Innovative Technology Education in a Virtual Reality Learning Environment: Some Findings

Thorsteinsson G., Page T., Lehtonen M., Niculescu A.

Abstract: This paper presents work done in the development and application of virtual reality technologies for the support of innovative technology education on an open-and distance-learning (ODL) basis. This work promotes an understanding of the implications and possibilities of virtual learning technologies in education to teachers, learners and educational decision-makers. Furthermore, to ensure that pedagogical considerations are given weight in the development of such integrated communication technology based learning services whilst considering innovation and improved methods in ICT for Technology Education.
The InnoTek project is concerned with the development and dissemination of a new model for distance learning in Innovative technology education (ITE) in primary and secondary schools in Europe. This model is based on the use of a virtual learning environment with supporting internet and database technologies to facilitate future 'virtual classrooms' and Technology Education "virtual laboratory rooms" on the World-wide Web. A number of teaching and learning scenarios (or lessons) have been devised and implemented within this virtual learning environment and current research has focussed on strategies for assessment and evaluation. This work reported here is very much applied research and such courses and lessons have been primarily designed for in-service training of technology education teachers as well as initial teacher training providers.

Keywords: Innovative technology education, virtual reality learning environment.

Gisli Thorsteinsson, is an Assistant Professor at Iceland University of Education, in the Department of Design and Craft. At present he is also a PhD student at Loughborough University, where he is exploring the values of using Virtual Learning Environment for ideation in general school education. Gisli has been the Chairman of the Association of Icelandic Industrial Arts Teachers since 1995 and is associated with the NST Coalition of Industrial Arts Teachers in Scandinavia. From 2000 he has been on the Board of 'Nordfo', the Pan Scandinavian co-operative researching art and design projects in Scandinavia. In 1999 he was involved in the National Curriculum development for technology education in Iceland and wrote the curriculum part for design and craft. Gisli has written numerous articles concerning design and craft education and has published several textbooks about innovation education.

Tom Page graduated in 1988 from Napier College, and then worked for Ferranti Defence Systems as a design engineer. In 1990, he returned to Napier as a Research Assistant and obtained an M.Phil. In 1992, he took up a teaching post in Computer-Aided Engineering at the University of Hertfordshire where was awarded a PhD in 2002. He has worked with the Open University. Tom is a Chartered Engineer with full membership of the Institution of Electrical Engineering (IEE) and the Higher Education Academy (HEA). Since May 2003, he has been teaching at Loughborough University. His research interests include learning technologies, electronics design and manufacture and logistics management. To date he has over 260 publications in these areas.

Miika Lehtonen is researcher at MOMENTS (Models and Methods for Future Knowledge Construction: Interdisciplinary Implementations with Mobile Technologies) - project. His research and development has recently focused on developing pedagogical models and tools for network-based learning utilizing the Vygotskian and neoGalperian ideas of 'mental tools' or 'mindtools' and Web based pedagogical agent orientation (cp. Jonassen 2000). His main interests lie at the area of using interactive & constructive simulations effectively as mental tools for learning.

Andrei Niculescu holds a bachelor's degree in English and Arabic Philology from Bucharest University (1980). He obtained his MA in Applied Linguistics from the same university in 2003 and is currently pursuing a doctorate degree in Education. His background also includes extensive working experience in foreign trade both in business operations and personnel training. Presently, Mr. Niculescu teaches Business English to undergraduate business students and his interests include: teaching strategies, e-learning, library science and documentation, course design and assessment, English for Specific Purposes and Second Language Acquisition.

1. Introduction to the InnoTek Project

Loughborough University is directing a three-year research project called InnoTek sponsored by Toyota. This project focuses on the practical use of information and computer technology for open and distance learning in 'innovative technology education'. The project's aim is to find out how such technologies can be used to encourage creativity, practical use of knowledge, communication and cooperation in design and technology education at school and university levels. This paper is based on collaborative research work of the authors in brainstorming the idea further in different phases from the early stages to the present situation on Focus Group-type sessions at Rovaniemi and by virtual conferencing since the project was started. The many participants in the InnoTek project on different countries have establish a community to nurture the innovative spirit in school children as well as embedding Innovative technology education in the different education systems in Europe. The project provides a niche, in the form of an interactive internet-based ODL (Open Distance Learning) environment, where students are provided with the tools, materials and necessary interactions for creative thoughts to become ideas and eventually products.

This work involves schools, teacher training institutions and companies in four countries building on successful yet culturally different work on innovative technology education already taking place in these countries. The European Young Inventors competition has been a sustainable outcome of the project and forms part of the web-based ODL environment. The objective of this project is to develop future

approaches all sub-disciplines of Technology Education (cp. Alamäki 1999; Dugger & Naik 2001) as well as to develop specific data-driven software technologies in support of innovative technology education and uses virtual reality technologies for integrated communication to support the process of idea generation, development and assessment of the process and products. InnoTek is a cooperative venture of four countries in the area of innovative technology education namely Iceland, Finland, England and Norway and has its roots on fifteen years of experience of such technology education in Iceland.

In this project, a distance-learning course in innovative technology education has been developed and implemented over the Internet. Here, the students work online with their ideas in real-time instead of using general classroom with handouts activity as in former classroom based model (Page and Thorsteinsson, 2003). The supporting companies have developed a data-driven Web based system located on website used for communication, learning and teaching whilst providing storage of research for students. Here the boundaries of Information Technology are pushed to their extremes in the area of VR supported Technology Education. The Icelandic software and multimedia companies Smartvr hf. and Skyrr hf. develop and oversee the virtual reality system, the Internet software and the database storage used by the InnoTek project (Page, 2003).

2. Innovative Technology Education

Innovation school activities arose from the original Design and Craft subject in Iceland. It is based on a creative emphasis in both teaching and learning (Gunnarsdottir 2001). The basis is conceptual work in the broadest sense which involves a search for solutions to needs and problems in our environment. It can also be used to enhance or redesign current designs, products or solutions. ITE is intended to be driven by an innovation process rather than subject content and as such is cross-curricula. In this work, ITE is discussed as fundamental approach to technology education. In IE, students call upon on their knowledge from all sources to find solutions (Aðalnámskrá grunnskóla, 1999). In many respects InnoTek is a specific approach to problem-based learning (PBL) (cp. Albanese & 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 students certain processes; from identifying a context, developing their own concepts and realisation with appropriate models;
3. To teach students to use their creative ability in daily life;
4. To encourage and develop the student's initiative and strengthen their self image;
5. To make students aware of the ethical values of "objects" while teaching them ways to improve their environment (Thorsteinsson, 1996).
6. To define the pedagogical issues of using the VRLE for ideation in Innovation Education.
7. To identify those issues influence the ideation process in the VRLE in Innovation Education.
8. To investigate the ways in which the can teacher effectively manage such issues.

3. Innovative Technology Education in a Virtual Learning Environment

The InnoTek project is based on a long experience of Innovative technology education in the Icelandic school system. Former model has been developed since 1992 in Iceland and is used as a background for a new model. The old model uses general classroom while the new model uses Virtual Reality, the Internet and specific data based software designed by the participants in the project.

The new model is a continuation of the old model and is built on the same creative processes. However, is formed for a virtual school environment instead of just using general classroom or Technology Education labs and it uses the InnoTek data based software, ICT, Virtual Reality and ODL possibilities. The students have the same freedom to bring their realities in to the school and work with them there. The virtual reality is essentially a shared virtual space and *mental tool* (Lehtonen 2003b cp. Vygotsky 1978; Jonassen 2000; Lehtonen 2003a) for sharing ideas and thoughts on symbolic level and tool for communication, tool for sharing knowledge and feelings or emotions as well as linking the participants together and motivating them in the ideation process (Runco and Albert, 1999). These opportunities for using VR as a mental tool for symbolic levels of problem solving activity and also as a tool for communication find a new and open way for ideation using virtual tools inside the VR.

The way the InnoTek VR application is going to be used has been discussed and carefully designed

because the ITE process has not been developed by only developing the technological innovations and tools. The way technology is used is as important as the tools. The process model "Network oriented studying with simulations" (e.g. Lehtonen 2003a; Lehtonen 2003b) developed in consortium process "MOMENTS" (Models and Methods of Future Knowledge Creation, funded by Academy of Finland and the Finnish National Technology Agency Tekes) Case study no. 6 "Network based Mental Tools in Technology Education) has been giving background for the ITE process development and becoming one part of the innovation process and process assessment model (see Figure 1).

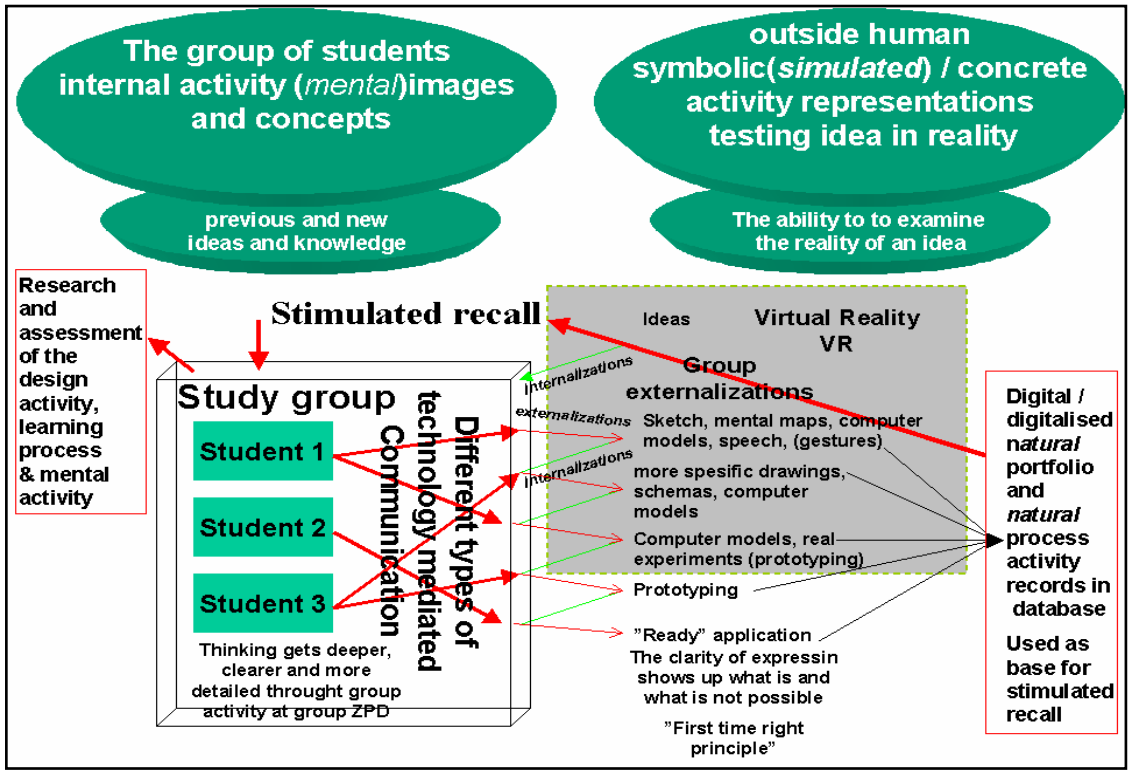

Figure 1. The preliminary VR innovation process & assessment model

4. The InnoTek VR Technology

As mentioned above the main aim for the InnoTek project is to find out how new technology can be used to encourage creativity, practical use of knowledge, team skills, communications and cooperation in school education (cp. Lehtonen 2002a). To fulfill this aim the participants have developed specific data-driven software. The software uses SQL2000 and ASP websites. The database is hosted by Skyrr in Iceland. Solutions based on standardised or de facto-standardised technology are used as much as possible to make it easy for the users to transfer material from other systems. The software works fast and is easy to control.

The virtual reality used in the InnoTek project works with the data-driven software and its main role is to support ideation through open communications. The former model has been developed since 1992 in Iceland and is currently used as a background for new model (Thorsteinsson 1994). This model uses general classroom and Technology Education labs while the new model uses virtual reality, the Internet and specific database software designed by the participants in the project. The InnoTek project uses version of a Virtual Reality technology developed by the Icelandic Smartvr company. This Virtual Reality is desktop computer based and uses specific local and server software applications the company has developed for many years. This project is in progress and the VR has been upgraded several times and built on the participants experience from the InnoTek project.

The Smartvr technology is built on the SmartVerse® software which is a platform for creating dynamic, multi-user, persistent simulated 3D environments. It is 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 idea of Edutainment (education & entertainment) and its influence on studying and learning is one of the background ideas (see e.g. Lehtonen 2003a; Lehtonen & Vahtivuori 2003; Vahtivuori & Lehtonen 2003; Prensky 2001; Crawford 2003). SmartVerse® also has a suite of communication tools to facilitate multimodal natural user-interaction. The modularity and flexibility of the framework and the deep level of dynamic interactivity (cp. Crawford 2003) possible in SmartVerse® worlds are make it an appropriate platform for the development of the InnoTek project.

5. The VR Communication

The virtual team project is heavily dependent on different types of technology mediated communication ways. The so-called cross communication inside the team is the most critical key for success of the project. Because the communication plays a big if not crucial role in the process it has been supported with many ways. The main user-communication components of the Virtual Reality used are:

1. The Text Chat system 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 both range-based chat, where you see the text being typed by Avatars near you, and group-based chat similar to internet relay chat (IRC).

2. The voice chat together with text chat allows multimodal communications; 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. The conferencing uses advanced compression to enable voice communications over low bandwidth (several voice streams over a 28K modem).

3. The shared whiteboard component implements a shared whiteboard that users can draw on. 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 fun approach to user communications. The idea of edutainment and game like or game based interaction model is very likely fitting well to its target user group; young people across the Europe. 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 with voice. These features are intended to make up for the inherent Internet network latency and the lack of verbal gestures that are a necessary part of eye-to-eye conversations and technology components to make communications inside 3D spaces easy and fun.

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 that can show expressive facial expression and gesture. Users can command their avatar on expanding the range of emotions which the avatar can express, letting them behave in human, realistic way, keeping eye-contact, gesture, showing facial expressions, giving "back channel" feedback and so fort. The goal is to make interaction in 3D spaces come as close to real-life interaction as possible. Simple interface: voice sound streams are 3D spatialised and appear to come from the speaker's avatar.

The InnoTek VR world cooperates with interactive database web environment that can be accessed from the VR. The InnoTek VR is an Internet and desktop based VR and can be structured according to technological advancement and system-inherent properties that makes it attractive for Innovative technology education. The concept of the student's autonomy is fundamental in Innovative technology education as the student brings his ideas in to the school environment and works with them there and at the same time promotes the society. This makes the Innovative technology education different from most other school activities and brings us its ideological issues.

Being in Virtual Reality it might give the student more freedom to think and act independently and communicate in a school environment without borders. However, the question arises, Can we work with

real world problems in virtual reality? To make this possible the InnoTek VR runs on the Internet and the student has access to the Internet through browsers and the communication is conducted in real time. Whereas telepresence is defined as the extent to which one feels presence as the extent to which one feels present in the mediated environment, rather than the immediate physical environment (Steuer, 1992).

Communications are seen as the key component in the VR as it creates 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 the presence? Presence is where we are immersed in a very high bandwidth stream of sensory input, organised by our perceiving systems, and our of this "bath" of sensation emerges our sense of being in and of the world (Whitelock, D 2000). Users need to communicate and interact with other people, search for information and share their work. 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.

6. The InnoTek Process with Use of the VR

The innovation process or methodology is simple, but a powerful tool to teach the student important creative relevant skills. After they have learned the process they can work increasingly independently and start to the innovation methodology as a tool to solve general problems that occur in life. The innovation model has not been aimed at specific age but been very much practiced in the age range of 9-16 years, but the methodology can be used at all levels.

Students register to the data driven software and go from there to the VR. This lesson is to find needs and problems on the Internet and host them in the workshop. Search engines are used and students work two together. Students share their need with other students. Brainstorming session in the VR where students communicate together about needs found and come up with solutions. Whiteboard are used to draw them and after that they are hosted on the database through the workshop after the individual students have saved the drawings to the hard drive such solutions are shared with the group. Students promote their concept inside of their workshop and make verbal description. After that they take part in the Young Inventors Competition.

Model and posters are made in the general classroom, in Technology Education labs and digital still pictures and video clips are taken. Students set up exhibition with their teacher on a website from their workshops. The website will be accessible from the VR on a browser and connected to the schools homepage as well. Open day in the VR where students invite their parents to the exhibition that have also been set up in the school. One computer will be open in the school with a video projector for everyone to test.

7. Research Methodology

The research is interpretive as it seeks to understand and interpret the VRLE, the learning experiences of the students and the developing pedagogy used by the teachers. Neuman (1997) defines this as exploring "…socially meaningful action through the direct detailed observation of people in natural settings in order to arrive at understandings and interpretations of how people create and maintain their social worlds".

To retain the integrity of the phenomena being investigated, efforts are made to 'get inside' the person and to understand them (Cohen et al., 2001). The interpretive researcher begins with individuals or groups and sets out to understand their interpretations of the world. Theory is emergent from particular situations; it should be grounded on data generated by research acts (Glaser and Strauss, 1967).

Action research was chosen as a way of observing the complex social/educational activity in the VRLE. One of the key principles is that action research is participatory: it is research through which practitioners work towards the understanding and improvement of their own practices (Kemmis and McTaggart, 1992). However, in this work, the researcher's role was as planner and external observer; the teacher took the lessons.

The research was built on three case studies. After analysing data from each study, the researcher revised the plan before starting the next (see figure 2). The first case study explored the use of the VRLE in relation to ideation, identifying factors and enabling a sharper focus. The second was built on educational material made to support students in using the VRLE. This material was based on the first case studies. The third was to identify possibilities of using mainly the VR part of the VRLE for the InnoTek ideation process.

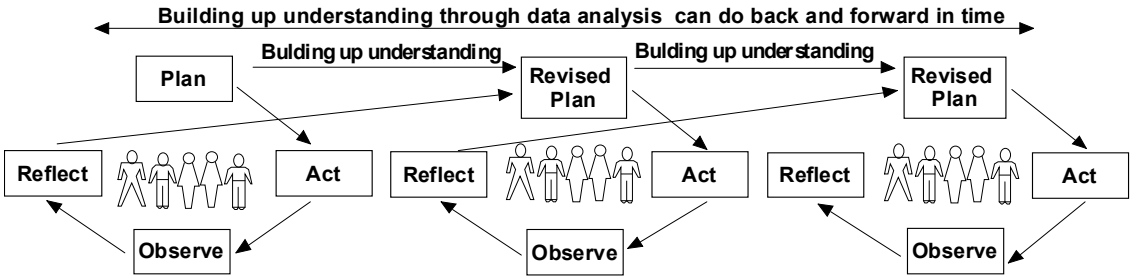

Figure 2. The action research cycle supported the research.

7.1 Instruments of Measure

The observer needed a comprehensive set of data collection in order to get as much of information as possible relating to the research questions. Different data were intended to triangulate the research and build validity. To analyse the qualitative data, the researcher employed the qualitative and inductive methodology developed by Glaser and Strauss (1967). The specific instruments used are listed against research questions in table 1, below.

7.2 The course plan and the data collection methods

A course plan based on four lessons was established to support the teacher:

1. Introduction and training in using the VRLE.
2. Individual students work out solutions using the VRLE.
3. Students develop solutions as a group inside the VRLE.
4. Individual students develop solutions for an exhibition in the VRLE.

The various data collection methods applied in the case study series enabled triangulation. Table one shows the connection between the data sources and the research questions. The data was treated as follows.

a) Data collected.

b) Summaries written.

c) Results identified in data.

d) Data analysed and classified.

e) Interpretations written

f) Interpretations used to form new research questions.

Table 1. Data collection methods and how they answer research questions.

	Data Sources	Q1 answer	Q2 answer	Q3 answer
1.	Screen captures in the VRLE	x	x	
2.	Interviews with the teachers	x	x	x
3.	Interviews with students group about the course and their work	x	x	x
4.	The researchers logbook	x	x	x
5.	Drawings and descriptions from students	x	x	
6.	Video recordings in the classroom	x	x	x
7.	Data from the VRLE		x	
8.	The Inventors Notebook	x	x	

8. Main Pedagogical Issues Emerging from Data

The main issues established by the pilot research were:

Computer literacy

Interviews with students and teacher plus observations indicated that the students easily learned to use the VRLE and cad software. Little teacher assistance was needed. However, further training helped them to draw better and faster using the hardware and software involved. The new VRLE technology can be used as children have enough computer literacy to use it.

Managing the VRLE in the school context

The interviews with the teacher, his logbook, and observations showed the importance of the teacher managing the VRLE hard and software. Appropriate facilities are needed to run the system such as graphic cards, headsets, and digital pens. Introducing such new approaches and technology does, however, require a great deal of effort for the teacher. Training would be necessary to enable teachers to manage.

The Role of The Teacher

In the interviews and logbook the teacher talked about the importance of being trained to use the VRLE. In addition, it is necessary to understand the InnoTek ideation process. In his observation, the researcher could sometimes see a lack of the teacher's understanding for the InnoTek innovation process. He frequently tried to give the students a brief it they had not found a problem or a need they could solve. He also tried to get them started with his own ideas when the children were meant to find solutions to needs they had identified in their environment and recorded in their Inventors Notebook.

The pilot case studies showed the teacher felt more an assistant/facilitator than a teacher. The VRLE was found to be user friendly and enabled the students to be self-reliant. Nevertheless, the teacher still had to use familiar pedagogical principles such as giving clear instructions. It was important to link the students' homework with their activities inside the VRLE through brainstorming sessions in the classroom. After that, the students could work independently. When they had to undertake their work in the VRLE, they sometimes got tired after 20-30 minutes. By using short brainstorming sessions the teacher found it was possible to refresh them. The teacher's role in InnoTek is one of the issues and relates to.

- The teacher's knowledge and skill in using the new technology.
- The teacher's preparation for the course.
- How the teacher organises the lessons.
- How the teacher understands the InnoTek ideation process.
- How aware the teacher is of the students' staying power when they are
- using the IE/VLE/VRLE to be able to refresh them when they get tired.
- How effectively the teacher uses brainstorming sessions in the lessons.

9. Ideation Within the InnoTek Process

The Inventors notebooks showed that students originate their ideas at home by identifying needs and problems. When the students started to use the VRLE in the second pilot case study, they talked about getting more ideas, not just at home but also while using the VRLE.

The pilot showed some confusion amongst the students in relation to what are needs, problems, and solutions. They were able to collaborate inside the VRLE and develop solutions based on a common need. This had, however, to be done through brainstorming.

Several observations on students' drawing skill showed they had difficulties using their computers to draw. They used simple cad software and used the specific whiteboard inside the VRLE. First, they used the mouse and later two different drawing pens. The earlier pen required the students to look at the screen as they drew. Students found it easier to use the mouse than these pens. The second pen was dual function in that it made a mark directly on paper while working with the computer. These pens were easy to handle and draw with as the student gained direct feedback on the paper in addition to the screen.

10. Discussion

Some issues of ideation when using a VRLE have been explored though the pilot case studies. They will be used as guidance for the next phase. The role of the teacher is one of the main issues when adopting a new technology or pedagogy in schools. Bork (1995) observes:

"New course structures, new roles for teachers, and new patterns for organizing classrooms in schools with the technology, often with very exciting possibilities, cannot be done unless we build whole courses from the beginning using the technology".

The teacher's role was different from the classroom-based teaching; he was more an assistant and facilitator than a tutor. In the interview, he speaks about lack of training for using the software and about the need for having a good training course before starting the research. An effective manual would also be helpful.

The student's computer and VRLE literacy is important. In the research, the student needed very little training to use the equipment. Many of them use computer games built on similar technology. To use such kind of technology in school was interesting, as they frequently told the observer in the interviews. The students' skill was different but in the video recordings and observations, the researcher could see them help each other in the classroom if they had technical problems. Using the VRLE outside the classroom as a tool for open and long distance education might change this, as the students would have to communicate with each other through the computer only.

Sketching is a valuable part of the InnoTek ideation process. It allows the students quickly to represent their design ideas in a physical medium. The students were able to cooperate using the VRLE but their work was dependant on their ability to use the computer technology for sketching. They had difficulties in using the computer to draw and their sketches were very inaccurate. They found it easier to use a simple pen and a paper. A wireless ink pen used late in the research was more user-friendly but not compatible with the whiteboard in the VRLE. Plimmer and M. Apperly (2002:6) came to similar conclusions in their research work, "Although most designs are rendered on a computer, most designers choose not to use a computer for the first stage of design because the currently available interfaces do not support the informality of sketching". In their article, they point out that using computers for drawing depends largely on the quality of the equipment and the software.

The student's understanding on the ideation process is important. Different ways of communication when using the VRLE seem to facilitate their ideation as they state they find more solutions when using the VRLE. It is important to train them in how to work together through brainstorming sessions and to use this technique frequently during the work. The students reported they got more ideas when they worked together inside the VRLE and when the teacher refreshed them with brainstorming sessions. This will be explored further in the next case study series.

Using the VRLE gives the students and teacher various ways of communicating their ideas and this seems to support the ideation process and motivates the students to come up with more ideas. The video recordings in the classroom show the students discuss their ideas with each other and explain them for each other. The concept of VRLE is linked to the feeling of being in a location other than where you actually are. This means that you can control an avatar or another device at a distance. It is possible that the fact that students can 'play a role' via the use of avatars when using the VRLE may be an issue which merits further research (EDS, 1991; McLellan, 1995; Ulman, 1993, 1997; Shimoga & Khosla, 1994; Wong, 1996).

11. Future Research

Other work in this field includes action research in using the new Innovative technology education model with focus on the approaches to the training of children and teaching creative skills inside of the VR in order to improve upon their ideation. The process is most likely to be done in interaction with several partners. The focus of the research will be mainly upon children's learning, planning of teaching; teaching and using techniques and the communication inside than VR and in the classroom. Three case studies will be made on the innovative technology education model of 11 –12 year old children's use of the virtual reality and the data driven software. The conclusion will be used for courses for teachers that want to use virtual school environment for Innovative technology education in the future.

12. Conclusion

Creative work can occur in all areas in the schools if educators are willing to foster and fully utilise the creative intelligence of the individual – we should remember that the play of young (as well adult's) and

creative process are very much linked. Joy, play and creativity are best seen in environments, which are attractive and allow them to be there. The InnoTek environment is to be one of such playground for joy, play and innovations. Innovation is therefore construed 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, one 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 use of computer and information technology as a cross curriculum way to better education.

The virtual reality system offers the participants in the InnoTek project many new opportunities for ideation. They no longer have to be passive spectators but can experience and work in 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 of the virtual learning environment.

Modern society and its economic implications are more and more built on knowledge and working with ideas. The team work, shared experience and building ideas together in European wide markets is going to be one of the future trends (e.g. Alamäki, Mäkinen & Lehtonen 2003). 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. As design and manufacturing technologies advance it could be claimed that traditional workshop skills are less relevant. If accepted as a premise, this implies that the approaches used by ITE are increasingly relevant in that they focus on initial ideation rather than prototyping.

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