PROBLEM BASED LEARNING IN DESIGN AND TECHNOLOGY EDUCATION SUPPORTED BY HYPERMEDIA-BASED ENVIRONMENTS

By

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ABSTRACT

Audio-visual advances in virtual reality (VR) technology have given rise to innovative new ways to teach and learn. However, so far teaching and learning processes have been technologically driven as opposed to pedagogically led. This paper identifies the development of a pedagogical model and its application for teaching, studying and learning with 3D virtual reality technologies. This is in the context of design and technology education, where it has been devised for the support of innovation education. This work promotes an understanding of the implications of virtual learning technologies in education for teachers, learners and educational decision-makers. Furthermore, it can be shown that when pedagogical considerations are given weight in the development of such technology-based learning services, improvements arise for all stakeholders..

Key Words: network- based mobile education (NBME), virtual reality (VR), design and technology education, pedagogical models, information and communication technologies (ICTs).

INTRODUCTION

Novel and exciting ways of stimulating and simulating design and technology education through the use of virtual reality (VR) are not currently being fully explored. However, it is clear that audio-visual advances in VR technology have given rise to new and innovative ways of teaching and learning. Nevertheless, it is acknowledged that teaching and learning processes have been technologically driven as opposed to pedagogically led. Previous research in the field of human computer interaction has studied the effect of presence, within these VR environments (Hannafin, 2004; Steuer, 1992; Whitelock et al., 2000). Thus this research has identified the need to map the pedagogical and theoretical implications of using VR technologies on the teaching learning processes. This has led to the creation of a pedagogical model as a foundation for using advanced technology. This paper seeks to outline this model and its implementation.

Previous pedagogical models have failed to take into account, new contextual and mobile methods of learning with the advance of technology- mediated learning. This paper describes a pedagogical model namely *Innovation education* (IE). This formed the basis of a three-year international research and curriculum development project entitled *Innovation Education (InnoEd)* (20012004), formulated on Network-Based (NBE) in technology education.

This work was sponsored by the European Union Socrates/Minerva fund and directed by Iceland University of Education. The InnoEd project is concerned with educational use of information and communication technologies (ICTs), specifically with the development and dissemination of a new pedagogical model for distance learning through *Innovation Education* (IE), in primary and secondary schools across Europe.

This model is based on the use of a virtual learning environment, with supporting Internet and database technologies, to facilitate virtual classrooms and virtual laboratories. This is in the context of design and technology education. The development of the IE pedagogical model focuses on the practical uses of information in technology education and the educational use of ICTs in IE. A pedagogical model and number of teaching, studying and learning processes have been devised and implemented within this virtual learning environment and current research considers strategies for their assessment and evaluation.

1. What is Innovation Education (IE)?

Innovation education (IE) in school activities has roots originally in the Design and Craft subject at schools in Iceland. It is based on a creative emphasis in teaching, studying and learning (Gunnarsdottir, 2001). The model is broadly similar to problem-based learning (PBL) (Boud and Feletti, 1999), the design model (Kimbell, 1987) and the neoVygotskian and neoGalperinian models (Vygotsky, 1978 a, b; Podolskij, 1997). These theoretical underpinnings involve the search for solutions to needs and problems in our environment as part of the method. It can also be used to encourage education in support of the redesign of current products or services. IE is intended to be directed by an innovation process rather than subject content and as such IE is cross-curricular. In this work, IE is discussed as a fundamental approach to technology education where students call upon on their knowledge and understanding from all sources to find solutions. In many respects IE is a specific *innovation centered approach to problem-based learning* (Albanese and Mitchell, 1993). In addition, innovation exercises can provide a context for the research into further understanding. The primary aims are:

1. To stimulate and develop the creative abilities of students;
2. To teach, study and learn certain problem-and innovation-based learning processes; from identifying a context, where students develop their own concepts and realization with appropriate models;
3. To teach, study and learn to use creative ability in daily life;
4. To encourage and develop the student's initiative and strengthen their self belief;
5. To make students aware of the ethical values of *object*s while teaching them ways to improve their environment.

2. Method

This is very much *a design-based action research* (Carr and Kemmis, 1993; Merrill, 2004) and as such courses and lessons have been primarily designed for in-service training of InnoEd technology teachers as well as initial teacher training providers. The overall aim is to develop a pedagogical model for IE and establish how information and communication technologies (ICT) can be used to encourage creativity, practical use of knowledge and understanding through communication and collaboration at school level in design and technology education. This paper is based on the cross cultural collaboration in researching the idea further in different phases, from the early stages to the present; for e.g. focus group sessions , by email and Internet-based online voice conferences, since the projects' inception in 2001. Many participants in the InnoEd project in different countries (i.e. UK, Norway, Iceland, Romania and Finland) have established a community to nurture the innovative spirit in school children as well as embedding IE in the differing education curricula in these countries. The project takes the form of an interactive NBE environment, where students are provided with the tools, materials and necessary interactions for their creative thoughts to become ideas and ultimately become prototype products.

A successful aspect of this work has been the involvement of schools, teacher training providers and companies, building culturally different work in innovation education, in participating countries. The European young inventors' competition has been a sustainable outcome of the project and forms part of the NBE environment. In this project, a pedagogical model of Innovation Education based on NBE courses has been developed and implemented over the Internet. Here, the students work both online and locally offline with their ideas in real-time and in face-to-face situations, instead of using only general classroom with handouts activity, as in former classroom-based model (Page and Thorsteinsson, 2003). Supporting companies Smartvr hf. and Skyrr hf. have developed a data-driven Internet-based portal used for teaching, studying and learning processes (Uljens, 1997; Tella et al., 2001; Lehtonen et al., 2004) whilst providing storage of research resources for students. These Icelandic software and multimedia companies develop and manage the virtual reality system, the Internet software and the database storage media used by the InnoEd project. Here the boundaries of information and communication technologies (ICTs) are extended to their limits in the area of VR supported technology education. The project was planned in three stages; the first stage was the culture specific dimension [MOMENTS metamodel at cultural and cross-cultural level, (Lehtonen et al., 2004)] and this preparatory stage was aimed at seeking suitable solutions to fit the existing educational surroundings in each participating country (Kananoja et al., 2000).

The work reported here has been based on the experiences of the participants in each country, sharing such experiences, and structuring a flexible NBE learning environment for teachers, students and teacher training providers in the field of design and technology education. Thus the second stage was the dissemination of innovation education within each country, training teacher trainers, in-service teachers and setting up learning environments based on the previous stage [12]. The third stage of this project is a European-wide dissemination of the Innovation Education pedagogical model based on the experience of the first two stages. The project is intended for technology education curricula across European collaborating countries, involving initial teacher-training providers, in-service teaching provision for dissemination in the classroom. The deliverable of this project is a teaching, studying and learning environment integrated with a database which stores user information, equipped with relevant tools for idea generation and development of the Innovation Education pedagogical model.

3. The Ideology Behind Innovation Education And Its Ethical Values

Innovation Education is based on the notion that everyone has creative ability that can be developed further through educational stimuli and self-developmental activities. Through such creative ability, the student uses his/her creativity to form the world. Creativity and problem-solving are intrinsic to design and technology education;. employing the creative process and problem-solving strategies based on it are important because they enhance the quality of solutions to real-life problems (Kimbell, 2000). Creative thinking results in original solutions to problems that continually arise in personal spheres (Runco and Albert, 1999). Everyone can call upon their creative ability if they have the opportunity to develop and mature through education in a conscious and directed manner. The ideology behind innovation work concerns one's ability to use their creative powers and intelligence to modify their environment (Kuo and Levis, 2002). Innovation projects are intended to augment such strengths or qualities in a student's makeup and this will hopefully strengthen society in the future (Thorsteinsson, 1998; Lehtonen, 2002).

3.1 Innovation Education in a Virtual Learning Environment

The InnoEd project is based on lengthy experience of Innovation Education in the Icelandic school system. The former model has been developed from 1992 in Iceland and is used as a background for a new pedagogical model. The old model uses general classroom environment whereas the new model combined NBE, virtual reality, the Web and specific data-based software designed by the participants in the project as shown in figure1.

The context of this model is formed for a virtual school environment instead of just using general classroom or technology education laboratories. Students have the freedom to bring their knowledge/ experiences from external sources, such as computer games into the school and work with them there in the classroom. The virtual reality environment is a shared virtual space and a *mental tool*, tool for thinking and mental problem-solving (Lehtonen, 2003; Vygotsky, 1978a; Jonassen, 2000; Lehtonen et al., 2005). It is especially suited for sharing ideas and thoughts on symbolic level and a tool for communication, distributed knowledge and shared expertise (Oatley, 1990). In addition, it engenders feelings or emotions as well as bringing the participants together and motivating them in the ideation process. Opportunities exist for using VR as tool for symbolic manipulation of problem-solving activities, and also, as a tool for cross-cultural communication, and it has established a new and open way for ideation using VR.

The way in which the InnoEd VR application will be used has been discussed and carefully researched, because the IE process was not fully developed as a pedagogical model. This model has evolved and as such the tools follow the pedagogy rather than merely fitting such model around the development of ICT and VR technologies. In other words, the way in which technology is being learned and used by the student through knowledge construction, understanding and application has much more relevance than the mere technical novelty of using such tools. The process model *Network-Oriented Studying with Simulations* was developed in MOMENTS (Models and Methods for Future Knowledge Construction: Interdisciplinary Implementations with Mobile Technologies) consortium project (Lehtonen, et al., 2005). MOMENTS is funded by Academy of Finland and the National Technology Agency of Finland and Finnish companies. MOMENTS case study *Network-Based Mental Tools in Technology Education,* has been giving background for the IE process development and becoming one part of the innovation process and process assessment model as shown in figure 1.

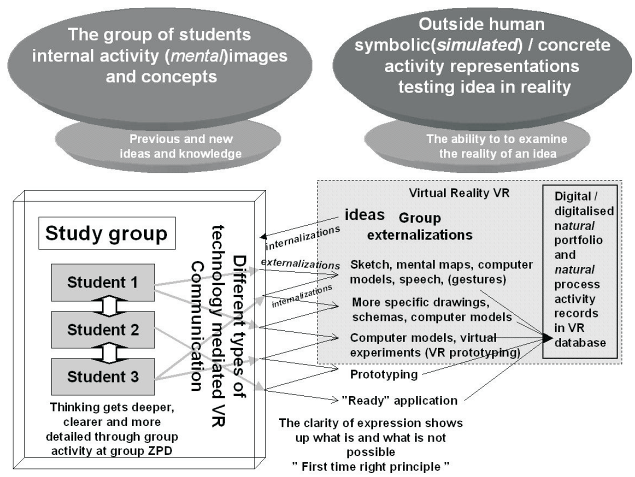

Figure 1. The preliminary VR innovation process and assessment model

Figure 1. describes the activity in the innovation education pedagogical model. The teaching has been designed to direct students' studying and learning activities both as an individual and as a member of a virtual group. This occurs through small groups towards Vygotsky's *Zone of Proximal Development (ZPD)* using instructional design solutions and mediating VR/ information technology environments (Lehtonen, 2003). The aim of this work has been to create a process in which ideas and topics are developed and studied. These related sub skills, e.g. knowledge and understanding, are constructed in the group process inside VR environment. In the initial stage of the process, students engage in network-guided activities in which they externalize, communicate and visualize their ideas to others. Such representations have been made through speech, diagrammatic figures, video-clips, drawing etc. and testing the viability of their ideas using VR environment together with physical materials.

3.2 Why use VR in Innovation Education?

The future and the prospects for teaching, studying and learning methods have not been suddenly invented. Instead of inventing them, those ways can be developed. It is a more of an evolutionary approach and revolution-like approach in developing future solutions. The InnoEd project and the MOMENTS project are future oriented projects creating ways of teaching, studying and learning. The new tools like VR are the future tools of learners. The reasons for using the VR in the InnoEd project are:

1. Communication: To enable easy communication inside 3-D spaces where students and teachers from different countries can easily meet cross-culturally and synchronously in real-time, freely sharing information and working together with their ideas;

2. Teaching: To make students able to meet each other and their teacher as avatars in network-based education (NBE) and in distance education (Vezina, 2004). This enables teachers able to guide students in their ideation processes;

3. Collaboration: To share expertise in working together around students' ideas as sharing problems would solve and develop solutions for such problems (Oatley, 1990);

4. Development: To provide opportunities for developing certain design skills, such as drawing and building prototypes from primitive shapes including cubes, spheres and cylinders;

5. Learning: To give a teacher an opportunity for delivering presentations for his/her students;

6. Audio - visual Demonstrations: To set up exhibitions of the students work as presentations from individual students and schools in the form of video or slideshows on video-projector screens;

7. 3D Demonstrations: To set up exhibitions of interactive 3D concept ideas by students;

8. Social: To facilitate VR meetings between the participants in the project possible.

9. Ethical: VR prototyping etc can be more environment-friendly (e.g. no waste of papers). Also fosters intercultural understanding of different design contexts which would take into account different cultural contexts (thus enabling more "usable" design).

4. Results From The InnoEd Vr Technology

As mentioned earlier, the main aim for the InnoEd project is to find out how new technology can be used to encourage creativity, practical use and construction of knowledge, team skills, communication, cross-cultural communication and collaboration in school education (Lehtonen, 2003). To fulfill this aim, the researchers have developed specific data-driven software. Solutions, which are based on open systems and standardized technology, are used as much as possible to make it uncomplicated for the users to transfer material from one to another systems. Furthermore, such software components function fast and are easy to control.

The data-driven software's main role is to support ideation through open communications. This Virtual Reality environment is desktop computer-based and uses specific local and server software applications. This project is in progress and the VR system has been upgraded several times reflecting the participants use and experience from the InnoEd project. The Smartvr technology is built on SmartVerse® software, which is a platform for developing and creating dynamic, multi-user, simulated 3D environments. It has a modular framework containing a large set of reusable software components that are easily assembled to create rich, truly interactive virtual worlds, suitable for a broad range of applications. Users are able to freely interact with one another, view multimedia elements and manipulate objects in the world in real-time. The inclusion of playfulness (Vahtivuori and Lehtonen, 2003) and "edutainment" (education and entertainment) and their combined influence on teaching, studying and learning is one of the underpinning ideas (Lehtonen et el., 2003; Prensky, 2001; Crawford, 2003).

For example, Prensky (2001) states that the present generation of students as *"the games generation of children"* are quite different from older generations, they want to manipulate presented objects and expect a degree of interactivity as opposed to merely and passively watching and listening. It can be proposed that the traditional way of thinking and learning has been shifted from deploying established media such as literature and print, to a considerably more interactive media such as digital video and audio. McLuhan (1997) predicted that the information environment (in this case the virtual reality environment) and the related effects engendered "by the computer are as inaccessible to literate vision as the world is to the blind" (McLuhan, 1997 p. 41). The present generation of students also learn to use the different forms of digital *media* as a *second language*. Furthermore, it becomes the essential *mediator* for their ICT *mediated* communication in different digital forms. For that purpose, the SmartVerse® also has a suite of *communication tools* to facilitate multi-modal natural user-interaction (see Figures 3. and 4.). The modularity and flexibility of the framework and the *deep level of dynamic interactivity* (Crawford, 2003) possible in SmartVerse® worlds, made it an appropriate platform for the development of the InnoEd project. The way that students use the IE VR environment seem similar to the ways they use networked 3D games. Utilizing the Internet for collaboration is combined with these VR environments as a scene and base for the digital interactive game storytelling (Prensky, 2001).

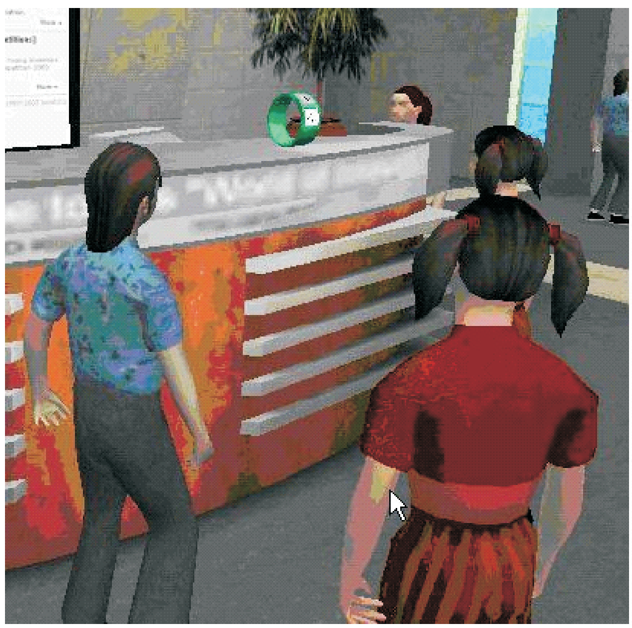

Figure 2. Inside the InnoEd environment

The activities inside VR, involve realistic, interactive virtual reality worlds in which the ideas are presented in different forms of their *externalizations* (see figure 1.), in other words, *their digital representations* are edited directly in real-time, using the SmartVR® world editor. Visual, drag-and-drop interfaces are there for editing and such changes can be seen and tested immediately. When built-in object types do not suffice for an application, new ones can be rapidly developed and added to the system. The system offers sufficient bandwidth communication, which supports many-to-many voice conferencing via the Internet (voice-over IP).

5. Discussion: Vr Communication Mechanisms In The New Pedagogical Model

The virtual team project is dependent on different types of technologies, which provide mediated communication in different ways. Cross-communication within the team is the most critical factor for the success of the project, because these different ways of communicating play a significant and crucial role in the process. The main user-communication components of the Virtual Reality used are:

1. The text chat system through Internet Relay Client (IRC), which implements traditional text chatting, where users type in sentences via the keyboard. The Text Chat system is implemented as a set of node types and User Interface Plug-ins that display them. It supports range-based chat, where you see the text being typed by avatars near to you, and group-based chat (Jensen et al., 2004).
2. The voice chat together with text chat facilitates multi-model communication; it is a many-to-many voice-over-IP conferencing system, allowing users with headphones and microphones attached to their computers to speak with one another. It is also faster to use than text chat. This approach of conferencing uses advanced compression to enable voice communications over low bandwidth telephone voice over internet protocol (VOIP) communication. The conferencing system will soon support avatar lip-synch and gesturing, making avatars move their mouth in synch with the user's speech while performing natural-looking hand and body-language gestures (Jiman, 2004).
3. The shared interactive whiteboard component implements a whiteboard, where users can express their designs within. Like the text chat system, it is implemented as a set of node types and user interface plug-ins that display them. These two subsystems are interesting examples of Q-State-enabled multi-user functionality, that is not related to 3D space at all. The whiteboard is populated with 2D graphical objects and the text chat doesn't involve spatial dimensions as the abstract design of Q-state, makes this possible.

The SmartVR® technology is an effective and somewhat pleasurable approach to user communications. The idea of edutainment, playfulness and game-based interaction fits very well to its target user group; i.e., young people across Europe. The representation of team members and their collaboration with each other inside the VR system, based on avatars, may be seen as an important phenomena in cross-cultural communication [see MOMENTS metamodel (Ruokamo and Tella, 2005)]. Here culture related objects, such as clothing and external appearance, may differ greatly as well as the gestures of communication. The avatars can be seen as representation, distinct from particular cultural and gender barriers. This can assist students in concentrating more on the IE process instead of distracting them through seeing and thinking about the personal, gender and cultural differences. The avatars offer both improved representation of presence inside the team and inside the VR, however, it provides them with limited presence as human beings. Offering a role-based interaction as opposed to a face-to-face situation, can provide a more empathic approach on the part of the student to design and technology process. In InnoED, the VR and avatar-based representation of team members may be seen to be similar to the way in which avatars and VR have been used in different (networked) computer games and in popular VR-based virtual worlds as The habbo hotel and Sim city.

The goal is to use the 3D space, avatar gestures, eye contact and camera control to help small groups of users communicate in an easy and natural way. This interaction occurs as different synchronous and asynchronous ways in parallel. The avatar-based chat and VOIP provide the most important forms of the direct co-communication (Vezina et al., 2004). These features are intended to make up for the inherent Internet network latency and the lack of verbal gestures that are a part of "eye-to-eye" conversations. SmartVR® believes that 3D spaces, graphics and avatars can recreate the sense of community and being there missing from many current voice-over-IP and teleconferencing solutions (Jensen et al., 2004; Jiman, 2004). They have become essential tools for natural and effective user communication and multimedia. These are very appropriate media for bringing people together in shared worlds so that they communicate with one another. SmartVerse® features several technological components to make communications inside 3D spaces easy and fun. The voice chat enables users to communicate with each other with speech, using the SmartVerse® world and the Internet like a phone conferencing system. The voice of each user is attached to his/her avatar in the 3D space, and this 3D is spatialised, so it sounds as if the voice comes from the direction of the avatar. You can hear the voices of those standing near to you, just as in real-life. Breaking up and forming conference groups is as simple as walking towards people's avatars (Vezina et al., 2004).

A fully featured text-chat system enables users to communicate by typing short text messages, which appear on the other user's screen in real-time. The SmartVerse® text-chat system is similar to well known text chat systems such as IRC or the text chat feature of instant messenger products. The shared whiteboard component allows users to draw on a shared 2D space. Users can draw boxes, circles, free-style lines and text.The whiteboard is comparable in features to the popular NetMeeting shared whiteboard.

The avatars are the main communication tools. They can show expressive facial expression and gesture. Users can command their avatar on the range of emotions available, which the avatar can express, letting them behave in human, realistic way, keeping eye-contact, gesture, showing facial expressions, giving back channel feedback. The goal is to make interaction in 3D spaces come as close to real-life interaction as possible. The simple interface: voice sound streams are 3D spatialised and appear to come from the speaker's avatar (Vezina et al., 2004).

The InnoEd VR world works together with a database-driven Internet environment, which can be restructured according to technological advancement and needs requirements of users. Therefore it is particularly useful for enabling and supporting the pedagogical model proposed in Innovation Education. The student's autonomy is fundamental within the Innovation Education model as the student brings his/her ideas in to the school environment and works with them there. Similarly this can promote a wider socio-economic view of inventive thinking and wealth creation (Thorsteinsson, 19987).

Innovation Education is ideologically different from most other school activities. Being in Virtual Reality gives the student more freedom to think and act independently and communicate in a school environment without borders, barriers, and power relations inherent in a fixed identity of a typical classroom situation. However, the question arises: Can we work with contextual and situational real world problems within virtual reality. The games generation of students often turn to the Internet to solve problems and fill gaps in knowledge. The InnoEd VR runs on the Internet, so the student has access to the Internet through familiar browsers. This is combined communication with others conducted in real-time. This give an immersive experience for the students, facilitating what has come to be known as telepresence. Moreover, telepresence is defined as the extent to which one feels present in the technology - mediated environment, rather than the immediate physical environment (Steuer, 1992).

Many modes of communication within this VR environment seems a key component to facilitating a sense of presence. The notion of presence is considered to be an important conceptual component of any virtual environment whether it is immersive or desktop. So what is presence? Presence is where we are immersed in a very high bandwidth stream of sensory input, organized by our perceiving systems, and out of this bath of sensation emerges our sense of being in and of the world (Whitelock et al., 2000). Users need to communicate and interact with other people, search for information and share their work and expertise.(see figure 3) All the components in the VR contribute towards making communication easier for the user navigation, avatar representation, choice of text or speech, use of sound and motion, and the general look of the world (Jensen et al., 2004; Jiman, 2004). Important communication forms are also the digital product development externalizations in different forms (digital photos, CAD designs, scanned drawings etc.) uploaded inside to the InnoEd VR world).

The VR communication system plays a significant role in the IE pedagogical model as students share problems, needs and solutions before they select their individual

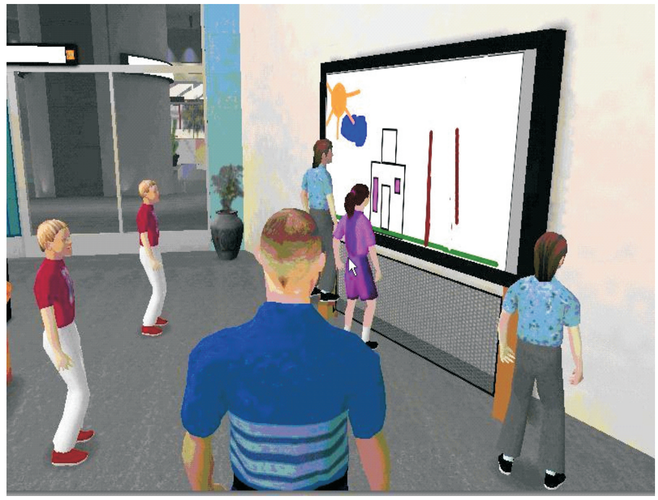

Figure 3. Inside the design studio within InnoED

solutions that they work further with on their own (Boud and Feletti, 1999). In the beginning, students log on to the Internet and search for the needs inside the VR system and share it to the other students through the database software. Once logged onto the VR system, they draw together on a whiteboard inside of the VR and put their solutions in to the database as well.

6. Discussion: The Ie Process With Use Of The VR

The innovation process in this VR environment is a simple, but powerful tool to teach the student important creative and relevant skills including collaborations. After they have learned the process they can work increasingly independently and start using the innovation methodology as an intellectual tool to solve general problems that occur in real-life (Vygotsky, 1978 a, b; Podolskij, 1997). The innovation model has not been aimed at specific age and can be used at any level. However the research has focussed in the age range of 9-16 years.

The internalisation of the needed fundamental skills and related sub skills to use the VR system as well as the requisite IE skills are studied and learned in phases. In the beginning, students will have lessons to introduce them to the fundamental skills of using the virtual environment as a tool for different subtasks in innovation process. Avatars are tested and students engage with the VR environment in shared knowledge construction. Tools such as whiteboards are tested and interactive prototypes from the students are explored. The students observe presentations on browsers with other inventions, designs and presentations made by other students. Communications tools are tested, such as small text messaging and speaking together.

Students register in the data-driven software and go from there into the VR. The first orientation lesson is to find needs and problems on the Internet and host them in the workshop. Search engines are used and students work in pairs together. Students share their needs and expertise with others in a group collaboration process, which demonstrates them as a group-to-group Zone of Proximal Development (ZPD) (see Figure 1. and Vygotsky, 1978 a).

Brainstorming sessions are conducted within the VR where students communicate together about needs found and devise solution to such needs. The theory of internalization (Podolskij, 1997) contains processes of internalization and externalization (see Figure 1.), theoretical models of technology education (Kimbell, 2000), PBL-models (Boud and Feletti, 1999) as well as ideas of reciprocal teaching (Palinscar and Brown, 2002) and provide the theoretical framework to the model. Whiteboards are used to draw the solutions, which are subsequently hosted within the database after the individual students have saved their drawings to the hard drive. Such solutions are shared with the group. Visualization tools, tools for visual externalization of objects obtain an important role during the discussion process (Zhang, 1997; Kriz, 1995). Students promote their concept inside the virtual workshop and provide a verbal description of it.

Models and posters are made in the general classroom, in technology education laboratories, and digital still pictures and video clips are then recorded and shared through VR. Students set up exhibitions with their teacher on an Internet site from their workshops. The Internet site is accessible from the VR on a browser and connected to the schools homepage also. An open day is held in the VR where students invite their parents to the virtual exhibition that has also been set up in the school. One computer with Internet access will be open in the school with a video projector for everyone to test.

7. Further Extensions: Pilot Research In Innovation Education

One of the authors has conducted an extension to the research project that took place in an Icelandic elementary school, with groups of 12 year old children. The project's main use is an action research approach to explore and develop ideation among students, when using IE materials within the InnoEd (IE) Virtual Learning Environment. The following questions guided this work:

1. What are the essential learning factors relating to IE?
2. How can the IE / VLE be used to reinforce ideation?
3. How do the students get their ideas and how do they express them?

The data collection methods used included screen captures from the VR system, external video recordings in the classroom, and interviews with the students as a group. In the first case study, the whole Virtual Learning Environment was used in both the student's workshops and the Virtual Reality part of the system. The students were given a notebook to record needs and problems identified at home and after a brainstorming meeting with the teacher in the classroom, they entered their virtual workshops. Inside the workshops, the students made drawings and descriptions, together and then hosted them inside the VR environment. This research concluded with the students setting up an exhibition that could be seen in the V R environment.

1. The following are important factors when students are using the VLE in innovation: their knowledge about innovation; to identify needs at home before entering the VLE; the training of teachers in using the system, and the motivation of the teacher in the use of the system,
2. It is important to train the students to use the whole system and all related software's such as CAD applications so that the quality of the design work will improve. It is also important to train them in how to work together through brainstorming sessions.
3. The teacher's role was different from the classroom-based teaching; he/she was more an assistant than a tutor. The autonomy of the student was increased leading to improved cooperation.
4. Through the interviews, the students implied that they came up with some of their ideas when they were working inside of the Virtual Reality, not just at home before the lesson. The students got more ideas when they were working together inside of the VR. The students liked to work in the VR, it was for them both interesting and motivating.

The main conclusion is that the VR environment can be used to reinforce the process of ideation and it is therefore necessary to develop appropriate pedagogy in the context of using the InnoEd Virtual Learning Environment. The next case study, as part of this project research, will focus on the use of the VR part of the system and the ideation process through collaboration. More emphasis will be put on exploring the ideation process and see how the factors that affect it can be modified. It is also necessary to develop the use of the technology further.

8. Future Research

Further work of this project is the development of future approaches in all sub-disciplines of technology education (Alamäki, 1999; Dugger and Naik, 2001). In addition, the development of specific data-driven software technologies in support of innovation education utilizing virtual reality (VR) technologies for integrated communication, in support of the process of idea generation, development, process evaluation and physical product prototyping. The VR system plays a major role in the innovation education pedagogical model. The model has been in development since 2001 and will be tested with students and student teachers, as well as schoolteachers during the school session .

Other proposed research includes design-based action research on using the new Innovation Education model, to examine the approaches in teaching, studying and learning on creative skills inside the VR environment in order to improve upon their ideation. This research will be intercultural; interaction with several partners from different countries will elucidate different teaching styles. More importantly, future research will focus on analyzing the pedagogical dimensions of the IE-model to investigate the advantages and disadvantages of different online and offline teaching tools. For such research purposes, a number of cross-cultural teaching experiments will be organized in the near future. The participating students will be from Iceland, England, Finland and Japan. The students' attitudes will be measured in pre and post-test settings during the experiments. Furthermore, data will be collected from students activities by simultaneous screen recording on video and by specialised software solutions (Lehtonen et al., 2004). Simultaneous screen recordings of students using the VR system, will be recorded into a single format to be analysed. The student groups will be interviewed after the lessons using the stimulated recall-method (STRI) (Marland, 1984; Bloom, 19553). Students will be shown some innovation process phases from video as well as the natural process outputs from the VR database, from the VR digital natural portfolio database. Further evaluations may reveal problematic situations for analysis from the collected simultaneous screen data. Qualitative data will be collected where the student participants will be asked to describe their design processes, thinking processes, and their feelings and emotions during these processes. A number of case studies will be organized, of 11-12 year old student's use of the virtual reality and the data driven software. The outcomes of this work will be used in courses for in-service teacher training and initial teacher trainees who would wish to use virtual school environment for Innovation education (IE) in the future.

One example of such a system has been planned in which 3D virtual models are designed using different CAD applications and physical objects (e.g. models or prototypes), which can be viewed inside the VR system. Physical objects will be placed into the viewpoint of a webcam system which will be connected into the desktop VR program and from which those would be immediately be seen also inside the VR. Through such a system, the VR world may also offer an opportunity for immediate interaction with real world objects in different forms as the externalized form of ideas in material form of communication to be shared with others.

In InnoEd project, the authors have also been exploring the possibilities to utilize novel emerging technologies which provide new interaction paradigms for multimodal communications inside the VR (Ye and Campbell, 2005). Those technologies are important because through these kind of tools, students may overcome the drawbacks from conventional interfaces. Instead of using a 2D mouse and keyboard, for interaction with 3D VR environments, for example, haptic technology can provide an attractive solution. It is asserted that this type of technology provides students with more natural and intuitive user interface when used in conjunction with the VR system. For example, students can view the design content in 3D as well also touch and feel the design result directly. It will be of interest to find out whether incorporating haptic interaction, along with CAD modeling programs, will enable the students to work more creatively by taking advantage of their existing skills and experience.

Conclusion

This paper has been revised in light of the developmental research project intended to develop pedagogical model for Innovation Education (IE) in the school environment and some of the basic principles and technological solutions developed for studying IE in virtual reality environments. More general background for the model is, that creative work can occur in all areas in the school, if educators are willing to foster and fully utilize the creative intelligence of the individual. We should remember that the play of young (as well the adult) and the creative process are very much linked. Joy, play and creativity are best seen in environments, both offline and online, which are attractive and allow students to be active, playful, and creative. These combine multimodal communication with joint real activities outside the VR. InnoEd environment is to be one of such playground for joy, play and innovations. Innovation Education is therefore, considered as an awakening and reinforcement for creative work in all areas in the schools. The Innovation process plays a bigger role in the educational system than before as technology moves forward. Innovation can be, to a certain degree, an answer to the need for a creative emphasis in modern and for the future education. With the use of virtual reality the innovation methodology can be used in all subject areas. The virtual reality assists with open communication without borders and provides an opportunity for ideation with the educational use of communication and information technologies as a cross-curriculum way to improve education.

The virtual reality system offers the participants in the InnoEd project many new opportunities for ideation. They no longer have to be passive spectators but can experience, collaborate and construct the virtual world in a number of ways. The data-driven software gives opportunity for recording every step taken in the system and makes it easily possible to research the ideation process inside the virtual learning environment.

Modern society and its economic implications are increasingly built on knowledge and working with ideas. Teamwork, shared expertise and building ideas together are just some of the benefits of this VR education. The modern environment, is always changing because of new technology and knowledge. In order to manage with that modern environment, the individual must be able to adapt to novelty and to see possibilities in using new knowledge to produce new products. Innovation Education environments are increasingly relevant for education, ideation and collaboration, and can provide an ethical, sustainable environment for design and technology education.

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