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

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

KEYWORDS
3D collaborative virtual environments, educational visualizations, Active Worlds, Second Life

1. Introduction

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

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

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

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

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

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

2. Educational Visualizations: Case Studies

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

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

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

2.1. Constructing Information Spaces

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

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

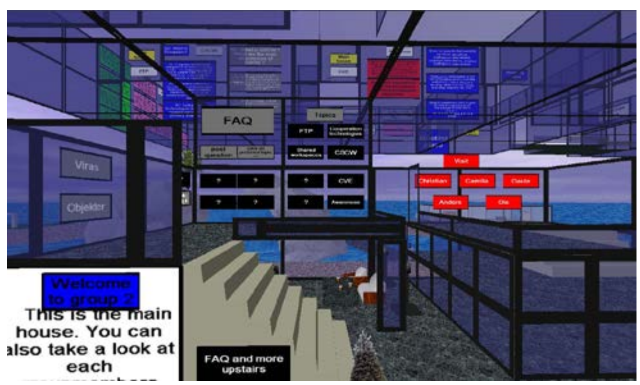

Fig. 1. FAQ as a building with rooms

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

2.2. Displaying Abstract Concepts

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

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

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

Fig. 3. Museum of communication means

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

2.3. Student constructions as crystallized activities

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

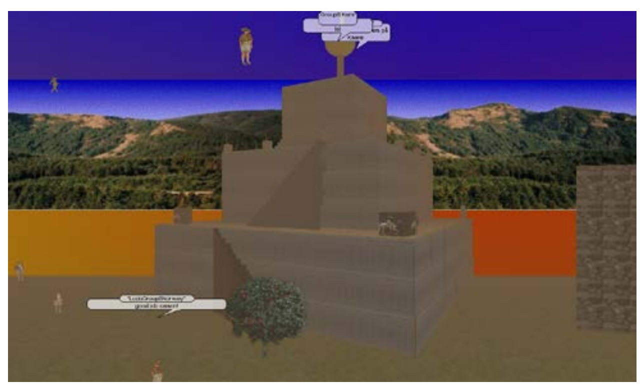

Fig. 4. A Babel tower in an 'authentic' ancient style

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

2.4. Constructing a student environment

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

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

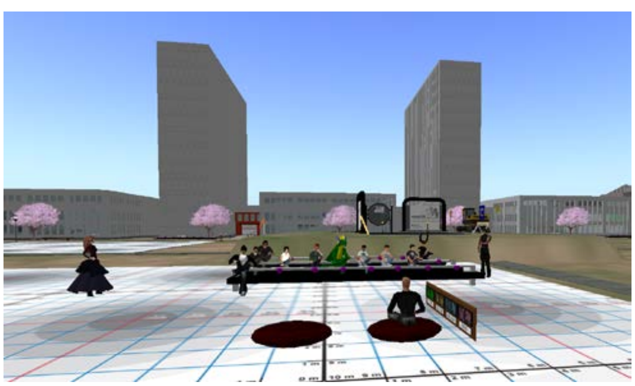

Fig. 5. Virtual Campus of NTNU in Second Life

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

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

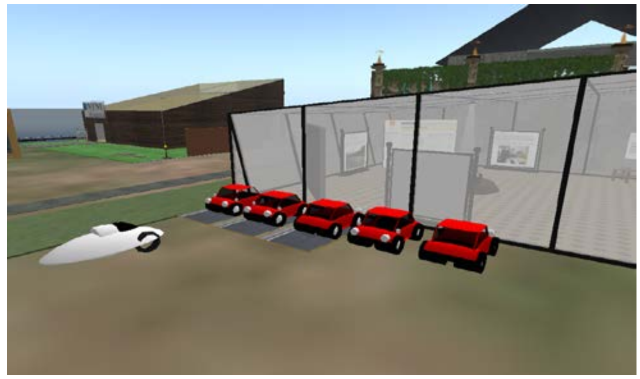

Fig. 6. DNV Fuel Fighter project with car models

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

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

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

3. Discussion

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

3.1. Visual Shells

By *visual shell* in a 3D CVE we mean a way of organizing, presenting and structuring content, for example in the form of a virtual museum. Although the content itself often has higher priority than its presented form (a shell in this context), these two concepts are interdependent and complement each other (being a duality). The role of the shell is complex and not limited to mere instrument. Shells are especially important in 3D virtual environments, considering their plentiful visualization opportunities. A 3D CVE can itself be considered as a special kind of shell for presenting content in comparison with other technologies.

Aesthetics of a shell plays an important role in enhancing students' motivation and triggering their creativity, especially when competition was involved (as was the case in most of the cases studied). On many occasions, the students spent a significant amount of time and put a lot of effort into making their constructions as elaborate as possible, in order to impress their peers that were voting for them at the end of the construction period. A lot of attention was paid to detail, such as interior decoration, furniture, lighting effects, art displays on the virtual walls and other items supporting a special atmosphere, such as 'torches' inside a construction resembling a medieval castle, and so on.

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

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

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

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

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

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

3.2. Filling visual shells with content

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

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

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

3.3. Platform issues

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

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

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

4. Implications

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

4.1. Choosing suitable technology

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

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

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

4.2. Choosing suitable content

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

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

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

4.3. Choosing suitable presentation form

Choosing a suitable presentation form for educational content is about finding a balance between aesthetics, meaning and functionality of the *visual shell* as well as different ways of displaying the virtual exhibits: text, images, 3D objects and ‘3D cartoons’ and ‘dioramas’.

It is necessary to produce harmony between the visual shell and the virtual exhibits, something that is not often obtained in practice. Generally, one of the major problems in the creative construction process can be summarized as the ‘content-presentation’ conflict, i.e. making the meaning of the visual shell in accordance with the displayed content. One of the groups in the *Displaying Abstract Concepts* study described their experience in this way: “It is impossible … to separate the design from the content. So, if one wants to make a design change, this cannot be one by itself, but the content needs to be adjusted as well”. If too much attention is paid to the meaning expressed in the construction, flexibility is reduced and a significant amount of advance planning is required. For example, if students design a thematic exhibition dedicated to ancient Egypt with the *visual shell* in the form of a pyramid, it would be difficult to extend such an exhibition or reuse it for a different theme. The same applies to using models of existing campus buildings for housing students’ exhibitions.

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

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

5. Conclusion and future work

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

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

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