Cognitive Technologies for Technology Learning

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Abstract: This article puts forward the pedagogical model "Network Oriented Study with Simulations" (NOSS) using simulation software and the ICT-based tool "Web Orientation Agent" (WOA) (Page et al., 2006) and supporting findings. The NOSS model was developed and implemented in CMC (computer mediated communications) type learning situations *around the use of computers* in technology education. In addition, this work utilises novel technologies such in the form of web-supported simulations and attempts to evaluate the effectiveness of such technologies in support of teaching, studying and learning.

Keywords: technology learning, cognitive technologies

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1. Introduction

This work is based on a research project entitled "Network-Based Mental Tools in Technology Education" which developed and tested the pedagogical model "*Network Oriented Study with Simulations*" using the "*Web Orientation Agent*" tool (Lehtonen, 2003). The case study included in this article, comprises design-based action research (Carr & Kemmis, 1989; Hannafin, 2004; Merrill, 2004) and was undertaken at the University of Lapland (Lehtonen, 2002a, 2002b, 2003, 2005a, 2005b; Lehtonen et al., 2004). Furthermore, this project has yielded valuable information that has contributed to further development of the pedagogical model. This includes study using simulation technologies, network applications and the ways in which traditional and modern media can be appropriately mixed with one another in support of learning. This work developed solutions for the integration of learning processes and associated technologies at several levels of organisational learning activity from individual to cultural. The main outcome of this has been the development of an online curriculum portal (Lehtonen, 2002a). Subsequently, his has been used to integrate activities and technologies in everyday life at the curriculum level, for students' daily activities.

The rationale for this research is the claim that in using computer and network-based learning technologies in technology education for guiding and helping students, the pedagogical model and activity based on it is just as significant as it is in traditional teaching. As Mayer & Moreno (2002) state, active media (such as highly interactive learning environments) that require hands-on behavioural activity do not necessarily promote appropriate cognitive activity on their own. In other words, hands-on activities and social collaboration are not always synonymous with constructivist learning, nor are they necessary conditions for constructivist learning to occur (Mayer & Moreno 2002, 110).

Teaching and studying will not work optimally by merely relying on the most modern educational technology applications and resources (interactive multimedia like simulations, animations or video media) (Uljens, 1997). As stated, a sound pedagogical model is needed to enable the integration and use of such resources in a pedagogical context. Furthermore, provision must be made to orient or guide students in the effective use of such technologies and resources for their own studies and ultimately empower them. Adapting Galperin's terminology, we refer to this guiding the attention in appropriate directions as cognitive and emotional orientation (Galperin, 1989, 1992; Lehtonen, 2003, 2005b; Podolskij, 1997). Only through the adoption of appropriate pedagogical models and associated technologies in technology education will we be able to help students to use computers as tools for developing skills, knowledge, and understanding. Our aim here is to foster student learning in technology education by providing improved cognitive technologies in addition to traditional resources for effective support of learning.

2. Theoretical Background and Aims of this Study

The aim of this case study "Web-supported Cognitive Technologies in Technology Education" is to develop the pedagogical model "Network Oriented Study with Simulations (NOSS)" to be used and implemented in CSCL (computer supported collaborative learning). This learning occurs *around computers* in technology education utilising novel technologies, in this case, web-supported simulations and evaluation of their suitability in teaching, studying and learning settings (Koschmann et al., 2002; Lehtinen, 2003; Page et al., 2006) see figure 1.

Figure 1: Studying around computer and using is as a tool and resource for shared attention in learning and in problem solving

This work encompasses other "cognitive" technologies and multimedia resources such as simulations to support thinking, problem solving, and learning in electronics technology (Jonassen, 2000; Mayer & Moreno, 2002). In addition, traditional and modern digital learning materials are examined in the context of the teaching-studying-learning process at university level. In this context, we need to differentiate between learning as outcome and the learning activity using the term "studying" (Uljens, 1997) here instead of "learning activity". As such, considerable efforts have been made to use literature, electronic documents, interactive documents, and different kinds of interactive technologies such as simulations. Such resources have been deployed in a manner that maximises their benefit and minimises their disadvantage to the student's study process for technology education. (Lehtonen, 2002a, 2002b, 2003, 2005a, 2005b; Lehtonen et al., 2004; Mayer & Moreno, 2002; Page et al., 2006.)

3. Why Web Based Learning with Simulations?

It is possible to develop local computer resources to simulate activities and learning but those are, in many ways, problematic in multi-user and multi-location environments where accessing and updating content resources are necessary. Furthermore, the web provides the opportunity of integrating different file distribution, storage and collaborative technologies which are needed for group based study activity support. In addition, current standardised web technologies do not provide good platforms for purely web based simulation solutions or in (slow) mobile networks. The development of a good quality simulation programme is a challenging task in many ways. At the same time, there are many commercially suitable and well functioning local simulation applications available. (Lehtonen 2005b.)

The development of the Web orientation agent (WOA) started when a problem emerged during preliminary experimentation with ready-made Web-based applications and local simulation technologies. That is, students found considerable difficulty in using multiple full screen applications on a single computer screen. These problems were particularly evident when students were required to switch between the simulation program and the full-screen browser window of the Web-based learning environment. This caused their collaboratively created shared attention to be split to different irrelevant locations affecting their cognitive and emotional load factors and causing the task focus to break down, to be directed away from learning activities to irrelevant and mundane tasks such as switching between programs. The WOA was designed to resolve some of these problems (Lehtonen, Hyvönen et al., 2005; Page et al., 2006; Ayres & Sweller, 2005).

Information and communication technology is considered as one technology lab tool or component rather than the whole ‘learning environment’. Moreover, it can be seen that when such cognitive technologies are used in social settings for socially important learning tasks, providing objects for shared attention and activity, we refer to them as socio-cognitive technologies (Jonassen, 2000; Vytgosky, 1978). They are considered as a shared (socio)cognitive tool for orientation, as externalisation tool for internal thinking and socio-cognitive tool for problem solving, visualisation and visual communication to help the building situations for *shared attention* and *shared cognitive activity* toward the same objects. Such cognitive technologies help to clarify one’s thinking for oneself and for sharing and co-visualizing it to others. The simulation technologies used in this case study were cognitive technologies allowing participants also not only to visualise and share but also develop and test the ideas and thoughts on a symbolic level (against the simulation model). The interactivity and the social settings were expected to be emotionally engaging. These technologies were intended to be used as a shared object for problem solving to be used in shared activities utilising *shared attention* in problem solving (Crook, 1994; Mayer, 2005).

The idea of providing a necessary *orientation basis of actions* (Podolskij, 1997) was of particular interest when developing this pedagogical model. The idea was to provide the learner with the essential conditions (the understanding and sub-skills) for problem-solving in the context of technology education. The goal of orientation (in Mayer’s term *segmenting and guided discovery*) was to support students for familiarising with and internalising the supportive ideas and sub-tasks that must be completed before they can demonstrate effective problem solving with the new technologies (Mayer, 2005). We argue that before being capable of using very open and constructive simulations as a part of a larger problem-based study activity, the student needs to know what to do and how to use the technologies in different ways as a tool in a real problem-solving process. It is our view that the Galperinian (1989, 1992) or neo-Galperinian (Podolskij, 1997) approaches to orientation and stage-by-stage formation of cognitive actions that make use of Web-based learning have not been fully realised because the orientation technologies for learning processes have typically been static, or more specifically, statically implemented. We therefore argue that the full potential of the Galperinian theory may be realised by developing agent type interactive, and adaptive Web-based technologies for successful orientation of the sub-skills to be internalised (*segmenting, guided discovery, worked out examples, animation- and navigational principles,* Mayer, 2005 also van Merriënbouer & Kester, 2005).

Traditional classroom situations are often not optimally resourced for successful collaboration (*collaboration principle,* Mayer, 2005) or proper individual or group level orientation. ICT based simulations as cognitive technologies may, in these situations, serve as new types of cognitive technologies. Furthermore, they can be considered as *socio-cognitive* technologies and as orientation and mediational resources for the essential support of shared attention and co-creative (Kangas et al. 2006) studying. Citing Crook (1994) we claim that there are not always enough appropriate and easy enough ways of visualising, externalising one's own thoughts and design ideas of electronics to others. In essence, there are insufficient *socio-cognitive technologies* available for successful collaborative processes of learning, design and problem solving. The capabilities of ICT used in this research are mediating technologies that provide for *shared attention* using *mutually shared objects in order to build social structures for it around computers* (Crook, 1994).

Despite the fact that the present research focuses on modern ICT-based materials in a technology education context, the more traditional and established resources and technologies still have an important role to play. For instance, Min (1994; 2003) concluded that the use of written sources, books, and handouts in parallel with a computer, *the parallelism principle in references and representations*, is often more motivating. Accordingly, no attempt has been made to transfer all such materials into electronic format. Min (2003) also contended that open simulation environments frequently work better when the instructions for their use are easily read and browsed, arguing for printed documents such as workbooks to used together with the material on the computer display. These materials can be made readily accessible to the students through the Internet as print on demand documents (e.g., PDF format) that can be output to a local printer in the technology education lab. We call that *the parallelism principle in references and representations* in simulation based multimedia learning.

4. The First Orientation Phase of the Pedagogical Model and the Web Orientation Agent (WOA)

The pedagogical model "Network oriented study with simulations" is based on two phases. The first phase is the *orientation phase* utilising the network-based orientation provided by the WOA. The goal of the first phase is to learn the content, in this case electronics, utilising the simulation and book together supported by the WOA in CSCL type collaborative process and to learn both the electronics and to use the simulation well enough for the later phases, which use problem solving in problem based learning type studying process. The combined use of the WOA in the pedagogical model was designed to orient the students' studying and learning activity as an individual and as a member of a group, consistent with Vygotsky's zone of proximal development (ZPD). This is engendered through the application of instructional design principles, social settings and through the used ICT (Bransford et al., 2000; Lehtonen, 2002a, 2002b, 2003, 2005a, 2005b; Lehtonen et al., 2004; Tella & Mononen-Aaltonen, 1998; Vytgosky, 1978). The aim was to develop a process and corresponding pedagogical model in which the topic being studied in groups occurs in phases supported and oriented by the WOA. Which, in turn, seeks to ensure that subject matter is learned gradually whilst at the same time, students have an opportunity to regulate the orientation and support offered to them in accordance with their needs to the minimum level possible. Nevertheless, students may keep these available should they want to resort to them (Ausubel, 1968; Bruner, 1985; van Merriënbouer & Kester, 2005).

The related sub-skills that are required in the final stage of problem solving are developed in these stages, i.e. the stage-by-stage formation of cognitive actions are developed within the group processes. In the initial stage of the process, students are engaged in network-guided activities in which they externalise, communicate, and visualise their ideas by discussing them with others. This is facilitated through modelling technologies, gestures, and viability testing of their ideas using a simulation tool. The idea is to tie the simulations from the beginning in the learning of basics of electronics so that such simulations and the basics of electronics becomes internalised at the same time in certain phases. In this process the goal is to learn to use the simulation as cognitive technologies for learning electronics technology as well as to learn simultaneously to use the simulations in the later phases for designing simple circuits with it.

Figure 2 shows the first phase of the pedagogical model, the orientation phase, based in the idea levels mainly on ideas of Kimbell (Kimbell, 1987, 2000; Kimbell et al., 1999), Vygotsky (1978) and Podolsky 1997). During this phase the topic is studied through the guided orientation of books and laboratory manuals together with the WOA. Students study, share, internalise, externalise, communicate and visualise their ideas to others through speech (internally as well as externally). This is facilitated through the WOA and by using gestures as well as viability testing of their ideas using a simulation tool which serves them as a resource for shared attention toward the same object.

The first phase of the pedagogical model utilises the experimental tool, WOA, illustrated in figure 4, which has been reported more precisely in our other article (Page et al 2006; see also recent discussion on agents in (Clark & Feldon, 2005). The WOA as described was developed to overcome some of the problems observed with simulations that were designed for rather open-ended problem-solving approaches where the students have been incapable of using the technologies for deepening, creating, or constructing their understanding and knowledge, as defined in the specified learning outcomes (Gonzales et al., 2001). Furthermore, it has been observed that students use such simulation technologies without the proper orientation merely for only "recreational" rather than goal-directed, meaningful purposes (Chen, 2002; Koopal, 1993/1997). The purpose of the WOA was to especially to guide the student in using local resources, such as simulation technologies, in a pedagogically sound manner as described earlier.

The rationale for this was based primarily on the Vytgoskyan and Galperinian or neo-Galperinian theory (Vygotsky 1978; Tella & Mononen-Aaltonen 1998; Galperin 1992; Podolskij 1997). In order to support the group study activity and to support collaboration between group members and between members in different groups, the Web collaboration application BSCW© (Basic Support for Cooperative Work) was customised, programmed, and included as part of the resources for the students. BSCW© offers collaboration capability, file storage, and file sharing space for the groups. The BSCW serves also as storage space for returning all solved tasks.

The WOA has an all-purpose database containing the guidance, content, and orientation technologies. By clicking with the mouse upon its contents, a smaller popup-type window opens, displaying orientation and interactive task windows on the screen. Here the research has drawn on usability studies and the ideas of cognitive load theory (Chandler & Sweller, 1991; Cooper, 1998; Mayer, 2005; Mayer & Moreno, 2002; Wilson & Peggy, 1996). In other words, these study technologies have been designed to avoid students from being distracted and attention splitting.

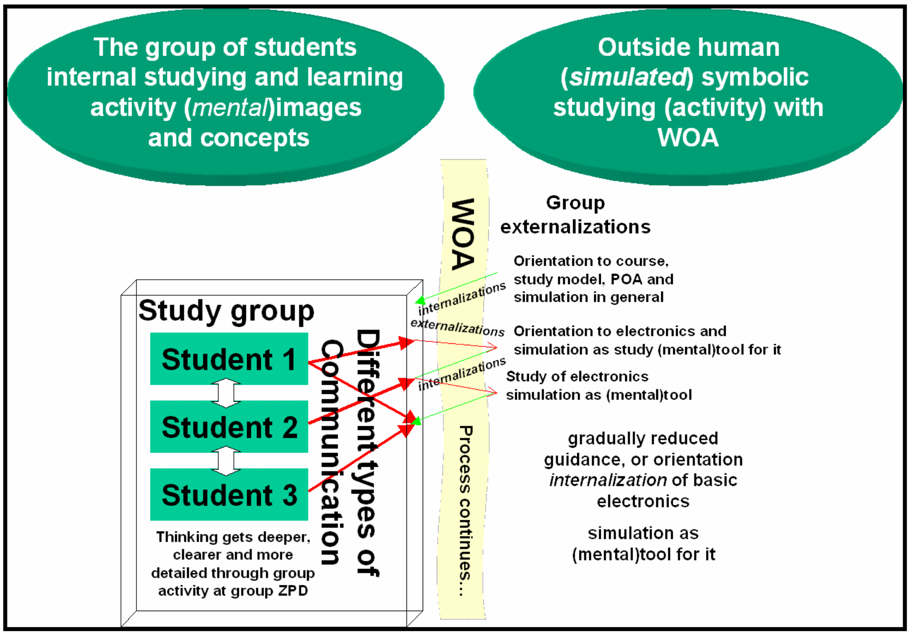

Figure 2: The pedagogical model first phase

The idea is for them to use as little screen area as necessary for a certain task and to use the browser windows with dialog boxes that offer the required orientation (Chandler & Sweller, 1991; Mayer & Moreno, 2002; Min, 1994; Nardi, 1997; Wilson & Peggy, 1996). Moreover, efforts have been made in the design process to exploit playfulness and "edutainment" (education and entertainment), providing game-like interactivity that can enhance and diversify the learning process. Figure 3 shows a screen capture of the WOA system illustrating the behaviour of a basic electronic component, in this case characteristics of a bipolar transistor (Chandler & Sweller, 1991; Kapetelinin, 1997a, 1997b; Lehtonen, 2003, 2005b; Mayer, 2005; Mayer & Moreno, 2002; Page et al., 2006; Wilson & Peggy, 1996).

The diagram is interactive and allows the students to observe the current in the circuit with a virtual meter. It was created using animated GIFs, HTML/JavaScript. It enables students to find the prerequisite information required to solve the problem. In addition to this, students may download the needed files to their local computer so that solving the problem can begin. When the task is completed it is returned to the BSCW which operates intrinsically as part of the WOA. The WOA is available at all times and by clicking the small WOA navigation area, links are made to popup–type interactive task orientation windows when needed. In the present research project the tasks were connected to course literature by page numbers. This literature is used to support electronic circuit design techniques. There has been recent discussion about the pedagogical agents e.g. Clark & Feldon (2005) and as in this research they point out that the agents itself are not the keys for the success or failure but instead the pedagogical method or model provided by the agents.

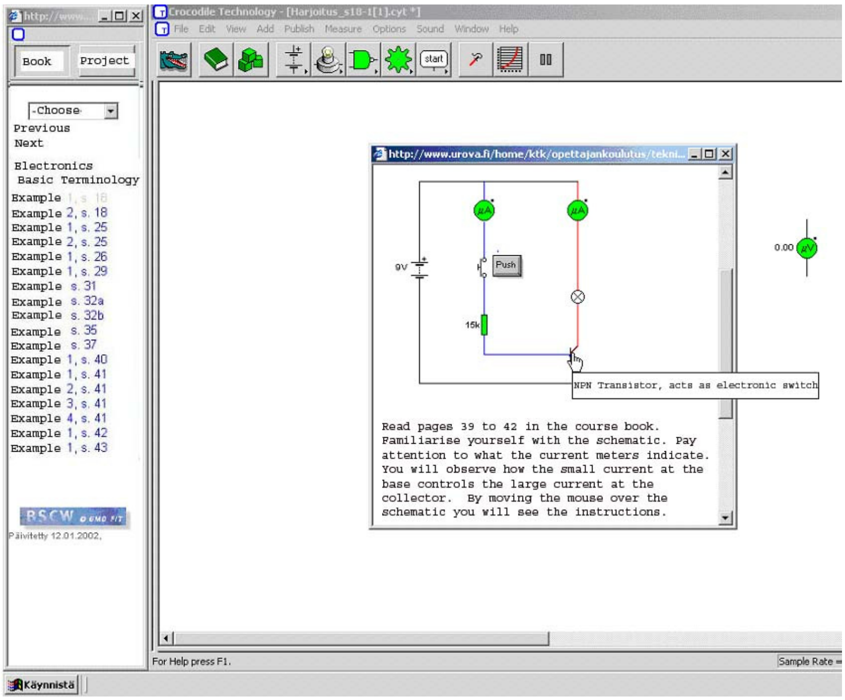

Figure 3: The Web Orientation Agent (WOA)

5. The Second PBPL Phase of the Pedagogical Model

The second phase of the model is the *problem based project learning (PBPL) phase* utilising the learnt simulation use and the basic knowledge of electronics as a resources for problem based type learning. (Problem Based Learning PBL; (Albanese & Mitchell, 1993; Boud & Feletti, 1999; Norman, 1998; Norman & Schmidt, 1992; Poikela, 2002). In this phase when the topics are gradually internalised as described earlier (Galperin 1989; 1992, Podolskij 1997) and it becomes possible to steadily reduce the guidance, or orientation of study, ultimately permitting the testing and application of what has been learned in a problem-based project as shown in Figure 4. Here, one may refer to Podolskij's (1997) statement, based on neo-Galperinian theory, that only when a learner has been oriented and helped to internalise certain routine activities and these no longer place an unnecessarily heavy cognitive load on his/her thinking and activities should he/she be given tasks requiring creativity, such as open problem-solving tasks. For this reason the teaching described has been designed to include orientation as Galperin describes it. The students work toward a solution first in a simulated environment using the computer and subsequently in reality in the technology laboratory. The approach is based on Kimbell (Kimbell, 1987, 2000; Kimbell et al., 1999), Vygotsky (1978), and Podolskij 1997). In addition, there is such an aspect that the skills and the procedural knowledge (the activity structure) generated in these types of studying and learning processes represent in many ways the abilities the modern information society needs. The "right first time principle", simulated prototyping is one of the key competences of modern technology industry in different sectors. Moreover, there is also scientific evidence that these kinds of learning activities generate transferable knowledge as well as a thinking and acting model. This can later help the learner to cope with these processes in similar tasks encountered in working life or in other sectors in society (Bransford et al., 2000, 207). The authors argue that this type of learning would be an important part of the qualifications needed in the modern information society (Lehtonen, 2002b; Rasinen, 2001).

Finally, at the last stage in Figure 5, the group is presented with an open scenario type problem based design problem to solve, first in a simulated environment and subsequently in reality situations in technology lab. It may be said that the process goes deeply beyond the "modular lab" –type approach and utilising only as much computer aided phases as seen to be useful (LaPorte, 2000). The guidance technologies and PBPL resources, book, printed lab notes, and WOA, remain at the student's and group's disposal throughout the process should they wish to resort to applying them. This can be considered extremely important not only for guidance of the student but also as an element that can provide the student with a sense of security and reduced situational anxiety, thus contributing to learning (Lehtonen, Hyvönen et al., 2005; Lehtonen, Page, & Thorsteinsson, 2005; Min, 1994; 2003). In addition, students' knowledge of electronics technology is gradually developed, learning activity can continue with a very open, problem-based lab period. In this case, the students must not only test their knowledge and acquire new knowledge, but also apply what they have learned during the first stage of the teaching, studying, and learning in lab situations serving as an assessment for the learning as well.

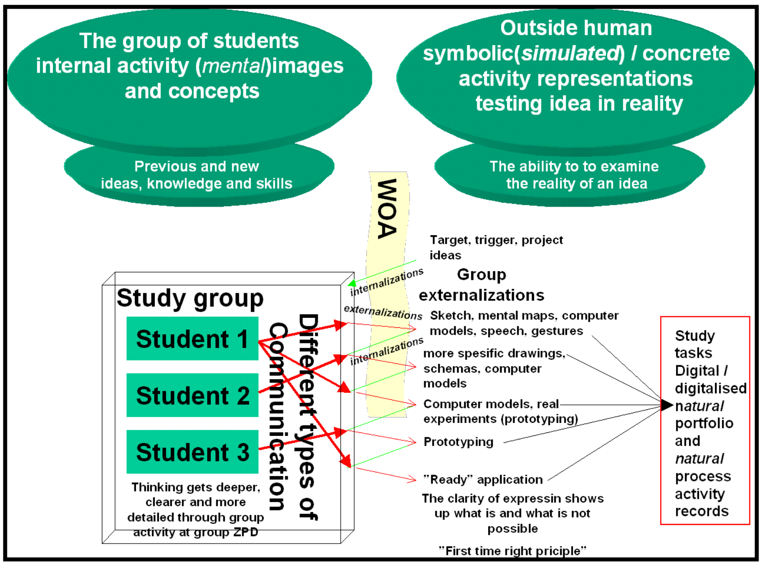

Figure 4: The second phase, the Problem Based project Learning phase

6. Emotionality, Game Based Learning and Edutainment as Part of Studying and WOA

For the purpose of effecting improved attention among students, the pedagogical model in general and the technologies used in it should produce positive experiences and feelings in support of teaching. This support is necessary and can often be seen as a necessary element in early stages of learning. Jonassen (2000) observed that many interactive technologies motivate students precisely because the technologies allow them to *learn by actively doing* (Bruner, 1996; ITEA, 2000) instead of passively watching and listening to a presentation on how the activity is done by someone else (Bransford et al., 2000). One's own activity and work as part of a group often engages emotions and experiences. Playfulness, game-baseness and edutainment provided by the interactivity has a contribution to make here in that the computer does not lose its significance as a tool; rather, its distinctive features are augmented to produce emotions in making the problem-solving pleasurable if not even entertaining (Lehtonen et al 2005; Prensky 2001).

Some benefits associated with simulations and games may be regarded as: functionality from the perspective of the learner as an individual and the learner as a member of a group; and emotionality. In merging both functionality and emotionality, simulation may foster strongly experiential studying/learning (Lehtonen, 2005c; Lehtonen, Page, & Thorsteinsson, 2005; Vahtivuori-Hänninen et al., 2005).

- Functionality and studying/learning by doing and (also by trial and error). By means of simulation, it is possible to study by concretely doing.
- Simulation fostered emotionality and the reduction of situational anxiety. Simulated action often arouses the same types of feelings as in the real situation. However, simulation allows for the possibility to safe experimenting

- Development of real problem-solving skills. The use of simulations in teaching helps develop real creative and elaborative “hands on tasks”-type problem-solving skills (Lehtonen, 2005c; Lehtonen, Page, & Thorsteinsson, 2005; Vahtivuori-Hänninen et al., 2005).

For example Crawford (1984; 2003) and Prensky (2001) notes that the principal motivation for playing is a desire to learn and to learn how to control a situation. They maintain that the desire to play is a mechanism that is innate to all which the designers of computer games make use of. For example, ramping levels of difficulty in other words maintaining the activity in Vygotsky’s zone of proximal development and not becoming too difficult to impede the motivation and success, immediate feedback, and the use of multimedia to produce different effects. These aspects can be used to focus students to the essential parts in their learning whilst providing entertainment which are some of the means by which these experiences are created in computer games (see also Lehtonen, Page & Thorsteinsson 2005). At the same time it should be noted that not all interactivity or multimedia helps, students learn more deeply from multimedia presentations that *exclude* irrelevant extraneous words and sounds which can guide their attention to split from the core processes of learning. (Lehtonen, 2005c; Lehtonen, Page, & Thorsteinsson, 2005; Mayer, 2005; Mayer & Moreno, 2002.)

The research reported here attempts to accommodate edutainment especially through carefully chosen commercial simulation. The electronic design simulation software Crocodile Clips© was chosen in 2001 for this work from among a number of potential applications. This has proven to be a successful one in many, but not all respects (the use of conceptual and symbolic schematic diagrams, interaction models, usability factors, edutainment factors), of course.

7. Design Based Research for the Model: Methods, Participants, Data Collection and Preliminary Findings

The research that contributed to the development of the pedagogical model comprised action research through case-based study and the methodology adopted was both qualitative and quantitative in nature. This work was undertaken on multiple levels of observation, data collection and units of analyses (Creswell, 2003, Lehtonen, 2005c; Lehtonen et al., 2004). The data was collected from the third and fourth year students (n=11) at University of Lapland. The students were all males and had no prior learning in electronics technology nor had they studied with the aid of simulations before the experiment. Their computer use history varied between 12 and 20 years, the average 16 years. Most of them felt that computer use was reasonably easy, all participants but two owned a 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 to the pre-experiment survey (Page et al., 2006.).

Data collection took place at the University of Lapland during spring 2002 in a 48 hour course module held in a university computer class and in technology labs. The study combined first-order perspective (through actual observations of study activity) and second-order perspective,(or the *phenomenological perspective)* where students described their study activities in response to queries or as interviewed. The data collection methods were qualitative with the exception of the queries before and after the study module. (Lehtonen, 2005c; Lehtonen et al., 2004; Bødker 1997)

The data collected as part of the case study included: queries (before and after the activity); interviews; and participant-technology based observations where the activity of the learners in groups was recorded on audio and video. Some research questions were based on thematic and semi-structured interviews. The interview data was analysed using a content analysis method with description, interpretation and categorisation (Giorgi, 2003; Jonassen, 2001; Lehtonen, 2005c; Lehtonen et al., 2004; Moustakas, 1994). In one data block, the group of students (n=3) were observed more closely through simultaneous screen recording, as evident in figure 5, which was also used as a base for stimulated recall interviews (STRI). In these recordings, the group and their computer screen appear in the same frame. In these interviews, the students were shown some problematic situations from the videotape and were asked questions to describe their thinking and problem solving processes. The idea is very much similar to Kimbell’s idea of using a natural portfolio of design data for the same use, to *recall* and evaluate the design activity and process. These interviews were also recorded on videotape and audiocassette for analyse purposes. (Barrows, 2000; Bloom, 1953; Marland, 1984; Page et al., 2006.)

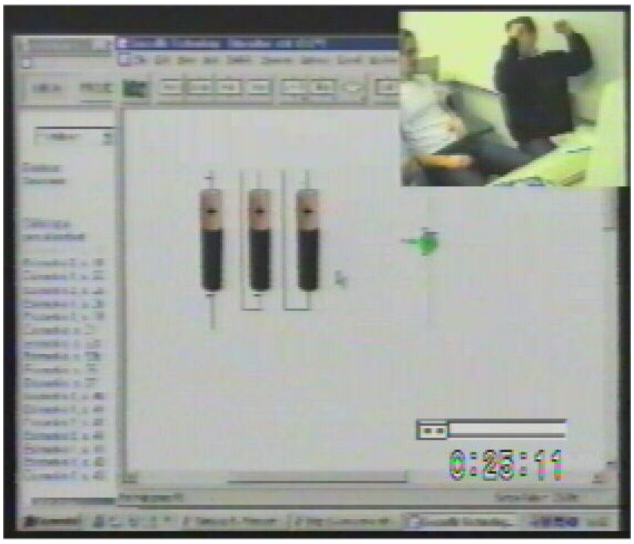

Figure 5: Capture from simultaneous screen recording

A quantity of data was analysed directly from the first-order perspective though investigation of the activity seen on tape recordings (Lehtonen 2005a; Bødker 1997; Rosenblum et al., 2004). In particular, the attention splits/focus breakdown situations as well as emotionally coloured situations (Lehtonen 2005a; Bødker, 1997; Lehtonen, Hyvönen et al., 2005; Lehtonen, Page, & Thorsteinsson, 2005; Rosenblum et al., 2004) were analysed directly from these recordings. As was noted in both case studies, satisfactory and unimpeded study processes combined with the identification of problems due to excessive cognitive load were observed from the tape recordings. Further to this, the way in which the students used these simulations and WOA resources as well as the way they studied and learned was also coded and analysed. The observed emotional responses to the studying processes were also coded into two classes 'situational pleasure' and 'situational anxiety/frustration' (Lehtonen, Hyvönen et al., 2005; Lehtonen, Page, & Thorsteinsson, 2005). The different video and audio data was analysed through review type listening/watching/searching the relevant parts and transcripted for those relevant parts and finally coded using the nVivo© application.

8. Preliminary Findings

Such preliminary findings support the effectiveness of this pedagogical model. Textbooks, lab notes and simulations in conjunction with an interactive WOA - WWW agent application to support them work very well together and demonstrate the effectiveness of the approach adopted. According to our data, distributed communication occurred in a deeply mediated manner through the mediating visual communication object, and the other forms of communications e.g. spoken communication and sketches. This was clearly evident in the first-order perspective through video data analysis. Figure 6 indicates the importance of the use of WOA in supporting simulation in both of these studies according the questionnaire responses after the study.

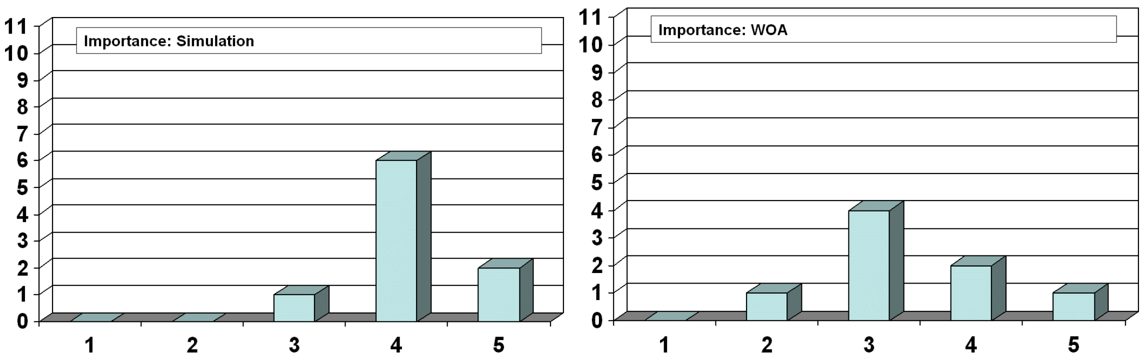

Figure 6: The preferred importance of the simulation technologies and WOA resources (5 = "most important") from the learning viewpoint at the questionnaire responses after the study

Furthermore, the pedagogical model containing extracts from textbooks and simulations supported by an interactive WOA –appeared to work as expected. Both the first-order data (video) and the second-order data (e.g. STRI, inerviews, query after) give support for such. The students used both the text book and the simulation using the WOA as planned. The directly analysed video data (*the functionality of the model and technologies, observed focus breakdown situations, situational pleasure/situational anxiety*) shows no indication for serious problems with the model or the and demonstrates that the students used the technologies as expected. It was of surprise to observe, the amount of time that the students spent on focussed concentration on the problem-solving tasks. Example of this is seen on the student comment:

> *Student (11) (in stimulated recall situation) 'See how concentrated we are – we are completely silent".*

In the query after, the students valued how the book and computer resources supported each other as well as how they experienced the usefulness of the WOA and simulation.

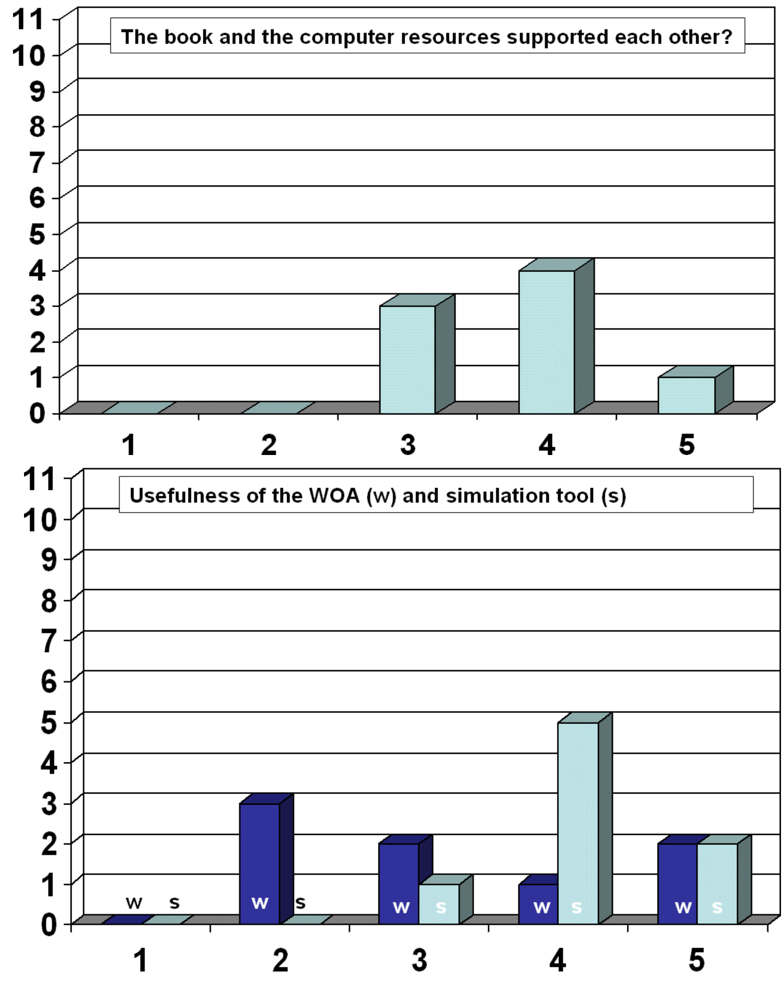

Figure 7: The preferred importance of combined use of the simulation technologies and WOA resources together (5 = "most important")

A preliminary analysis indicates that Galperin's ideas of the gradual internalisation of relevant sub-skills by guiding the process through different orientation phases appears to work reasonably well in a network environment (Galperin, 1989). The importance of taking playfulness and edutainment into account in instructional design also seems to be just as helpful (see figure 7). That is evident in the tape data and in students' comments on the technologies. The situations where situational pleasure were observed (through coded and analysed video sections) indicate that the playful and edutainment type features were both related to social activities. The interactive components which indicated the functionality e.g. by light etc. or the dysfunctionality by exploding components were mostly contribute to instances of situational pleasure. Moreover, the indirect data supports that, when one of the computers used in this study couldn't produce sound as it had no sound output, this was heavily criticised in both the analysed tape data (*e.g. smiling laughing and also some clearer verbal responses*) as well as expressed in the stimulated recall situation. Some examples from the direct videodata:

Group (2): (the circuit starts to work) "Wow, clear movements and heavy laugh together";

Student (6): "Why I cant explode the battery?" (laugh);

Student (11): (student tries the circuit functionality) "it gave light!";

Student (10): (components explode in the circuit) (laughing) "Luckily those were not real components, otherwise would have been expensive fun".

The guiding/orienting function of this first stage of the pedagogical model can be considered very important in light of the types of technologies used in the present research and in simulation programs for electronics open problem-solving. In commenting on such technologies, Jonassen (2000) observes, that the technologies enable learners to represent their own thinking in the ways that they explore, manipulate and experiment with the environment. It is evident that from, Gonzales et al. (2001) and Chen (2002), one problem associated with technologies that make use of open problem-solving is that without teaching, learning, sufficient practice and control of the tool this can often lead to superficial and recreational type study activity, which rarely results in high-level learning.

In relation to student comments regarding the length of the computer use periods and the analysis of video data it was obvious that the average of two hours of simulation activities seems to be the maximum. After the two hours the activity in the video data seemed to decline, this was also discussed in the recorded group discussions and students also reported that same phenomena when interviewed. Moreover, some quite unexpected results were found, which related to the commercial simulation program usability and the most unexpected were problems related to the English language used in the program for the Finnish university student users.

What was also seen in preliminary research findings is the need for a general understanding for the whole process "the general orientation base" (Podolskij, 1997). Here, the student group should be directed to developing an electronic solution in the early phase of the pedagogical model. This can be very well facilitated through the WOA and followed with guided laboratory practice to produce some simple working electronic device -from simulation to a ready made working system (*$_4$C/ID-model* by van Merriënbouer and Kester, 2005). Through that type of "guided mini design process" the student group would very likely reach the general understanding of the whole process. This helps them to internalise the needed skills and knowledge by seeing the importance of such whilst being capable of understanding the whole process in advance of the second problem based process (Gokhale, 1996; Gonzales et al., 2001).

9. Conclusions and Future Research

The pedagogical model "Network oriented study with simulations" and the WOA work as expected and in accordance with the theoretical viewpoints. Further study and analysis is producing supporting knowledge in this area, where teaching, studying and learning resources in use are analysed through different means. From the initial evaluation, the future development of the WOA should be targeted to developing a more interactive and adaptive user interface and using a variety of multimedia instructional messages utilising different media types. This will help in reducing the cognitive and emotional load factors (e.g. flash animation, HTML/AJAX, streaming movie clips, sound e.g.) utilising multiple representation principle and *contiguity principle* as a part of a supplementary smoothly working edutainment-oriented solution (Mayer & Moreno, 2002; Min 1994; 2003).

Moreover, integrating hands-on activities with real components into the WOA system in different formats of pictures and video are challenges for the future development of the WOA tool. One interesting phenomenon is that the pedagogical model "Learning through simulations" (Joyce et al., 1997) used in a similar project has yielded parallel evidence substantiating the results of Network-Based Mental Tools in Technology Education. It is also noted, that the model of $_4$C/ID-model by van Merriënbouer and Kester (2005) contained surprisingly similar parts and ideas as evident the NOSS-model developed in this project. This provides parallel evidence for the model relevance. Furthermore, the model has been implemented in a second case study which concerning virtual reality (VR) settings utilising *through computer* type computer mediated communication and interaction. This has also provided some research results about the model and its use indications in different contexts (Lehtonen, Page, Thorsteinsson et al., 2005; Lehtonen, Thorsteinsson et al., 2005).

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