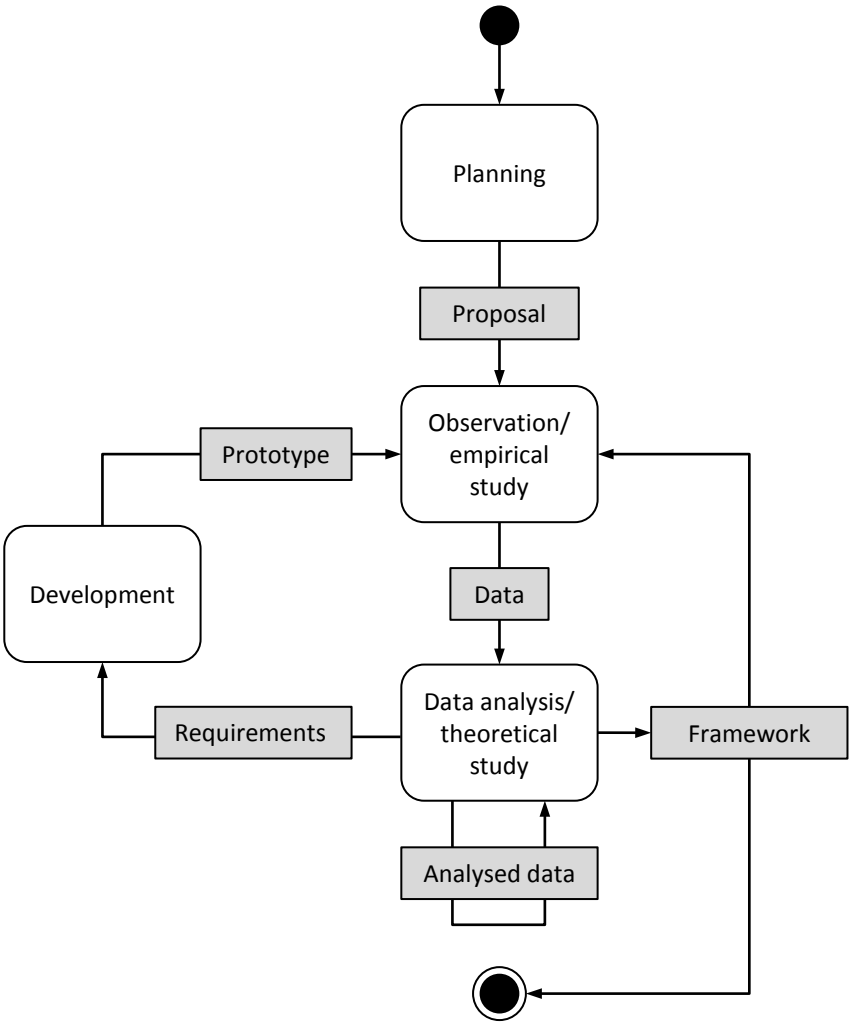

Figure 1: General research approach

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.

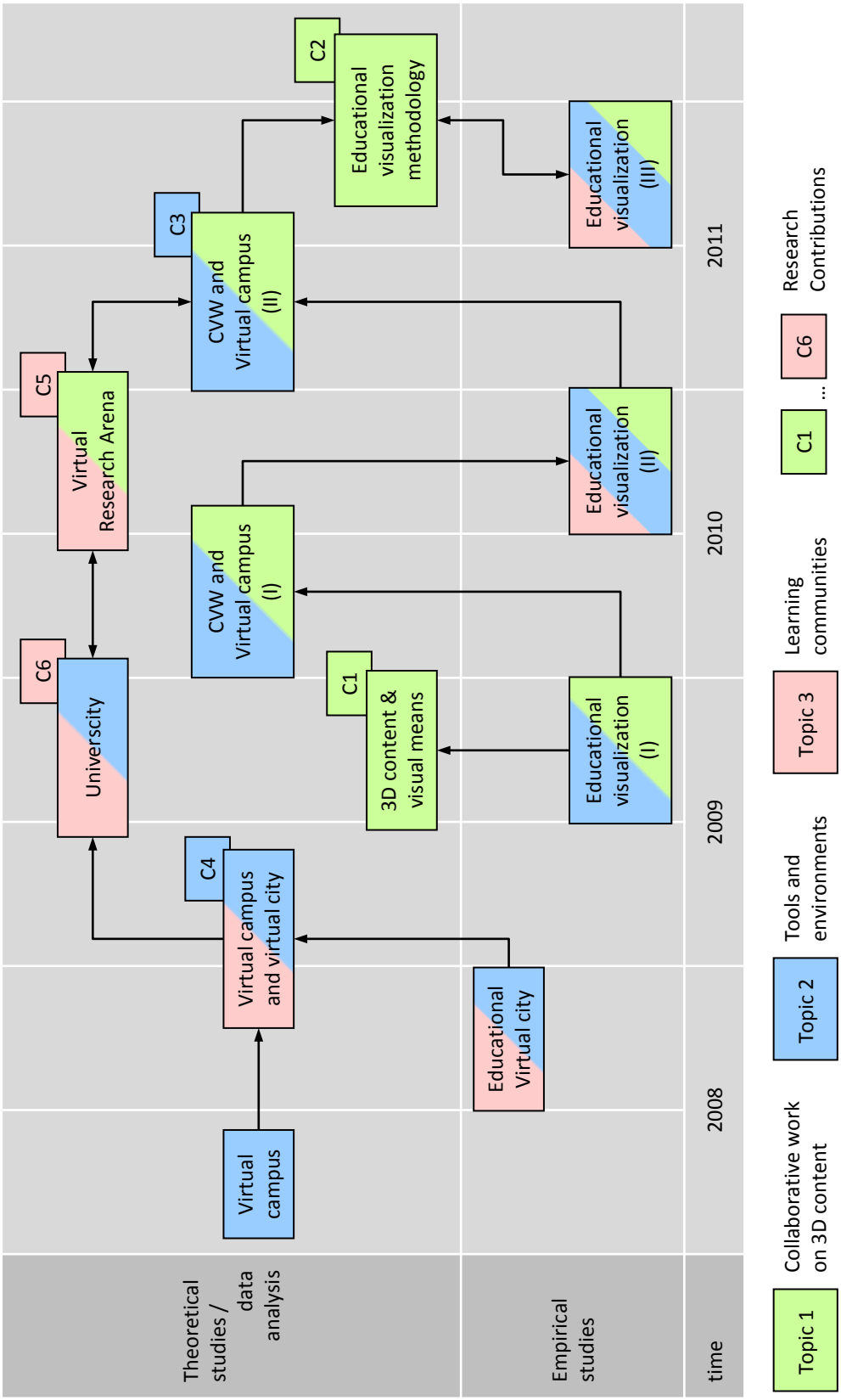

Figure 2: Timeline of research activities and contributions

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).

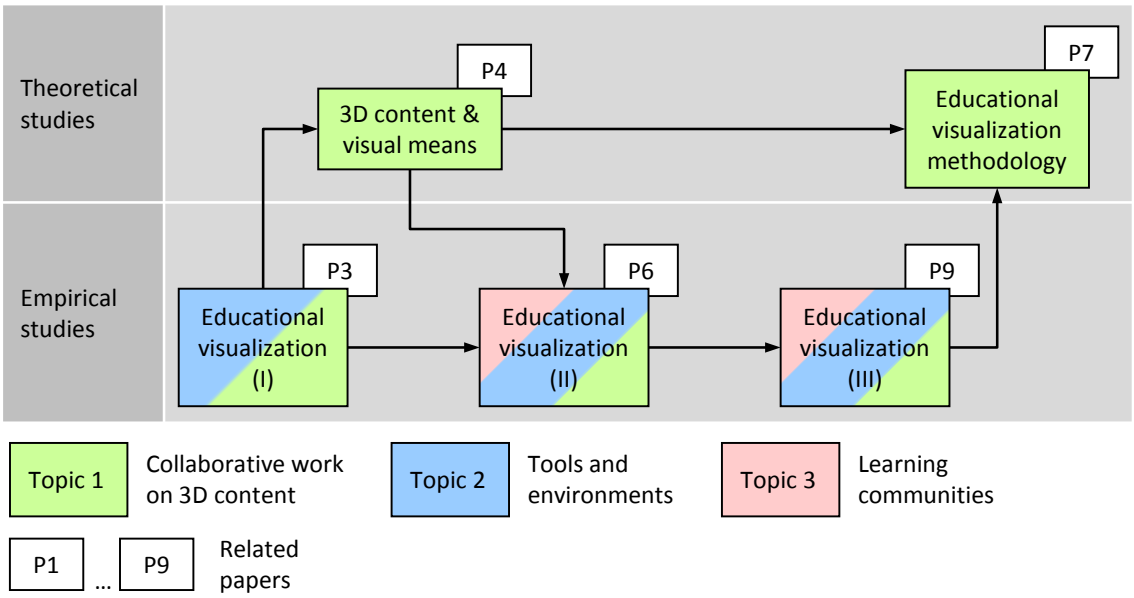

Figure 3: Studies on the collaborative work on 3D content

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).

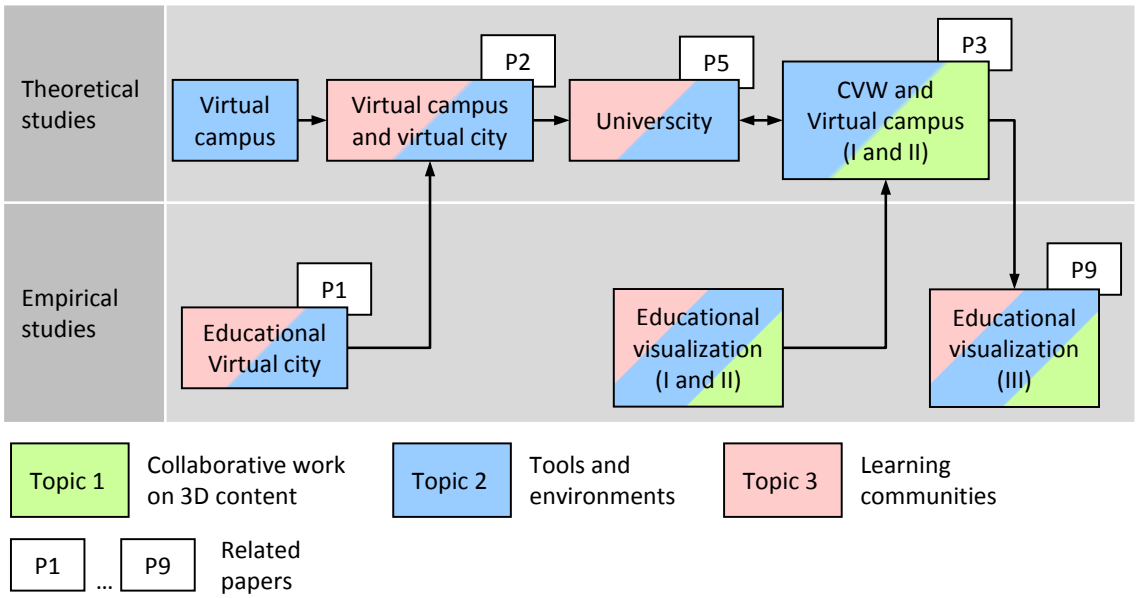

Figure 4: Studies on the design of tools and environments in 3D CVEs

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).

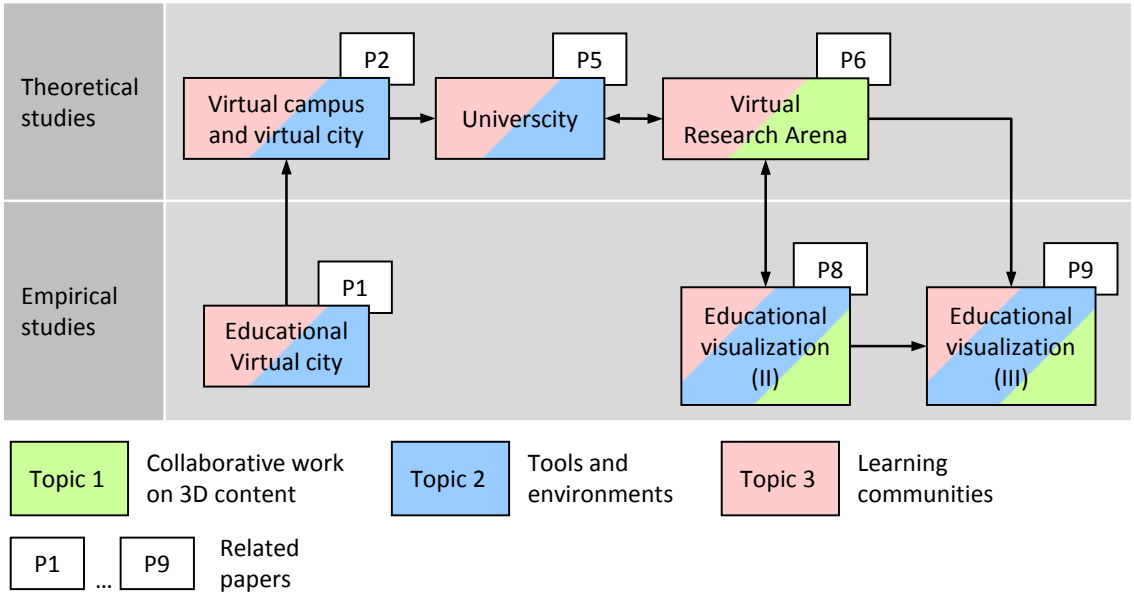

Figure 5: Studies on the support for learning communities in 3D CVEs

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.

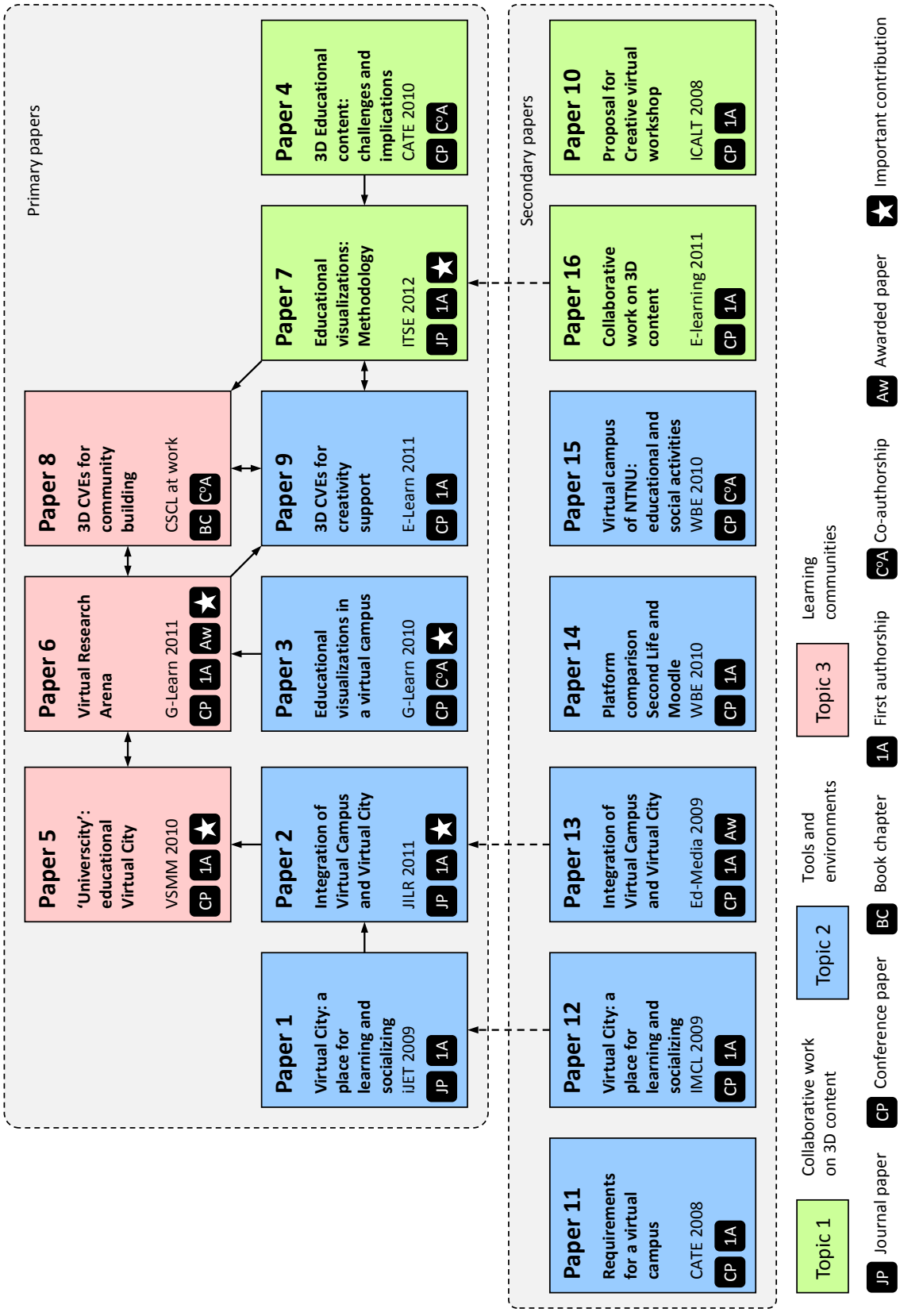

Figure 6: Relations between papers and research topics

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.

References

Abbattista, F., Calefato, F., De Lucia, A., Francese, R., & Tortora, G. (2009). Virtual Worlds: do we really need the third dimension to support collaborative learning? Paper presented at the *8th International Conference on Web-based Learning (ICWL), ViWo Workshop*, Springer.

Andreas, K., Tsiatsos, T., Terzidou, T., & Pomportsis, A. (2010). Fostering collaborative learning in Second Life: Metaphors and affordances. *Computers & Education, 55*(2), 603–615.

Antonacci, D. M., & Modaress, N. (2008). Envisioning the Educational Possibilities of User-Created Virtual Worlds. *AACE Journal, 16*(2), 115–126.

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

Ary, D., Jacobs, L. C., Razavieh, A., & Sorensen, C. K. (2009). *Introduction to Research in Education* (8 ed.). Belmont, CA, USA: Wadsworth Publishing Company.

Atkins, C. (2009). Virtual Experience: Observations on Second Life. In Purvis, M. & Savarimuthu, B. (Eds.), *Computer-Mediated Social Networking*, Berlin / Heidelberg: Springer, 7–17.

Ausburn, L. J., & Ausburn, F. B. (2004). Desktop Virtual Reality: A Powerful New Technology for Teaching and Research in Industrial Teacher Education. *Journal of Industrial Teacher Education, 41*(4), 33–58.

Bell, M. W. (2008). Toward a Definition of "Virtual Worlds". *Journal of Virtual Worlds Research, 1*(1), 1–5.

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

Bignell, S., & Parson, V. (2010). *A guide to using problem-based learning in Second Life*. Derby, UK: University of Derby.

Bijnens, H., De Gruyter, J., Op de Beeck, I., Bacsich, P., Reynolds, S., & Van Petegem, W. (2008). Re-defining virtual campuses: from a "fully-fletched" virtual campus to a blended model. Paper presented at the *European Distance and E-Learning Network conference (EDEN)*, EDEN, 1–6.

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

Bowman, D. A., North, C., Chen, J., Polys, N. F., Pyla, P. S., & Yilmaz, U. (2003). Information-rich virtual environments: theory, tools, and research agenda. Paper presented at the *10th symposium on Virtual reality software and technology (VRST)*, ACM, 81–90.

Bronack, S., Sanders, R., Cheney, A., Riedl, R., Tashner, J., & Matzen, N. (2008). Presence Pedagogy: Teaching and Learning in a 3D Virtual Immersive World. *International Journal of Teaching and Learning in Higher Education, 20*(1), 59–69.

Brown, J. S., & Duguid, P. (1991). Organizational Learning and communities of Practice: Towards a Unified View of Working, learning, and innovation. *Organization Science, 2*(1), 40–57.

Brown, J. S., Duguid, P., & Haviland, S. (1994). Toward Informed Participation: Six Scenarios in Search of Democracy in the Information Age. *The Aspen Institute Quarterly, 6*(4), 49–73.

Bruckman, A. (1998). Community Support for Constructionist Learning. *Computer Supported Cooperative Work, 7*(1–2), 47–86.

Bryceson, K. (2007). The online learning environment - A new model using social constructivism and the concept of 'Ba' as a theoretical framework. *Learning Environments Research, 10*(3), 189–206.

Burkle, M., & Kinshuk. (2009). Learning in Virtual Worlds: The Challenges and Opportunities. Paper presented at the *8th International Conference on CyberWorlds (CW)*, IEEE, 320–327.

Callaghan, M. J., McCusker, K., Lopez Losada, J., Harkin, J. G., & Wilson, S. (2009). Integrating Virtual Worlds & Virtual Learning Environments for Online Education. Paper presented at the *1st International Consumer Electronics Society's Games Innovations Conference*, IEEE, 54–63.

Campbell, C., & Jones, S. (2008). Using Second Life as an Educational Instructional Tool with Pre-service Education Students: A Work in Progress. Paper presented at the *20th World Conference on Educational Multimedia, Hypermedia and Telecommunications (Ed-Media)*, AACE, 3638–3642.

Carswell, L. (1998). The "Virtual University": toward an Internet paradigm? Paper presented at the *Joint Conference on Integrating Technology into Computer Science Education (ITiCSE)*, ACM, 46–50.

Che, W., Lin, H., & Hu, M. (2011). Reality-Virtuality Fusional Campus Environment: An Online 3D Platform Based on OpenSimulator. *Geo-Spatial Information Science, 14*(2), 144–149.

Chen, C., & Börner, K. (2005). From spatial proximity to semantic coherence: a quantitative approach to the study of group dynamics in collaborative virtual environments. *Presence: Teleoperators and Virtual Environments (Special Issue on Collaborative Information Visualization Environments), 14*(1), 81–103.

Coffman, T., & Klinger, M. B. (2007). Utilizing Virtual Worlds in Education: The Implications for Practice. *International Journal of Human and Social Sciences, 2*(1), 29–33.

Cram, A., Hedberg, J. & Gosper, M. (2011). Beyond Immersion – Meaningful Involvement in Virtual Worlds. Paper presented at the *2nd Global Conference on Learning and Technology (Global Learn Asia Pacific)*, AACE, 1548–1557.

Dalgarno, B., Bishop, A. G., Adlong, W., & Bedgood, D. R. (2009). Effectiveness of a Virtual Laboratory as a preparatory resource for Distance Education chemistry students. *Computers & Education, 53*(3), 853–865.

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

Dawley, L. (2009). Social network knowledge construction: emerging virtual world pedagogy. *On the Horizon, 17*(2), 109–121.

de Freitas, S. (2008a). *Emerging trends in serious games and virtual worlds*. Coventry, UK: Becta.

de Freitas, S. (2008b). *Serious Virtual Worlds report*. Bristol / London, UK: Joint Information Systems Committee.

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

De Lucia, A., Francese, R., Passero, I., & Tortora, G. (2009). Development and Evaluation of a Virtual Campus on Second Life: the case of SecondDMI. *Computers & Education, 52*(1), 220–233.

Dede, C. (1996). The evolution of constructivist learning environments: Immersion in distributed, virtual worlds. In Wilson, B. G. (Ed.), *Constructivist Learning Environments: Case Studies in Instructional Design*: Educational Technology Publications, 165–175.

Dede, C. (2009). Immersive Interfaces for Engagement and Learning. *Science, 323*(5910), 66–69.

Dekker, G. A., Moreland, J., & van der Veen, J. (2011). Developing the Planck Mission Simulation as a Multi-Platform Immersive Application. Paper presented at the *3rd World Conference on Innovative Virtual Reality (WINVR)*, ASME, 1–9.

Dickey, M. D. (2005). Three-dimensional virtual worlds and distance learning: two case studies of Active Worlds as a medium for distance education. *British Journal of Educational Technology, 36*(3), 439–451.

Dodge, M., Doyle, S., Smith, A., & Fleetwood, S. (1998). Towards the Virtual City: VR & Internet GIS for Urban Planning. Paper presented at the *Virtual Reality and Geographical Information Systems Workshop*, Birkbeck College, 1–11.

Dokonal, W., Martens, B., & Plösch, R. (2004). Creating and Using Virtual Cities. Paper presented at the *22nd International Conference on Education and research in Computer Aided Architectural Design in Europe (eCAADe)*, Architecture in the Network Society, 580–585.

Dondera, R., Jia, C., Popescu, V., Nita-Rotaru, C., Dark, M., & S. York, C. (2008). Virtual Classroom Extension for Effective Distance Education. *Computer Graphics, 28*(1), 64–74.

Duncan, I., Miller, A., & Jiang, S. (2012). A taxonomy of virtual worlds usage in education. *British Journal of Educational Technology*. DOI:10.1111/j.1467-8535.2011.01263.x

Elger, D., & Russell, P. (2003). The virtual campus: a new place for (lifelong) learning? *Automation in Construction, 12*(6), 671–676.

Falconer, L., & Frutos-Perez, M. (2009). Online Simulation of Real Life Experiences; the Educational Potential. Paper presented at the *21st World Conference on Educational Multimedia, Hypermedia & Telecommunications (Ed-Media)*, AACE, 3564–3569.

Fischer, G. (2000). Social Creativity, Symmetry of Ignorance and Meta-Design. *Knowledge-Based Systems Journal (Special Issue on Creativity & Cognition), 13*(7–8), 527–537.

Fischer, G. (2001). External and shareable artifacts as opportunities for social creativity in communities of interest. Paper presented at the *5th International Conference on Computational and Cognitive Models of Creative Design*, University of Sydney, 67–89.

Fischer, G. (2005). Distances and Diversity: Sources for Social Creativity. Paper presented at the *5th Conference on Creativity & Cognition*, ACM, 128–136.

Fischer, G., Rohde, M., & Wulf, V. (2007). Community-Based Learning: The Core Competency of Residential, Research Based Universities. *International Journal for Computer-Supported Collaborative Learning, 2*(1), 9–40.

Fitzpatrick, G. (2003). *The locales framework: understanding and designing for wicked problems* (Vol. 1). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Grieu, J., Lecroq, F., Person, P., Galinho, T., & Boukachour, H. (2010). GE3D: A virtual campus for technology-enhanced learning. Paper presented at the *1st Global Engineering Education Conference (EDUCON)*, IEEE, 725–730.

Gu, N., Williams, A., & Gül, L. F. (2007). Designing & Learning in 3D Virtual Worlds. Paper presented at the *4th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA)*, IADIS Press, 227–234.

Hai-Jew, S. (Ed.). (2010). *Virtual Immersive and 3D Learning Spaces: Emerging Technologies and Trends* (1 ed.). USA: IGI Global.

Hayes, E. R. (2006). Situated Learning in Virtual Worlds: The Learning Ecology of Second Life. Paper presented at the *American Educational Research Association Conference*, AERA, 154–159.

Helmer, J. (2007). *Second Life and Virtual Worlds*. Sheffield, UK: Learning Light Limited.

Hendaoui, A., Limayem, M., & Thompson, C. W. (2008). 3D social virtual worlds: research issues and challenges. *IEEE Internet Computing, 12*(1), 88–92.

Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33–55.

Hill, V., & Lee, H.-J. (2009). Libraries and immersive learning environments unite in Second Life. *Library Hi Tech, 27*(3), 338–356.

Huang, H.-M., Rauch, U., & Liaw, S.-S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. *Computers & Education, 55*(3), 1171–1182.

Hudson-Smith, A., Milton, R., Dearden, J., & Batty, M. (2009). The neogeography of Virtual Cities: Digital Mirrors into a Recursive World. In Foth, M. (Ed.), *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City*, London, UK: Information Science Reference, 270–290.

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

Jarmon, L., Traphagan, T., & Mayrath, M. (2008). Understanding project-based learning in Second Life with a pedagogy, training, and assessment trio. *Educational Media International, 45*(3), 157–176.

Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009). Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life. *Computers & Education, 53*(1), 169–182.

Jennings, N., & Collins, C. (2008a). Virtual or Virtually U: Educational Institutions in Second Life. *International Journal of Social Sciences, 2*(3).

Jennings, N., & Collins, C. (2008b). Virtual or Virtually U: Educational institutions in Second Life. *International Journal of Social Sciences, 2*(3), 180–186.

Jermann, P., Dillenbourg, P., & Brouze, J.-C. (1999). Dialectics for collective activities: an approach to virtual campus design. Paper presented at the *International Conference on Artificial Intelligence in Education*, IOS Press, 570–577.

Johnson, S. (2010). *Where Good Ideas Come From: The Natural History of Innovation*. New York, USA: Riverhead Books.

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

Kluge, S., & Riley, E. (2008). Teaching in Virtual Worlds: Opportunities and Challenges. *The Journal of Issues in Informing Science and Information Technology, 5*(1), 127–135.

Ku, K., & Mahabaleshwarkar, P. S. (2011). Building interactive modeling for construction education in virtual worlds. *Journal of Information Technology in Construction, 16*(2011), 189–208.

Lee, M. J. W. (2009). How Can 3d Virtual Worlds Be Used To Support Collaborative Learning? An Analysis Of Cases From The Literature. *Society, 5*(1), 149–158.

Leong, P., Joseph, S. R. H., & Boulay, R. (2010). Applying Constant Comparative and Discourse Analyses to Virtual Worlds Research. *Journal of Virtual Worlds Research, 3*(1), 3–26.

Li, F., & Maher, M. L. (2000). Representing Virtual Places - A Design Model for Metaphorical Design. Paper presented at the *22nd Annual Conference of the Association for Computer-Aided Design in Architecture (ACADIA)*, ACADIA, 103–111.

Maher, M. L., Skow, B., & Cicognani, A. (1999). Designing the virtual campus. *Design Studies, 20*(4), 319–342.

Mckerlich, R., Riis, M., Anderson, T., & Eastman, B. (2011). Student Perceptions of Teaching Presence, Social Presence, and Cognitive Presence in a Virtual World. *Journal of Online Learning and Teaching, 7*(3), 324–336.

Messinger, P. R., Stroulia, E., & Lyons, K. (2008). A Typology of Virtual Worlds: Historical Overview and Future Directions. *Journal of Virtual Worlds Research, 1*(1), 1–18.

Meyers, J., Lamarche, J., & Eisenberg, M. (2010). Craftopolis: blending tangible, informal construction into virtual multiuser communities. Paper presented at the *9th International Conference on Interaction Design and Children*, ACM, 242–245.

Minocha, S., & Reeves, A. J. (2010). Design of learning spaces in 3D virtual worlds: an empirical investigation of Second Life. *Learning, Media and Technology, 35*(2), 111–137.

Molka-Danielsen, J. (2009). The new learning and teaching environment. In Molka-Danielsen, J. & Deutschmann, M. (Eds.), *Learning and Teaching in the Virtual World of Second Life*, Trondheim, Norway: Tapir Academic Press, 13–25.

Molka-Danielsen, J. (2011). Exploring the Role of Virtual Worlds in the Evolution of a Co-Creation Design Culture. Paper presented at the *2nd Scandinavian Conference on Information Systems (SCIS)*, Springer, 3–15.

Molka-Danielsen, J., Deutschmann, M., & Panichi, L. (2009). Designing Transient Learning Spaces in Second Life - a case study based on the Kamimo experience. *Designs for Learning, 2*(2), 22–33.

Owen, M. L., Grant, L., Sayers, S., & Facer, K. (2006). *Social software and learning*. London, UK: Futurelab.

Pana, Z., Cheokb, A. D., Yanga, H., Zhua, J., & Shia, J. (2006). Virtual reality and mixed reality for virtual learning environments. *Computers & Graphics, 30*(1), 20–28.

Papert, S., & Harel, I. (1991). Situating Constructionism. In Papert, S. & Harel, I. (Eds.), *Constructionism*, Westport, CT, USA: Ablex Publishing Corporation, 193–206.

Perera, I., Allison, C., Nicoll, J. R., Sturgeon, T., & Miller, A. (2010). Managed Learning in 3D Multi User Virtual Environments. *International Journal of Digital Society, 1*(4), 256–264.

Prasolova-Førland, E. (2005). Place Metaphors in Educational CVEs: An Extended Characterization. Paper presented at the *4th Conference on Web-based Education (WBE)*, ACTA Press, 349–354.

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

Prasolova-Førland, E., Sourin, A., & Sourina, O. (2006). Cybercampuses: design issues and future directions. *Visual Computer, 22*(12), 1015–1028.

Rheingold, H. (2003). *Smart Mobs - The Next Social Revolution*. Cambridge, MA, USA: Perseus Publishing.

Rittel, H. (1984). Second-Generation Design Methods. In Cross, N. (Ed.), *Developments in Design Methodology*, New York, USA: John Wiley & Sons, 317–327.

Salmon, G. (2009). The future for (second) life and learning. *British Journal of Educational Technology, 40*(3), 526–538.

Sant, T. (2009). Performance in Second Life: some possibilities for learning and teaching. In Molka-Danielsen, J. & Deutschmann, M. (Eds.), *Learning and Teaching in the Virtual World of Second Life*, Trondheim, Norway: Tapir Academic Press, 145–166.

Schell, C. (1992). The Value of the Case Study as a Research Strategy. Manchester, UK: University of Manchester, Manchester Business School. Retrieved from http://www.finance-mba.com/Case%20Method.pdf

Schmeil, A., & Eppler, M. J. (2009). Formalizing and Promoting Collaboration in 3D Virtual Environments – A Blueprint for the Creation of Group Interaction Patterns. Paper presented at the *1st International Conference on Facets of Virtual Environments (FaVE)*, Springer, 121–134.

Schmidt, K., & Bannon, L. (1992). Taking CSCW Seriously: Supporting Articulation Work. *Computer Supported Cooperative Work, 1*(1), 7–40.

Slavin, R. E. (1991). *Research methods in education: A practical guide* (2 ed.). Boston, MA, USA: Allyn & Bacon.

Smith, R., Oblinger, D., Johnson, L. F., & Lomas, C. P. (2007). *The Horizon Report*. Austin, TX, USA: The New Media Consortium.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In Sawyer, R. K. (Ed.), *Cambridge Handbook of the Learning Sciences*, Cambridge, UK: Cambridge University Press, 409–426.

Star, S. L. (1989). The Structure of Ill-Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving. In Gasser, L. & Huhns, M. N. (Eds.), *Distributed Artificial Intelligence*, San Mateo, CA, USA: Morgan Kaufmann Publishers Inc, 37–54.

Stebbins, R. A. (2001). *Exploratory research in the social sciences* (Vol. 48). SAGE Publications: Thousand Oaks, CA, USA.

Tait, A. (1992). Desktop virtual reality. Paper presented at the *Colloquium on Using Virtual Worlds*, IEEE, 5/1–5/5.

Thackara, J. (2005). *In the Bubble: designing in a complex world*. Cambridge, MA, USA: MIT Press.

Thompson, M. (2005). Structural and Epistemic Parameters in Communities of Practice. *Organization Science, 16*(2), 151–164.

Twining, P. (2009). Exploring the Educational Potential of Virtual Worlds – Some Reflections from the SPP. *British Journal of Educational Technology, 40*(3), 496–514.

van Nederveen, S. (2007). Collaborative Design in Second Life. Paper presented at the *2nd International Conference World of Construction Project Management (WCPM)*, TU-Delft, 1–6.

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

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

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity*. New York, USA / Cambridge, UK: Cambridge University Press.

Wenger, E., McDermott, R., & Snyder, W. (2002). *Cultivating Communities of Practice: A Guide to Managing Knowledge*. Boston, MA, USA: Harvard Business School Press.

Wenger, E., White, N., & Smith, J. D. (2009). *Digital habitats: Stewarding Technology for communities*. Portland, OR, USA: CPsquare.

Wrzesien, M., & Raya, M. A. (2010). Learning in serious virtual worlds: Evaluation of learning effectiveness and appeal to students in the E-Junior project. *Computers & Education, 55*(1), 178–187.

Yin, R. K. (2003). *Case study research: design and methods*. Thousand Oaks, CA, USA: SAGE publications.

Youngblut, C. (1998). *Educational Uses of Virtual Reality Technology* (No. D-2128). Alexandria, VA, USA: Institute for Defense Analyses.

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

Title: Virtual City as a Place for Educational and Social Activities

Published in: International Journal of Emerging Technologies in Learning, 4(s2), 2009

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

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

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

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

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

Paper 7

Authors: Mikhail Fominykh and Ekaterina Prasolova-Førland

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

Published in: International Journal of Interactive Technology and Smart Education, 2012, in press

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: CSCL at work, 2012, Springer, in press

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