INNOVATION EDUCATION ENABLED THROUGH A COLLABORATIVE VIRTUAL REALITY LEARNING ENVIRONMENT

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ABSTRACT

This article provides a descriptive account of the development of an approach to the support of design and technology education with 3D Virtual Reality (VR) technologies on an open and distance learning basis. This work promotes an understanding of the implications and possibilities of advanced virtual learning technologies in education for teachers, learners and educational decision- makers. Furthermore, this work aims to ensure that theoretical and pedagogical considerations are given weight in the development of integrated Information and Communication Technology (ICT)-based learning services, while considering innovative and improved methods of educational use of integrated learning technology (ILT) for technology education.

KEYWORDS: Design, technology education, Network-Based Mobile Education (NBME), Virtual Reality Learning Environment, Information and Communication Technologies (ICTs)

INTRODUCTION

This paper describes a pedagogical model namely Innovation education (IE), which was the focus of a three-year international project entitled Innovation Education (InnoEd) which is based on NBE in technology education. This work has been 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 Technology (ICT) and the development and dissemination of a new pedagogical model for distance learning in Innovation Education (IE) in primary and secondary schools across Europe. This model is based on the use of a virtual learning environment, with the support of Internet and database technologies, to facilitate virtual classrooms and virtual laboratories in support of technology education, on the Internet. This work is focused on the development of the IE pedagogical model and practical use of information in technology education as well as the educational use of ICT 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. This is very much a *design based action research* (e.g. [1] [2] [3]) 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 project's major 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. The project is founded on G. Thorsteinsson's visions about future education and innovation education (IE). Many participants of the InnoEd project in different countries like 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 provides a niche, in the form of an interactive NBE environment, where students are provided with the tools, materials and necessary interactions to develop their creative thoughts into energetic ideas and ultimately to create the best products.

This work involves schools, teacher training providers and companies, building on successful yet culturally different work in innovation education, which has already been taking place in the countries which participates in IE. The European young inventors' competition has been a sustainable outcome of the project and forms part of the NBE environment. Further work considered in this project is to develop future approaches for all sub-disciplines of technology education (cp. [4] [5]). In addition, to the development of specific data-driven software technologies, in support of innovation education, virtual reality (VR) technologies are used for integrated communication in support of the process of idea generation, development, process evaluation and physical product prototyping.

In this project, a pedagogical model of Innovation Education based on NBE courses have been developed and implemented over the Internet [http://www.innoed.is]. 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 purely classroom based model [6]. The supporting companies Smartvr hf. and Skyrr hf. have developed a data-driven Internet-based portal on the Internet-site used for teaching, studying and learning processes [7] [8] [9] whilst providing storage of research resources for students. Here the boundaries of information and communication technology (ICT) are extended to their limits in the area of VR supported technology education. The 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.

The project was planned in three stages; the first stage was the culture specific dimension (cp. MOMENTS metamodel cultural and cross cultural level, [9] and preparatory stage where the work was aimed at seeking suitable solutions to fit the existing educational surroundings in each participating country (see e.g. [10]).The work reported here has been based on first hand experience and know-how by 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 Innovation Education. 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 [11]. 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, equipped with relevant tools for idea generation and development of the Innovation Education pedagogical model.

1. What is Innovation Education (IE)?

Innovation education in school activities arose from the original Design and Craft subject in Iceland. It is based on a creative emphasis in teaching, studying and learning [12]. The model is broadly similar to problem-based learning (PBL) (e.g. [13]) and the design model [14] as well as the neoVygotskian and neoGalperinian models (cp. [15] [16] [17]). The basis is conceptual work in the broadest sense, which involves the search for solutions to the needs and problems in our environment. It can also be used to enhance or redesign 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 [18]. In many respects IE is a specific *innovation centered approach to problem-based learning* (PBL) (cp. [13] [19]). 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 in 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 skills to take initiative and strengthen their self confidence.
5. To make students aware of the ethical values of "objects" while teaching them ways to improve their environment ([20]).

2. The Ideology behind Innovation and its Ethical Values

Innovation work is based on the notion that everyone has creative ability that can be developed further to some degree through educational stimuli and self-developmental activities. Through such creative ability the student uses his/her creativity to form the world [21]. Creativity and problem solving are intrinsic to Technology Education or Design and Technology Education (D&T). Technology education and D&T are linked with the creative process, and problem-solving strategies based on it are important because they enhance the quality of solutions to real-life problems (cp. also [22]). Creative thinking results in original solutions to problems that continually arise in personal spheres [23]. Everyone can call upon their creative ability if they have the opportunity to develop and mature through education in a conscious and direct manner. The ideology behind innovation work concerns one's ability to use their creative powers and intelligence to modify their environment [24]. Innovation projects are intended to augment such strengths or qualities in a student's makeup and thus strengthen society in the future [25] [26].

3. Innovation Education in a Virtual Reality 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 when the new model uses NBE, virtual reality, the Web and specific data based software designed by the participants in the project.

The new model is a continuation of the old model and has been developed on the same creative processes. However, it is formed for a virtual school environment instead of just using general classroom or technology

education laboratories. Moreover, it integrates the InnoEd data-driven software, ICT, VR in an IE scenario. Students have the freedom to bring some models of reality from external sources such as home and environment into the school and work with them there in the classroom. The virtual reality environment is essentially a shared virtual space and a *mental tool*, tool for thinking and *solving* mental problem, [27] [15] [28] [29] [30] for sharing ideas and thoughts on symbolic level and a tool for communication, distributed knowledge and shared expertise (cp. [31]). In addition, it engenders feelings or emotions as well as bringing the participants together and motivating them in the ideation process. Such opportunities for using VR as tool for symbolic manipulation of problem-solving activities and as a tool for even cross-cultural communication 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 (e.g. [29] [32] [30]) was developed in MOMENTS (Models and Methods for Future Knowledge Construction: Interdisciplinary Implementations with Mobile Technologies) consortium project. The MOMENTS is funded by Academy of Finland and the National Technology Agency of Finland and Finnish companies. MOMENTS case study number 6 Network- based Mental Tools in Technology Education has been giving background for the IE process development, and become one part of the innovation process and process assessment model see Figure 1.

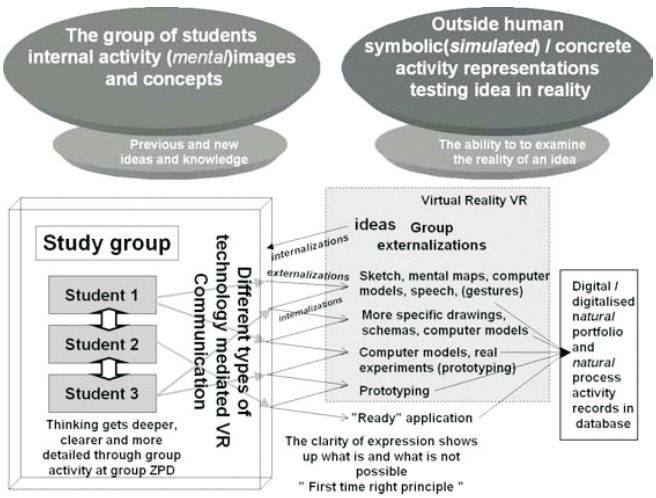

Figure 1. The preliminary VR innovation process and assessment model (based on [30])

Figure 1. describes the activity in the innovation education pedagogical model. The teaching has been designed to direct students' studying and learning activities as an individual and as a member of a virtual group. This occurs through small groups towards Vygotsky's zone of proximal development (ZPD) [15] using instructional design solutions and mediating VR environment information technology [29] [30]. The aim of this work has been to create a process in which ideas and topics being developed and studied and their related sub skills, 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 are through speech, diagrammatic figures, video-clips, drawing etc. as to test the viability of their ideas using VR environment together with physical materials.

4. Why use VR in Innovation Education?

The future teaching, studying and learning methods have not been suddenly invented. It is more of an evolution like 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. 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 share information and work together with their ideas;
2. To make students able to meet each other and their teacher as avatars in network-based education (NBE) (see [9] [33]) and in distance education. This enables teachers to guide students in their identification processes;
3. To share expertise (cp. [31]) in working together around students' ideas and sharing problems in order to solve and develop solutions to such problems;
4. To give opportunities for developing certain design skills by drawing and building prototypes from primitive shapes such as cubes, spheres and cylinders;
5. To give a teacher an opportunity to deliver presentations for his/her students;
6. To set up exhibitions of the students work as a presentation of individual student or of a school in the form of video or slideshows on video-projector screens;
7. To set up exhibitions of interactive 3D concept ideas by students;
8. To make VR virtual meetings between the participants of the project if possible.

5. 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 (cp. [29] [32] [30]). To fulfill this aim the participants have developed specific data-driven software solutions [http://www.innoed.is]. which are based on open systems and standardized technology, and are used as much as possible to make it easy for the users to transfer material from another systems. Furthermore, such software components function fast and are easy to control.

Figure 2. Inside the InnoEd

The data-driven software's main role is to support ideation through open communications. The former model has been developed from 1992 in Iceland and is used as a background for new pedagogical model [34]. This model uses general classroom and technology education labs, where the new model uses virtual reality, the Internet and specific database software, designed by the participants of the project. The InnoEd project uses a version of a virtual reality technology developed by the Icelandic Smartvr hf. company. This Virtual Reality environment is desktop computer-based and uses specific local and server software applications, which has been developed by the

company for many years. 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, persistent 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 [35] and edutainment (education and entertainment) and their combined influence on teaching, studying and learning are some of the background ideas (see e.g. [29] [36] [35] [37] [38]). SmartVerse® also has a suite of communication tools to facilitate multi-modal natural user-interaction. The modularity and flexibility of the framework and the deep level of dynamic interactivity (cp. [38]) possible in SmartVerse® worlds made it an appropriate platform for the development of the InnoEd project.

The activities inside VR, involve realistic virtual reality worlds, which are edited directly in real-time, using the powerful SmartVR® world editor.

Visual, drag-and-drop metaphors for editing, 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).

6. The VR Communication Plays Big Role in the New Model

The virtual team project explained in figure 1 is dependent on different types of technologies, which provide mediated communication in different ways. The so-called cross communication within the team is the most critical key for success of the project, because different ways of communication play a significant as well as a 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 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 can see the text being typed by avatars near you, and group-based chat (cp. [39]).
2. The voice chat together with text chat allows multi model 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. It is also faster to use as text chat (cp. [39]). This approach of conferencing uses advanced compression to enable voice communications which are very low. 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 (cp. [39] [40]).
3. The shared interactive whiteboard component implements a whiteboard where users can express their designs within (cp. [39]). 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 for user communications. The idea of edutainment, playfulness and game-based interaction model is fitting very well to its target user group; young people across Europe. The goal is to use the 3D space, avatar gestures, eye contact and camera control to help small groups of users to communicate in an easy and natural way with voice (cp. [33]) . 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. SmartVR® believes that 3D spaces, graphics and avatars can recreate the community which is missing in many current voice-over-IP and teleconferencing solutions [40] [39]. They have become essential tools for natural and effective user communication and multimedia. These are very appropriate media for bringing people together in to the shared worlds, so that they communicate with one another. SmartVerse® features several technological components to make communications inside 3D spaces with ease 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 data is compressed with software specifically designed for voice compression. The voice of each user is attached to his/her avatar in the 3D space and is 3D spatialised, so it sounds as if the voice comes from the direction of the avatar. One can hear the voices as they are standing near to you, just as in real life. Breaking up and forming conference groups is as simple as walking towards people's avatars (cp. [33]).

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 the well known text chat systems such as IRC or the text chat feature of instant messenger products. The shared whiteboard (Figure 3.) component allows users to draw on a shared 2D space. Users can draw boxes, circles, free-style lines and text. The whiteboard is comparable with the features of the popular NetMeeting shared whiteboard.

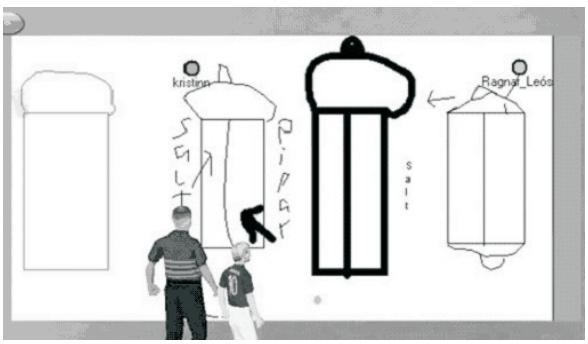

Figure 3. Inside the InnoEd

The avatars as shown in figures 2. and 5. are the main communication tools. They can show facial expression and gesture. Users can command their avatar on expanding the range of emotions, which the avatar can express, letting them to behave as realistic as human beings, keeping eye-contact, gesture, showing facial expressions, giving back channel feedback and so forth. The goal is to make interaction in 3D spaces come as close to real-life interaction as possible. Simple interface: voice streams are 3D spatialised and appear as coming from the speaker's avatar (cp. [33]).

The InnoEd VR world works together with a database-driven Internet environment, which is desktop-based and can be restructured according to technological advancement and system-inherent properties, therefore making it 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 [25]. This makes the Innovation Education different from most other school activities and brings us its ideological issues. Being in Virtual Reality might give the student more freedom to think and act independently and communicate in a school environment without borders (Figures 4. and 5.). However, the question arises, whether one can work with contextual and situational real world problems within virtual reality. To make this possible, the InnoEd 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 an extent in to which one can feel a sense of presence in the mediated environment, rather than the immediate physical environment [41].

Communications are seen as the key components within the VR environment 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, organized by our perceiving systems, and out of this bath of sensation emerges our sense of being in and of the world [42]. Users need to communicate and interact with other people, search for information and share their work as given in Figures 1., 2., 3. and 4. 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 [39] [40]. Important communications 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).

Figure 4. The InnoEd virtual reality and communication tools in use at school level

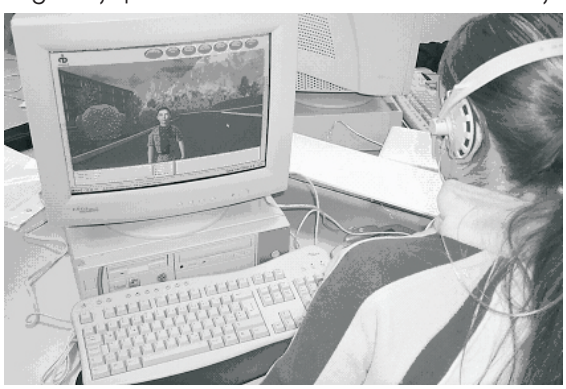

Figure 5. A view for the InnoEd virtual reality

The VR communication system (see Figure 5.) plays a significant role in the IE pedagogical model as students share problems, needs and solutions before they select their individual solutions that they work further with on their own (cp. [13]). In the beginning, students log on to the Internet and search for the needs inside of 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 into the database as well.

7. The IE Process with Use of the VR

The innovation process is simple, but a powerful tool to teach creative skills to students (see Figure 4. and 5.). After they have learned the process they can work increasingly independently and start using the innovation methodology as an intellectual tool (cp. [15] [16] [17]) to solve general problems that occur in real life. The innovation model has not been aimed at specific age group, but has been very much practiced in the age

range of 9-16 years, but the methodology can be used in all levels.

The VR system plays a major role in the innovation education pedagogical model. The model has been under development for two years since 2001 and will be tested with pupils and student teachers as well as school teachers during this academic session 2004-2005. The internalisation of the needed fundamental skills and related sub skills to use the VR system as well as the needed IE skills are studied and learned in phases. In the beginning, students will have lessons to introduce and learn the fundamental skills for using the virtual environment as a tool for different subtasks in innovation process and as a part of the innovation education (IE) process in general (see process in Figure 1.). Avatars are being tested by students engaged with the VR environment in shared knowledge construction. Tools such as whiteboards are tested and interactive prototypes from the students are explored (see process in Figure 1.). The students observe presentations on browsers with older inventions, designs and presentations made by other students. Communications tools are tested as small text messaging and speaking together.

Students would be able to register in the data-driven software and can go into the VR. The first orientation lesson is to find needs and problems on the Internet and host them in the workshop. Search engines would be used and two students would be working together. Students share their needs and expertise with others in technology-mediated group collaboration process, which leads them as a group-to-group Zone of Proximal Development (ZPD) (see Figure 1. and [15]).

Brainstorming sessions are conducted within the VR where students communicate together about their needs and devise solution for such needs. The theory of internalization [17] comprises for the processes of internalization and externalization (see Figure 1.), theoretical models of technology education (e.g. [22]), PBL-models (e.g. [13]) as well as ideas of reciprocal teaching (e.g. [43]) 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 in the hard drive, and such solutions are shared with the group. Visualization tools, tools for visual externalization (see process Figure 1.), obtain an important role during the discussion process [44] [45]. Students are able to promote their concept inside their workshop and can make a verbal description of it.

Models and posters are made in the general classroom, in technology education laboratories (or D&T classrooms) and digital still pictures and video clips are recorded and shared through VR. Students set up exhibition with their teacher on an Internet site from their workshops. The Internet site will be accessible, from the VR on a browser and connected to the schools homepage as well. On the opening day, the VR students can invite their parents to the virtual exhibition. One computer with Internet access will be open for all in the school with a video projector.

7. Future Research

Other work in this field includes design-based action research (e.g. [1] [2] [3]) in using the new Innovation Education model with focus on the approaches of teaching, studying and learning on creative skills inside the VR, in order to improve their innovative ideas. The process is most likely to be done in interaction with several partners. The focus of the research will be mainly upon pupil's learning and studying, planning of teaching and using information and communication technology inside the VR and in the classroom. Three case studies will be organized on the innovation education model of 11-12 year old pupil's use of the virtual reality and the data driven software. The outcomes of this work will be used for courses

for in-service teacher training and teacher trainees who want to use virtual school environment for Innovation education (IE) in the future.

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 schools if educators are willing to foster and fully utilize the creative intelligence of the individual. We should remember that the creative process of young as well as the adult are very much linked (e.g. [46]). Joy, play and creativity are best seen in environments, both offline an online, which are attractive and allow students or pupils to be active, playful, and creative and use multimodal communication connected with real activities outside the VR. InnoEd environment is to be one of such playground for joy, play and innovations. Innovation is therefore described 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, explained to a certain degree, as an answer to the need for a creative emphasis in modern and 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 to foster innovative ideas with the use of communication and information technology as a cross curriculum way to improved education.

The virtual reality system offers the participants in the InnoEd project with 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. The teamwork, shared expertise and building ideas together in European wide markets are the current trends. 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. IE environments are increasingly relevant for ideation and collaboration, which in later phases goes outside the VR for concrete prototyping but still works together with process inside the VR.

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