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SIMULATIONS AND VIRTUAL REALITY TOOLS IN TECHNOLOGY LEARNING: RESULTS FROM TWO CASE STUDIES

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ABSTRACT
We present the results of two design-based action research case studies. These case studies sought to develop pedagogical models and computer applications for teaching, studying and learning in technology education. The first pedagogical model entitled "Network oriented study with simulations" (NOSS) supports teaching and learning in technology education in laboratory settings using a computer-based tool, termed the "web-orientation agent (WOA)" and graphical simulations. The second pedagogical model entitled "Innovation education in virtual reality" (IEVR) happens in a virtual reality environment. The virtual realities and simulations represent shared virtual spaces and sociomental tools, tools for thinking, problem-solving, sharing ideas and thoughts on a symbolic level. Furthermore, they provide for tools of communication and shared attention toward the same objects. Article presents results and an understanding for the implications, possibilities and limitations of the both models.

KEY WORDS
Simulations, virtual reality, pedagogical models, learning environment

1. Introduction

This work investigates computer-mediated collaboration through two case-based research projects. The emphasis of this work is in the way the that computer-mediated collaboration happens: *around* or *through* computers. We describe the outcomes of the development of pedagogical models and their applications for teaching, studying and learning (TSL) in Technology Education. As background to that, we refer to notions of Computer-Supported Collaborative Learning (CSCL) and Computer-Supported Collaborative Work (CSCW) which have been introduced recent years as powerful concepts for utilising computers in education ([1],[2],[3]). The rationale for this research is the claim that in using modern media like computer and network-based learning tools in technology education for guiding and helping students, the pedagogical model and activity based on it is just as significant as if not more as it is in traditional teaching. As Mayer & Moreno ([4]) state, active media (such as highly interactive learning environments) that require symbolic hands-on behavioural activity do not necessarily promote appropriate learning activity on its own. In other words, symbolic hands-on activities and social collaboration are not always synonymous with high quality learning, nor are they necessary conditions for constructivist learning to occur ([4]).

1.1 Collaboration around and through computers in technology education: Two pedagogical models

The main aim of this work as stated has been to develop the pedagogical models:.

- **Network Oriented Study with Simulations (NOSS) (**[3],[5],[6]) and
- **Innovation Education in Virtual Reality (IEVR)** ([7]).

This work presents results for understanding the possibilities of utilising simulation-based learning and the virtual reality based pedagogies in technology education. Main findings from the two case studies are presented. The focus of these studies is on human-centred ways of utilising appropriate pedagogies coupled with the novel technologies that are supported.

1.2 Collaboration around computers: Network oriented study with simulations (NOSS)

The aim of the first case study was to develop the pedagogical model entitled "Network oriented study with simulations" (NOSS) ([3],[5],[6]). NOSS has been developed to support teaching and learning in technology education in the laboratory settings using graphical simulations with a network-based tool developed for that model, termed the web-orientation agent (see figure 1.) for providing web-based support for the learners studying with or without the teacher ([5]).

The focus has been to create a pedagogical model for the process in which the topic being studied and the related sub-skills (stage-by-stage formation of mental actions) and knowledge are constructed through the stage-by-stage formation in group processes. In the initial stages of the process, students engage in network-guided activities where they externalise, communicate and visualise their ideas to others through speech, simulation tools and gestures, and test the viability of their ideas using a simulation tool. Finally, the groups are given a problem-based design task to solve, first in a simulated environment and later in a physical situation ([3],[5],[6]). The particularly innovative aspect of this work has been the Web-based agent orientation as seen in figure 1. (see more ([5]). The idea of the WOA is to guide or orient students in using local resources such as simulation tools in a pedagogically appropriate way by the interactive web-based materials provided by the WOA ([3]). In order to accommodate group study activity and to support collaboration between group members, a WWW-groupware application BSCW© was developed as part of the present system to offer collaboration, file storage and sharing space for the groups. The project has undertaken also to analyse the advantages and disadvantages of different tools and media in their appropriate roles in the model. For example, Min ([8]) concludes that open simulation environments often work better when the instructions for their use include easily read and browsed (printed) documents, such as workbooks, alongside material on the computer display which was one of the ideas applied in the study ([3],[5]).

1.3 Collaboration through computers: innovation education in virtual reality (IEVR)

The second pedagogical model entitled "Innovation education in virtual reality" (IEVR) is a model for co-creative [9] problem-solving and learning in technology education ([7],[6]). The virtual reality learning environment in the model was a commercial one which was seen as a shared virtual space and *a sociomental tool* for collaborative/co-operative creative processes. Furthermore, it was seen as a tool for thinking and mental problem-solving in sharing ideas and thoughts on a symbolic level and a tool for parallel communication through different multimedia (e.g. visualisation simultaneously with spoken and textual communications supporting each others). In addition, it was expected to influence to feelings or emotions as well as affecting to the social presence and structures for co-creative learning. Moreover, the question for bringing the participants together in a proper ways or the influences for the ideation process were under observation in this case study ([7]).

2. Methods

This involved the analysis of four questions concerning the structure and functionality of the pedagogical models developed. The research methodology in both case studies is based on qualitative and quantitative data collection and analyses. The studies introduced here combine case study and qualitative evaluation, action research, and design-based research approaches ([6],[10],[11],[12],[13]). The studied activities are seen on multiple levels (seen in table 1.) The five levels of the activity observation and units of analysis are based on the MOMENTS metamodel ([3],[6],[14]). The studied activities are seen especially, on the levels of 1, 2 and 3 of Table 1. The central unit of analysis is the group TSL activities seen on the dyadic/social level. The analysis unit is the group activity instead of the individual, but the individual level is also analysed in some settings ([3]).

Table 1: Conceptual and observational levels of human-centred activity in TSL processes ([6]).

1	cultural discourses and practices	***a***	Inter- or transcultural (IC/TC) layer in global-level mixing national and organizational cultures between teachers, students and learners with different national cultural backgrounds.
		b	The national culture layer (NC).
		c	The institutional/organization cultural layer (OC).
2	pedagogical models and principles		The level of ***intellectual tools*** e.g. ideas and models to plan and to organize teaching, studying and learning.
3	functional level of concrete action	***a***	The dyadic/social ***activity*** level - subject in interaction with the technology in joint attentions.
		b	The individual ***activity*** level - subject in interaction with the technology.
4	level of individual acts	***a*** / ***b***	The level of subject's conscious (a) and (b) unconscious layer of acts and their internal underlying (neural) mechanisms (studied by psychology, neuropsychology / cognition science) in relation to technological and social environment. (cf. ***the level of operations***)

2.1 Participants and data collection

The NOSS model data was collected from the third and fourth year students (N=11) at university of Lapland ([3]). The students were all males and they had not been studying the subject, electronics at this sense before elsewhere nor felt to be qualified in it according the pre-test query. They had not been either studying with simulations before the experiment. Their computer use history varied between 12 to 20 years of computer use (average 16 years). Most of them felt that computer use was reasonable easy. All but two did have an own PC-computer at home and all but one rated themselves as average in skills using computers. Their attitude toward computer use, as well as toward the use of it in technology education studies was neither critical nor enthusiastic according the query before ([6]).

The data collected for the NOSS case study included: queries, (before, after), interviews, participant and technology based observations where the activity of the learners in groups was recorded on audio and video. For some research questions thematic interviews and semi-structured interviews were used. In one data block, the group of students (n=3) were observed more closely through simultaneous screen recording (see Figure 1.) which was also used as a base for stimulated recall interviews. In these recordings, the group and their computer screen appear in the same frame. The idea of stimulated recall in Bloom's terms is that a subject may be enabled to relive an original situation with great vividness and accuracy if he is presented with enough cues or stimuli which occurred during the original situation and recall the thinking processes that occurred during it. ([6], [15],[16] cp. [17]). In the STRI the students were shown some problematic situations from the videotape and were asked questions to describe their thinking and problem solving processes.

We found out very early in these situations that because the students did use the simulation as a primary mediator of their shared activity (as expected) and also mediator of their communication it was not possible to utilise e.g. analysis methods which were analysing only/mostly the spoken aspects of communications. In these analyses the activity theory was utilised ([13],[18]), also the ideas of CT (conversation theory, Boyd ([17]) were partly utilised. In particular, the focus breakdown situations ([18]), were analysed directly from the recordings for investigation of the potential causes of problems in their study process and the excessively heavy mental load situations that were experienced. The way in which the students used the simulations and WOA resources and the way in which they studied and learned were coded and analysed. It was observed that externally seen emotional responses to such studying processes were also clearly evident in the data in the visual and audible forms. Those were coded into two classes 'situational pleasure' and 'situational anxiety/frustration' ([19]).

The IEVR model data was based on the data collected in Innovation Education project by Thorsteinsson ([7]). The participants were four males and four females all aged 12. In the VRIE case the data collection was qualitative, interviews with students and teachers, collecting the natural portfolio data (e.g. the students "Inventors notebooks") as well as participant observations interviews, participant and technology based observations where the activity of the learners in groups was recorded on the video. For some research questions also the thematic interviews and unstructured interviews were used. The IEVR data was analysed like in NOSS-study.

3. Results

3.1 Collaboration around computers in technology education: The NOSS model

The data in NOSS case except the queries before and after as well as in the VRIE case was analysed in a qualitative manner. The qualitative interview data was analysed in the both studies (NOSS and IEVR) with a content- and phenomenological analysis method with explication, interpretation and categorisation, also the ideas of CT (*conversation theory*) were partly utilised ([20],[17],[21],[12]). The aim is in this phase was to develop pedagogical models and the tools for those models rather than test the outcomes. Despite it, the learning outcomes from this learning activity were verified to be at the same level as in previous situations with the old methods.

The different video and audio data was raw analysed through review type listening/watching hunting the relevant parts and transcripted for those relevant parts and finally coded with nVivo-program. The nVivo main classes for coding were focus breakdown situations, simulation use in different tool categories, WOA and media usage, pedagogical model functionality, likely emotional reaction and organisational level functionality.

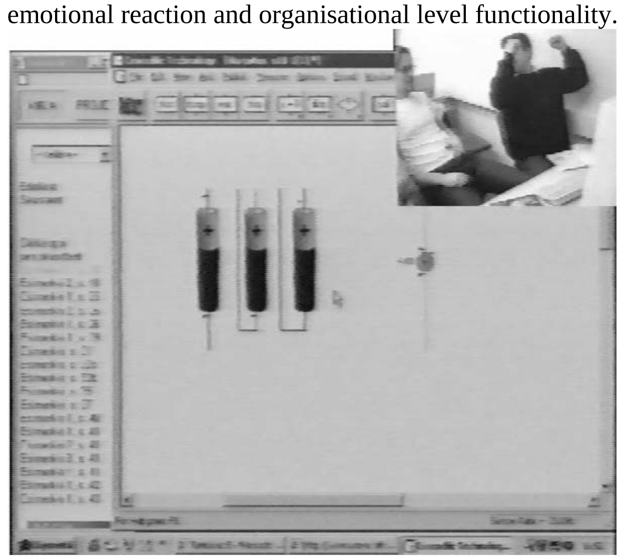

Figure 1 Capture from simultaneous screen recording

With regard to collaboration around computers in technology education: the NOSS model of teaching, studying and learning was analysed on different conceptual levels of observation as described in Table 1.

The first research question (seen at the levels 2, 3 and 4 of Table 1., pedagogical principles and practises at the level of study activity 1). *How the pedagogical models developed on the basis of theoretical background and on the basis of studied real TSL processes during the case studies is seen to function*? The unit of analysis was the study activity of the student group. Both the findings of first-order and second-order perspective qualitative analyses may be seen to support the effectiveness of this pedagogical model. The interesting result was that the power of CSCL-type social level activity was seen to be at least as important as expected. This was seen on all the qualitative data, as well as in the questions of the post-test query.

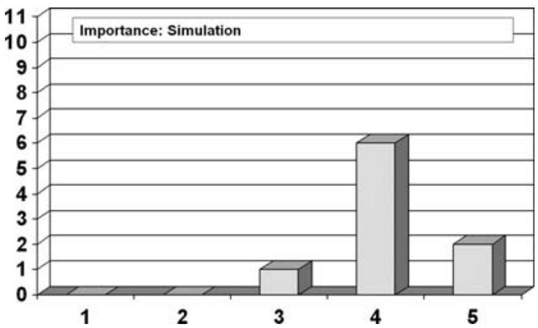

Figure 2. The preferred importance of the simulation tool (5=”most important” from the learning viewpoint at the questionnaire responses after the study ([6]).

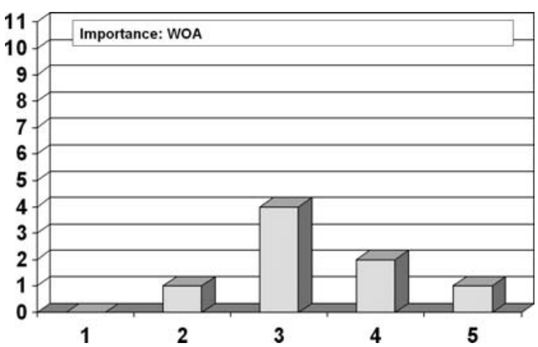

Figure 3. The preferred importance of the WOA resources (5=”most important” from the learning viewpoint at the questionnaire responses after the study ([6]).

Student (4) “When you did not understand something the other [peer] was capable for helping and vice versa……if you do not understand you may think together. Forces you to argue your opinion”[6].
Student (6) “In group one student makes less, than if done individually… …discussion you realise the many sides of the studied subjects/phenomena……discussions are heavy to me……lot of talk…”[6].
Student (3) “Group activity gave a wider perspective… …Solutions we did think together were fostering the problem solving required by the book.”[6].

The second research question: *How are the tools developed and selected (the web-supported simulation tools, VR tools and resources) for this specific research purpose, functioning as a part of the TSL process in technology education studies*? was analysed from the first order perspective data as well as from the post-test query and interviews. The simulation tool was the most important resource as expected (see Figures 2. and 3.). The second important was referred the WOA and third the book. The Internet materials in general and also additional references were not so highly valuated. ([6].)
The quantitative results from the research questions: “The book and the computer resources supported each other?” can be seen seen in Figure 4. and “The simulation tool helped me to build the required electronic systems with real components?” can be seen at the Figure 5.

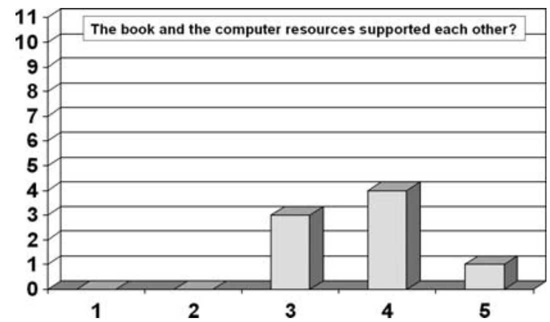

Figure 4. The preferred co-support of computer resources and the book (5=”most important” from the learning viewpoint at the questionnaire responses after the study ([6]).

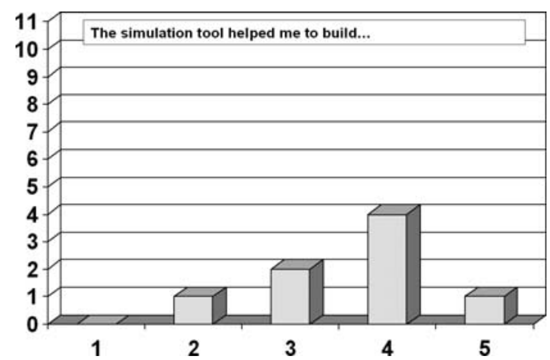

Figure 5. The preferred co-operation of the resources for building with real components (5=”most important” from the learning viewpoint at the questionnaire responses after the study ([6]).

The one limitation which was seen from the videotape data was that *the students did not reflect very much on the tasks cognitively, after such tasks were completed - they continued onto next task to be solved.* That would obviously *require an externalisation phase, after each simulation activity to force the students to reflect their learning, e.g. question to fill in why the task was solved as it was. It was evident that without that the simulation was sometimes treated as a game where the understanding is not always following the task. That was also reported in some post-test queries as well as in interviewing data*:

Student (10) “If it works so you just slap those components there, but if you got problem so you are forced like to think…” ([6]).

A second important limitation was that *the students did have some problems in relating the simulated designs to physically reality to be built with real components*. Moreover, the overall understanding of the process phases and required skills for designing electronics was problematic when the simulation models were built with real components. That would require a much guided project at the earlier phase of the model where some simple system would have been built together before the PBL-phase to learn the required structure and some of the required sub skills needed in building those systems. Through that kind of "*guided mini design process*" the general orientation base - from mental to material reality the student group would very likely reach the general understanding of the whole process which helps them in two ways; to internalise needed skills and knowledge by seeing the importance for those whilst being capable of understanding the whole process in advance of the second problem based process. The simulation tool was the most important resource as was expected. The second important was referred the WOA and third the book. ([6].)

Furthermore, qualitative analysis in both levels, at the level of observation of direct activity as well as students' comments revealed the importance of the presented tools, especially the simulation. It was seen important in
a) as a resource for shared communication (externalised thinking processes) and
b) as a resource for a shared attention as well as a shared socio-mental tool for testing their ideas against the simulation model just as expected. ([6].)

Student (9) "You do not have to draw [manually]. For that is very useful" Student (5) "So complex project work would otherwise be almost impossible" ([6]).
Student (1) "Easier to fix bugs => understanding" ([6])
Student (3) "You could design the circuit and seen the problems beforehand." ([6])

The Web Orientation Agent (WOA) ([5]) offering the study materials for the students was seen the second important resource (The question "*The simulation tasks supporting book have been useful to me from the learning viewpoint?*" was average 3,4 at 5 point Likert scale) and the WOA was used mostly as planned and expected despite it that the students did not use it in the second problem based phase of the pedagogical model. The student commentary refers quite well its role in the students' comments:

Student (1) "More beneficial than just reading the book" ([6]).

The third research question 3) *Which ways should the most modern computerised and web-supported simulation-based methods of designing and problem solving should be taken into account at the curriculum and organisational cultural level and in TSL processes*? The focus of the analysis is how the simulation and networked study activities, pedagogical model and tools are integrated, do fit and function at the curriculum level and how the "*online curriculum portal*" – developed for this purpose do function ([22],[23]). The unit of analysis was the organisational cultural activity structure or activity situation. According the results, the activity did function reasonable well at this level. There were not serious problems seen from any of the analyses, the portal itself and its functionality has been reported elsewhere ([22]).

The fourth research question 4) *How does the network-based education (NBE) afford and mediate emotional and experiential learning processes*? The students reported that the simulation was valuable resource for "learning by doing" –type study processes. The students, all except two, also reported that the degree of interactivity as well as the social settings was also in many ways emotionally engaging. The source of emotionality, categorised for the two classes '*situational pleasure*' and '*situational anxiety/frustration*' the source of pleasure seemed to relate to the social level activities and to the interactive (game-like) nature of the simulations which give feedback in multimedia format for the success of failure. It was sometimes surprisingly how long the students did concentrate on the problem solving tasks very focused. ([22]) Example of that is seen on the student comment:

Student (11) (in stimulated recall situation) 'See how concentrated we are – we do not even give a voice" ([22]).

The situational anxiety/frustration was mostly related to problems with the computer tools and in some cases difficulties to solve some problem related to study content. The most common cause of problem was the file storage space BSCW© and the slow and sometimes problematic browser upload procedures in returning the study answers to the database. Sometimes the anxiety/frustration was caused because of the unreliability of the computer environment. ([6].)
In relation to both the student comments about the length of the computer use periods as well as the video data shoved that the average the two hours of simulation activities seems to be the maximum. After the two hours, the activity also in the video data seemed to suffer, it was also discussed in the recorded group discussions and students also reported that same phenomena when interviewed. Surprisingly, also the English language of the program for our Finnish students, it was seen to be problematic for over 60% of the students. ([6].)
In general, the simulation tools in the first case study were true mental tools ([24]) allowing participants to share, develop and test their ideas and thoughts on a symbolic level (against the simulation model). The interactivity and the social settings may be seen to be emotionally engaging in many respects. The tools provided a *shared object for problem solving* to be used in shared activities utilising *shared attention* (cp. *joint*

attention, [25],[26],[17]). Moreover, these tools were critical for successful communication, distributed learning and for sharing and testing knowledge and expertise between the participants. According to our data, distributed joint attention and communication occurred in a heavily mediated manner through visual simulation objects, mediating visual communication objects, and the other forms of communications like spoken communication gestures and paper and pencil ([3],[5],([6]).

We further argue that the traditional classroom situation is in many cases not optimally resourced for successful collaboration utilising *shared attention*. Particularly, in the highly conceptual areas such as in the electronics design, there are not always enough ways of visualising (externalising ones own thoughts) or anchoring points for sharing those with the others. We maintain in our studies that there are insufficient proper *sociomental tools* available and the social settings to achieve successful collaborative processes in learning and problem-solving ([3],[6]).

3.2 Collaboration through computers in technology education: The IEVR model

In the IEVR case the methods were qualitative, interviews with students and teachers, collecting the natural portfolio data (e.g. the students "Inventors notebooks") as well as participant observations interviews, participant and technology based observations where the activity of the learners in groups was recorded on video. For some research questions also the thematic interviews and unstructured interviews were used.

The teaching, studying and learning was analysed on different conceptual levels of observations as described earlier (see Table 1.).

The first research question 1) *How the pedagogical models utilising the VRLE in the school context are seen to happen and function providing co-creative processes*? Training was being necessary to enable teachers to manage the tools at a proper ways. 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. The Inventor's 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. They were able to use the VR as a collaborative space for co-creation and developed solutions based on a common needs. This was done through brainstorming.

The VRLE was found to be user friendly and enabled the students to be self-reliant. When they had to undertake their work in the VRLE, they sometimes got tired after 20-30 minutes. In these cases the teacher was using short brainstorming sessions founding it possible to refresh them. Several observations on students' drawing skill showed the limitation in computer usage that *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 split their attention, 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.

The second research question 2) *What is the role of teaching and the teacher in these processes*? The teacher's role was different from the classroom-based teaching; he was more an assistant and facilitator than a teacher. In the interview, teacher talked about lack on training for using the software and about the need for having a good training course before starting the research. An effective manual, guiding agent and 'how to' presentations for example, would also be helpful. ([6].)

In the interviews and logbook the teacher talked about the importance of being trained in the pedagogy, for having the pedagogical model of using the VRLE. In addition, it is necessary to understand the IE ideation process. In his observation, the researcher could sometimes see a lack of the teacher's understanding for the whole IE innovation process. He frequently tried to give the students a brief it they did 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 brought in their Inventors Notebook. ([6].)

The third research question 3) *How are the VR tools for this specific research purpose functioning in individual and social level*? Interviews with students and teachers as well as the participant and technology based observations indicated that the students easily learned to use the VRLE and CAD software. There was still some need for the teacher assistance. However, further training helped them to externalising and communicating their ideas to others for co-creative further ideation by drawing them well and fast using the hardware and software involved. ([6].)

The fourth research question 4) *How the co-creative ideation within the IE process did happen*? The student's computer and VRLE literacy is important. In this research, the student needed very little training to use the equipment.

Many of the students were used to 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 and that will be paid a lot of attention. ([6].)

Sketching was a valuable part of the IE ideation process as it allowed 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. The problem was that this could not be mediated without the scanner to any other location nor changed easily online. A wireless ink pen used late in the research was more user-friendly but not compatible with whiteboard in the VRLE. Plimmer ([27]), 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". He points out that using computers for drawing depends largely on the quality of the equipment and the software ([27]). The student's understanding on the pedagogical model phases an especially 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 the feel of presence, social structures various ways of externalising their ideas (visualisation). That 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 co-creatively discussing their ideas with each other and giving comments to each other. The concept of VRLE is linked to the feeling of being in a location and a social setting 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 *regulate their psychosocial distance* and '*play a role*' as being represented by the avatars in comparison to f2f situation and using the VRLE. It may be an issue which merits further research ([7],[6]).

4. Conclusion

With respect to these case study results, these sociomental tools such as simulations, WOA and virtual reality learning environments do function in accordance with the appropriate pedagogical models and the functioning technology. New course structures, roles for teachers, and patterns for organising spaces in schools, universities and other organisations with these technologies, cannot be done unless we build whole courses using the technology and develop appropriate pedagogical models for such teaching, studying and learning. Both studies showed the critical questions of the *mediation of the shared attention* in all relevant forms as well as the problems – but also *benefits of computes in externalising ones own thinking in co-creative processes as a sociomental tool*. The research data also indicates that the group processes in the simulation model and in the VR model *were dependent on different non-verbal ways of communication especially on graphical externalisations representing individual's internal thinking* as well as *on gesture based and verbal communication*. For example, in sketching, the co-creative collaboration toward the same shared object and the mediation of the proper forms of that human activity in design was challenging in the through computer approach. We propose that it is one of the big challenges of the whole network-based education in general. *How to mediate in proper forms the adequate forms of human activities for externalising ones own thinking to others and how to share that object to support their smooth shared attention and design collaboration toward those objects* ? On a more general level both the simulations and the VRLE were seen to be used for two essential purposes as a sociomental tool for representation and sharing their internal thinking and ideas to others: to clarify it simultaneously to themselves by externalizing it through graphical forms; and in the case of simulations also to test the functionality of the proposed solution with the simulation. It should be noted that the presented limitations of the present models should be taken very seriously into account in developing the proper pedagogical models. Also the importance of taking the social and emotional aspects into account in designing the pedagogical model also seems to be very important.

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