A Pedagogical Consideration of Technology Enhanced Laboratory Work in Technology Education

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Abstract: This paper discusses the development of a pedagogical model entitled "Network oriented study with simulations". This model supports teaching and learning in technology education particularly in the laboratory setting using a computer-based tool, termed the web-orientation agent (WOA). The aim of this research is to examine the pedagogy of technology education in order to establish a model for such pedagogy so that appropriate tools can be developed and implemented to support it. In essence, the WOA is a software-based tool, providing a supportive and interactive learning environment that makes use of local applications, in this work, an electronic circuit design and simulation application.

We introduce some preliminary research findings with our university level student group (N=9), all males, using qualitative design based action research (e.g. Hannafin 2004; c.p. Carr & Kemmis 1989). The methods are based on simultaneous video, stimulated recall and group interviews data. It has yielded valuable information to develop the described pedagogical model further on how study using simulation tools and network applications that support these and how more traditional media can be appropriately organized to be closely linked with modern media to support learning.

This study describes also the "Network-Based Mental Tools in Technology Education" case research, which made it possible to test the theoretical bases described in this paper. Evaluation of the preliminary conclusions, the future development of the WOA will be targeted at least to developing a more interactive and adaptive user interface and using a variety of media types (gif/flash animation, streaming movie clips, sound e.g. as a parallel information channel and as a part of a supplementary edutainment-oriented solution.

Keywords: technology education, simulation

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1. Introduction

In a somewhat light-hearted vein, it could be said that, the meta-cognitive work on the part of a teacher in teaching - and the work of a magician in the creation of an illusion - are closely related. The magician's task is to create an emotionally engaging situation and atmosphere which guides the viewer to focus on the inessential by a certain tool or means. The aim of a teacher in the technology education lab – or for the purpose in this work, the computer or network teaching method for supporting teachers work – is to guide a student or group of students to observe, do and discover what is essential in its content and to create a comfortable context for studying and learning. It might be said that both the teacher and magician try to guide observations and emotions and use different materials and distractions to that end. Adapting P.J. Galperin's terminology, we refer to this guiding of observations in appropriate or

inappropriate directions as (cognitive and emotional) orientation (Lehtonen to appear; Lehtonen 2003; Galperin 1989; 1992; Podolskij 1997; Talyzina 1981).

In using computer and *network-based learning tools* in technology education, such as in electronic circuit design and simulation applications as used in this research project (Lehtonen 2002 a, b; Lehtonen 2003). The notion presented above on steering and helping the student or group of students, the pedagogical model and activity based on it, is just as significant as it is in conventional teaching. The activity in which teachers direct students' or pupils studying and learning (Uljens 1997) - will frequently not work in an optimal fashion solely by using the most modern educational technology applications or resources (e.g. video media). A sound pedagogical model is needed to enable the integration and use of such resources in pedagogical context. Therefore provision must be made in order to orient or guide students and pupils in the effective use of such tools and resources for their own studies and ultimately empower the student (Lefrere 2004). Only through the adoption of appropriate pedagogical models and associated tools in technology education we may help students to use computers as a tool for developing their skills, knowledge and understanding (c.p. ITEA 2000; Dugger & Naik 2000).

2. Theoretical Background

The purpose of the work reported here is to present the case study undertaken in the development of the aforementioned pedagogical model "Network oriented study with simulations (NOSS)" and use of the ICT-based tool "*Web Orientation Agent*" (*WOA*) as a tool for this model. This has formed part of a learning activity based on a design based action research project titled "Web-supported Mental Tools in Technology Education" the aim of which is to develop a pedagogical model and to evaluate the effectiveness of electronics simulation tools and modern network-based platforms that support learning and teaching. This work encompasses other "mental" tools and multimedia resources that support thinking, problem solving and learning within electronics technology in this research (c.p. Jonassen 2000). In addition, traditional and modern digital learning materials are examined in a context of normal teaching-studying-learning-process at university-level (c.p. Uljens 1997; Illeris 2002). In this context the term "studying" (Uljens 1997) is used here instead of "learning activity" (cp. Illeris 2002). The project also analyzes the advantages and disadvantages of different educational technology tools and resources for the purpose of evaluating their suitability in support of teaching and learning of electronics in technology education. As such, considerable efforts have been made to use: literature; electronic documents; interactive documents; and different kinds of interactive tools, such as simulations. Such resources have been deployed in such a manner as to maximize their benefit and minimize their disadvantage to the student's study process for technology education (Lehtonen 2002 a, b; Lehtonen 2003).

The WOA was developed to overcome some of the problems observed when simulations that allowed rather open-ended problem-solving approaches (Vygotsky 1978; Jonassen 2000), have been used in technology education contexts and in general i.e. in other studies and teaching processes (Devedzic & Harrer 2002). In many cases the problem has been that students are incapable of using the tool for deepening, creating or constructing their understanding and knowledge, as defined in the specified learning outcomes (Gonzales, Reitman & Stagno 2001 a, b). Furthermore, it has been observed that students use such tools as simulations merely for 'playful', rather than goal-directed purposes, instead of using them for meaningful study use (Chen 2002; Koopal 1993/1997).

Why develop pedagogical models for web-based learning and tools for them? It is possible to develop local computer resources to direct study activities and learning but those are, in many ways, problematic especially in multi-user and multi-location environments where accessing and updating content resources are necessary. The Internet provides an opportunity for the integration of collaboration tools, which are needed and used in this project for group-based pedagogical models for study activity support.

A problem encountered when developing the WOA emerged during preliminary experimentation with ready-made *WWW-learning environment applications* and local simulation tools. Here students found considerable difficulty in using multiple applications on the same computer screen, particularly when the student was required to switch between the simulation program and the full-screen browser window of the "www-learning environment". This caused their attention to be directed away from learning activities to irrelevant activities such as switching between programs that caused concern and avoidance in later phases, the WOA tries to resolve some of these problems. It is a tool for directing and orienting students' study activity, to approximate the phases derived from the *System of Planned, Stage by stage Formation of Mind Actions*, or a system of PSFMA (Galperin 1989, 1992; Podolskij 1997).

The subsystem "*Conditions for the formation of necessary orientation basis of action*" was of particular interest when developing the WOA (Podolskij 1997). The subsystem provides the learner with essential conditions for a sufficient approach to problem solving in technology education. Each student has a structure for internalizing and becoming

familiar with the subtasks concerned, for example the content tools and the required activities. However, before being capable of using it such as a part of a larger problem-based process or study activity, the student needs to know what to do in general and how to use the tools as a part of the process. It is the view of the authors that the Galperinian (1989, 1992) or neoGalperinian (Podolskij 1997) approaches to orientation that make use of web-based learning have not been fully realized because the learning process has typically been static, that is statically implemented. We therefore argue that the full potential of the Galperinian theory may be found by developing conceptual, electronic *interactive and adaptive web-based tools* based on modern ICT e.g. www resources.

Despite the fact that the present research focuses on modern ICT-based materials in technology education context, the more traditional and established resources still maintain an important role to play. For instance, Min (2003) concludes that the use of written sources, books and handouts as parallel media along with a computer is often motivating, accordingly, no attempt has been made to transfer all such materials into electronic format. Min (2003) also puts forward that open simulation environments frequently work better when the instructions for their use comprise easily read and browsed (printed) documents, such as workbooks together with material on the computer display. Furthermore, those may be also shared through internet as *print on demand*-documents (e.g. PDF-format) for local printing in technology education lab.

3. Aims of the Pedagogical Model and the Web Orientation Agent (WOA)

The pedagogical model utilizes the experimental tool, WOA which is an Internet-based application, illustrated in figures I and II. The WOA has an all-purpose database containing the guidance, content and orientation tools. These figures provide guidance for the study activity including tools for representing necessary subtasks, a general plan of final process achievement and a representation of the action tools being formed (orientation and execution tools). When a student or a student group has become familiar with the common aspects of the goals and the tools used in them, they are guided to open the real WOA, which is a platform-adaptive interactive "navigation area". By mouse clicking upon its contents a smaller popup type window opens –an orientation and interactive task windows on the screen. Here the research has drawn on usability studies and the ideas of cognitive load theory (Cooper 1998; Wilson & Cole 1996; Chandler& Sweller 1991). In other words, these study tools have been built to avoid students from having to divide their attention excessively among different focuses and activities. The idea is for them to use as little screen area as is required for a certain task and to use the browser windows providing GUI (Graphical User Interface)-type dialog boxes which offer the required orientation information for submitting certain tasks with local software (Min (2003); Kapetilinin & Nardi 1997; Wilson & Cole 1996; Chandler & Sweller 1991). Moreover, efforts have been made to exploit "edutainment" (*edu*cation and enter*tainment*) as part of the nature of tools and materials to provide game-like interactivity as factors that can enhance and diversify the learning process. Figure 1 is a screen capture of the WOA system illustrating the behavior of a basic electronic component, in this case a battery polarity and connection circuit.
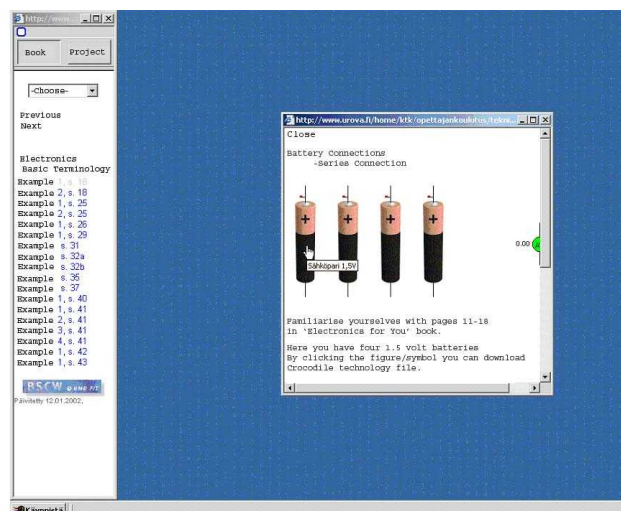

Figure 1. The WOA

The task-orientation windows enable students to find the information required to complete the task successfully. In addition to this, students may download the needed files for the local simulation tool through which the task to be solved can start, see figure 2. The file, which is based on the MIME-type separation of files, the target application can start. Finally the situation is like in figure II where the WOA is available all the time and by clicking the small WOA navigation area links it opens popup–type

interactive task orientation windows when needed. In the present research project the tasks were connected to course literature through page numbers in the course WOA. These were used to support a course in electronic design techniques.
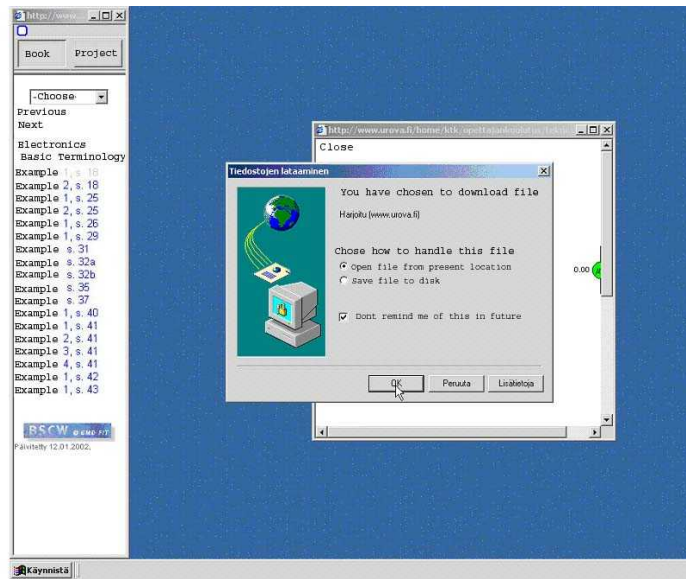

Figure 2. The WOA showing downloadable local resources

Figure 3 is an example of an interactive task dealing with the use and characteristics of a bipolar transistor and interactive representation formats of the tasks utilizing interactive (HTML/JavaScript) applications.
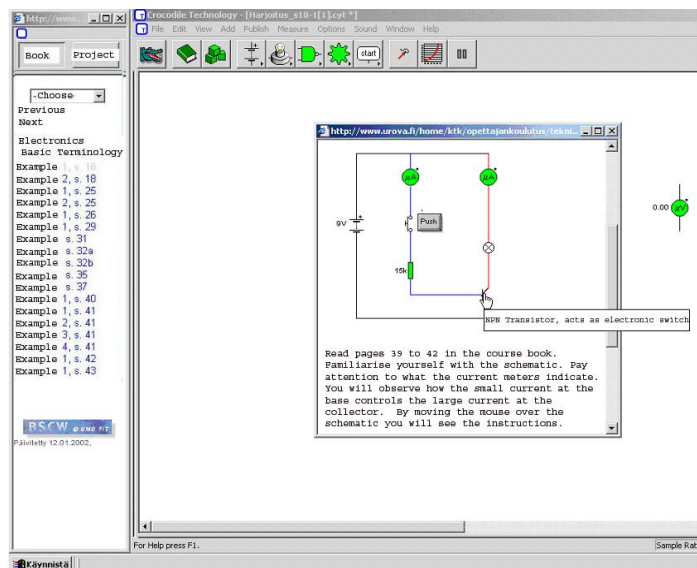

Figure 3. Example of interactive subtasks

The pedagogical model *Network oriented study with simulations* and the idea of the WOA, is to guide or orient (Lehtonen 2003; Lehtonen to appear; Podolskij 1997; Galperin 1989, 1992) a student in using local resources such as simulation tools (e.g. computer simulation or simulator programs) in a pedagogically sound manner as described earlier. The background for this was, as mentioned earlier, developed and based primarily on the Vygotskian and Galperinian or neoGalperinian theory (Vygotsky 1978; Tella & Mononen-Aaltonen 1998; Galperin 1992; Podolskij 1997). In order to support the group study activity and support for collaboration between group members and between members in different groups, the www collaboration application BSCW© (Basic Support for Cooperative Work) was customized and programmed as part of the present web-based learning environment system, BSCW© offers collaboration, file storage and sharing space for the groups.

4. Description of the WOA, the Pedagogical Model, Educational Theories

The combined use of the WOA and BSCW in the pedagogical model has been designed to orient the student's studying and learning activity as an individual and as a member of a group, i.e., small groups towards Vygotsky's zone of proximal development (ZPD). This is engendered through the use of instructional design solutions and educational technology (Lehtonen 2002; Lehtonen 2003; Lehtonen (to appear); Ruokamo et al. 2002; Vygotsky 1978; Wertsh 1985; Bransford et al. 2000 and Tella & Mononen-Aaltonen 1998). The aim has been to create a process and a pedagogical model, in which the topic being studied occurs in phases. The related sub-skills which are required in the final stage problem solving are analyzed in these stages i.e. the stage-by-stage formation of mental actions are analyzed within the group processes. In the initial stage of the process, students are engaged in network-guided activities in which they externalize, communicate and visualize their ideas to others through speech (internally as well as externally). This is facilitated through modelling tools, gestures and viability testing of their ideas using a simulation tool as illustrated in Figure 4.

In this way, the topics are gradually internalized (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 Figure V. Drawing on the ideas of Vygotsky, (1978) Galperin (Galperin 1989; 1992, Podolsky 1997) and Kimbell (1987, 1997, 2000 a, b), the internal and external speech and social interaction among the students occupies a central role in the pedagogical model and learning process based on it. This is supported with the "externalization" – (interacting with material or immaterial electronic representations of the process) and internalization phases where there is a deeper requirement for thinking and understanding. Finally, at the last stage in Figure V, the group is presented with a 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 beyond the "modular lab" approach and utilizes as much computer aided phases as seen useful (e.g. Laporte 2000). The guidance tools and 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 which can provide the student a sense of security and a reduced situational anxiety, thus contributing to learning (Farnill 2001; Min 2003; Bransford 2000). When the sub-skills and ideas that have been mastered following the process described, in which guidance is gradually reduced and different sub-skills practised. 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 in lab situations, what they have learned during the first stage of the teaching, studying and learning.
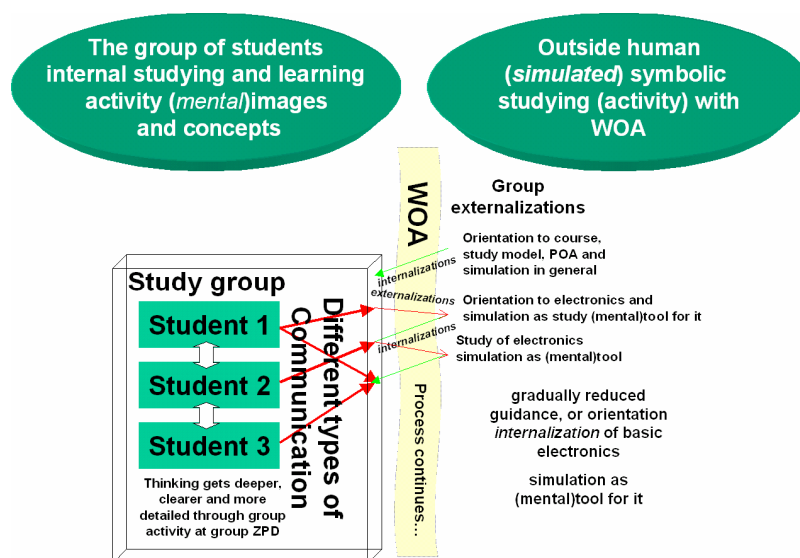

Figure 4. The pedagogical model first phase

Figure 4 reveals the first phase of the pedagogical model, the orientation phase based on Kimbell (1987, 1997, 2000 a, b), 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, internalize, externalize, communicate and visualize their ideas to others through speech (internally as well as externally). This is facilitated through the WOA modelling tools and gestures as well as viability testing of their ideas using a simulation tool.
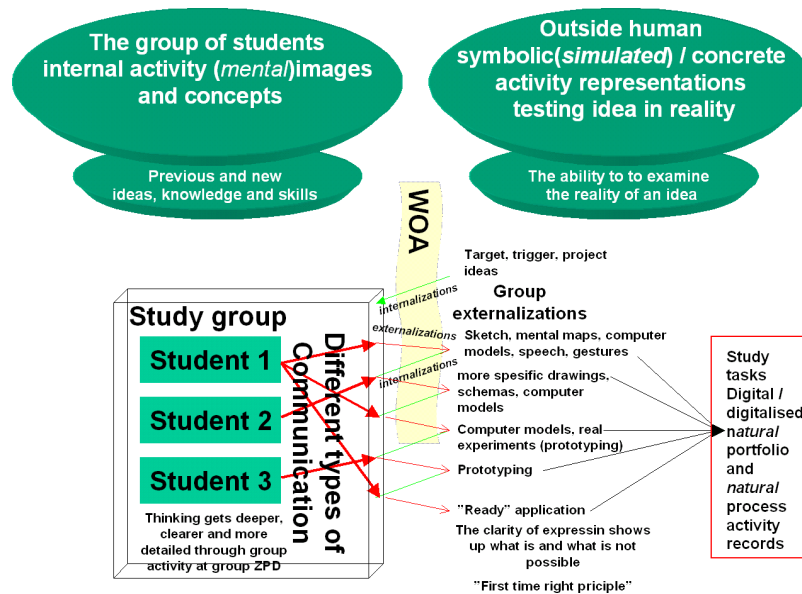

Figure 5. The pedagogical model second phase

The second Problem based learning (PBL) phase of the pedagogical model (Figure 5). In this stage the group is presented a design problem to solve; first in a simulated environment and subsequently in reality situations in technology laboratory based on Kimbell (1987, 1997, 2000 a, b), Vygotsky (1978) and Podolsky 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 "First time right 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. Which later helps the learner to cope with these processes in similar tasks encountered in working life or in other sectors in society (e.g. Bransford, Brown & Cocking 2000, 207). The authors argue that this type of learning would be an important part of the qualifications needed in the modern information society (e.g. Rasinen 2001), (Lehtonen 2002a.).

5. Testing 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 tools 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 *tools* motivate students precisely because the tools allow them to learn by doing (c.p. 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. Edutainment 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 and entertain the user (Kangas 1999; Ruokamo et al. 2002; Prensky 2001). For example Crawford (1984) and Prensky (2001) notes that the principal motivation for playing is a desire to learn and to learn how to control a situation. He maintains that the desire to play is a mechanism that is built into each and everyone of us which the designers of computer games make use of. For example, ramping levels of difficulty, immediate feedback, and the use of multimedia to produce different effects are some of the means by which these experiences are created in computer games.

The research reported here attempts to accommodate edutainment through choice of a commercial simulation. The electronic design simulation software Crocodile Clips© has been chosen 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.

The research project entitled "*Network-Based Mental Tools in Technology Education*" tests this pedagogical model named "Network oriented study with simulations" and tools (WOA) for it is one of the ongoing MOMENTS-consortium case-based research studies. This work is funded by the Academy of Finland and the Finnish Technology agency. This work is conducted at the University of Lapland (see e.g. Lehtonen 2002a,b; Lehtonen 2003; Lehtonen 2004 and Lehtonen *et.al.* 2004). MOMENTS is an acronym for (*Models and Methods for Future Knowledge Construction: Interdisciplinary Implementations with Mobile Technologies*). It is a multidisciplinary research project focusing on future teaching, studying and learning. In this project, many areas of knowledge and research combine their strengths and capacity to generate visions and scenarios, much as focus groups do. The "Network-Based Mental Tools in Technology Education" case study has made it possible to test the theoretical bases described in this paper. Furthermore, it has yielded valuable information in developing the described pedagogical model further. This includes study using simulation tools, network applications and how more traditional media can be appropriately organized to be closely linked with modern media to support learning.

The preliminary research findings have been observed from a university level student group of nine male students, using qualitative research methods, which have been adopted from the methodology of design-based action research (e.g. Hannafin 2004; Carr & Kemmis 1989; c.p. Merrill, 2004). The data collection techniques applied are through simultaneous video screens (see figure 4 and 5), stimulated recall and group interviews (see figures 4 and 5).

During the teaching experiment, one student group's simultaneous screens were recorded on video while the students used simulations (see figure 4 and 5). In these video recordings, the group and their computer screen appear in the same frame. The student groups were interviewed after the lessons using the stimulated recall-method (STRI). Students were shown some problematic situations from the videotape and were asked questions to describe their thinking processes. The groups' interviews were recorded on videotape and audiocassette (cf. Ruokamo-Saari 1997; Lehtonen, Ruokamo & Tella 2004).

Such preliminary findings appear to 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 as envisioned and support the effectiveness of the approach adopted. Furthermore, the pedagogical model containing excerpts from textbooks and simulations supported by an interactive WOA –seem to work as planned.

A preliminary analysis indicates that P.J. Galperin's ideas of the gradual internalization of relevant sub-skills by guiding the process through different orientation phases appears to work in a network environment. The importance of taking edutainment into account in designing instruction also seems to be just as helpful.

The guiding/orienting function of this first stage of the pedagogical model can be considered very important in light of the types of tools used in the present research and in simulation programs for electronics open problem-solving. In commenting on such tools, Jonassen (2000) observes, that the tools 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, Reitman and Stango (2001) and Chen (2002), one problem associated with tools that make use of open problem-solving is that without teaching, learning and sufficient practice in the use of the tool itself. In addition, control of the tool, and without experimenting with and study of the tool in problem solving thereafter as well as acquisition and building up of sufficient knowledge and skills in the subject concerned as part of studying (c.p. Gokhale 1996). These tools can often lead to superficial and game-like study activity, which rarely results in high-level learning. 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 internalize certain routine activities and these no longer place an undue cognitive load on his/her thinking and activities should he/she be given tasks requiring creativity, such as open problem-solving tasks (c.p. Problem Based Learning PBL; Albanesi & Mitchell 1993; Norman 1998). For this reason the teaching described has been designed to include orientation as Galperin describes it. 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). Moreover, some quite unexpected results were found, which related to the commercial simulation program usability characteristics and the most unexpected were problems related to the English language used in the program for the Finnish university student users.

What has also been seen in preliminary research findings is the need for a general understanding for the whole

process "*the general orientation base*" in Podolskij's (1997) words. Here, the student group should possibly be directed to developing an electronic solution in the early phase of the pedagogical model in some manner. 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. Through that kind of "g*uided mini design process*" the student group would very likely reach the general understanding of the whole process which helps them in two ways; to internalize 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 (c.p. Gokhale 1996; Gonzales, Reitman, & Stagno 2001b).

6. Conclusions and Future Research

The pedagogical model "*Network oriented study with simulations*" and the WOA seem to work in many ways as envisioned from the theoretical viewpoints. Further study and analysis is producing a great deal of knowledge in this area, where teaching, studying and learning resources in use are analyzed through different means. Evaluation of the preliminary conclusions, the future development of the WOA will be targeted at least to developing a more interactive and adaptive user interface and using a variety of media types (gif/flash animation, streaming movie clips, sound e.g. as a parallel information channel and as a part of a supplementary edutainment-oriented solution. One interesting phenomenon is that the pedagogical model "*Learning through simulations*" (Joyce et al. 1997) used in another MOMENTS case study, Educational Use of ICT in Higher Education, has yielded parallel evidence substantiating the results of Network-Based Mental Tools in Technology Education.

REFERENCES

1. ALBANESI, M.A., MITCHELL, S. **Problem-based Learning: A Review of Literature on Its Outcomes and Implementation Issues**, Academic Medicine, Volume 68, No 1, 1993, pp. 52-81.

2. Ausubel, D., **Educational psychology: A cognitive view**, New York: Holt, Rinehart & Winston, 1968.

3. BRUNER, J., **The Culture of Education**, Cambridge: Harvard University Press, 1996.

4. BRUNER, J., **Vygotsky: A Historical and Conceptual Perspective**, In: J. Wertsch. Culture, Communication, and Cognition, Cambridge, Cambridge University Press, 1985.

5. BRANSFORD, J., BROWN, A.L., COCKING, R.R. (Eds.), **How people learn**, Washington D.C.: National Academy Press, 2000.

6. CARR, W., KEMMIS, S., **Becoming Critical. Education, Knowledge and Action Research**. Philadelphia: Falmer Press, 1989.

7. CHANDLER, P., SWELLER, J., **Cognitive Load Theory and the Format of Instruction**, Cognition and Instruction, 8*,* 1991, Hillsdale, New Jersey, pp. 293–332.

8. CHEN, T., **Design Considerations for Computer-based Simulations in Education**, In Proceedings of the ED-Media 2001 Conference Tampere, Finland, June 25–30, 2002, pp. 293-294.

9. COOPER, G., **Research into Cognitive Load Theory and Instructional Design at UNSW**, University of New South Wales, Australia. Retrieved 22nd August 2003, from http://www.gmp.usyd.edu.au/vguide/students/samplew/mscp/learningtopics/Kk9HHkf.html, 1998.

10. CRAWFORD, C., **The Art of Computer Game Design**, Berkley: USA, McGraw-Hill, 1984.

11. DUGGER, W.E., JR., NAIK, N., **Clarifying Misconceptions between Technology Education and Educational Technology**, The Technology Teacher, Sept. 2001, pp. 31–35.

12. FARNILL, D., **Communication in a Medical Emergency**, Dept of Behavioural Sciences, University of Sydney, Retrieved 12th February 2003, from http://www.gmp.usyd.edu.au/vguide/students/samplew/mscp/learningtopics/Kk9HHkf.html, 2001.

13. GALPERIN, P.I., **Organization of Mind Activity and Effectiveness of Learning**, Soviet Psychology, 27(3), 1989, pp. 65-82.

14. GALPERIN, P.I., **The Problem of Activity in Soviet Psychology**, Journal of Russian and East European Psychology, 30(4), 1992, pp. 37–59.

15. GOKHALE, A., **Effectiveness of Computer Simulation for Enhancing Higher Order Thinking**, Journal of Industrial Teacher Education, 33(4), Retrieved 22nd June 2004, from http://scholar.lib.vt.edu/ejournals/JITE/v33n4/jite-v33n4.gokhale.html, 1996.

16. GONZALES, J.J., REITMAN, L., STAGNO, T., **An Interactive System for Teaching Electronics**, Seminar paper, ED-Media 2001 Conference Tampere, Finland, June 25–30, 2001a.

17. GONZALES, J.J., REITMAN, L. STAGNO, T. **An Interactive System for Teaching Electronics**, In Proceedings of the ED-Media 2001 Conference Tampere, Finland, June 25–30, 2001b, pp. 608-612.

18. HANNAFIN, M., **Disciplined Inquiry and the Study of Emerging Technology: The Emergence of Design Based Research**, Paper presented at the eoppimaisteri: eKesä 3, University of Joensuu Savonlinna College, 2004, 6.8.2004.

19. ILLERIS, K., **The Three Dimensions of Learning. Contemporary Learning Theory in the Tension Field between the Cognitive, the Emotional and the Social,** Roskilde: National Institute of Adult Continuing Education (Roskilde University Press), 2002.

20. ITEA, **Standards for Technological Literacy: Content for the Study of Technology**, Reston (VA): International Technology Education Association, 2000.

21. KANGAS, S., **Mukautuvat käyttöliittymät elektronisissa peleissä**, In: Pelit, tietokone ja ihminen. [Games, Computers and People]. (Ed.) T. Honkela. Suomen tekoälyseuran julkaisuja. Symposiosarja No 15. University of Art and Design UIAH & Finnish Association of Artificial Intelligence, Helsinki., 1999, pp.128-134.

22. KAPTELININ, V., NARDI, B.A., Activity Theory: Basic Concepts and Applications. Retrieved 22nd February 2004, from http://www.acm.org/sigchi/chi97/proceedings/tutorial/bn.htm, 1997.

23. KIMBELL, R., **Design and Technological Activity. A Framework for Assessment**, Department of Education and Science. Assessment of Performance Unit. London. Her Majesty's Stationary Office, 1987.

24. KIMBELL, R., **Assessing Technology. International Trends in Curriculum and Assessment**. London Open University Press, 1997.

25. KIMBELL, R. (2000a). **Design for Learning. Article and Seminar paper based on article**. Kajaani Kytke 2005 –seminar 28.4.2000.

26. KIMBELL. R. (2000b). **Assessing Technology. Technology Education – from a problem to a solution**. Seminar presentation. Kajaani Kytke 2005 –seminar 28.4.2000.

27. KOOPAL, W. (1993/1997). Instructional design for computer simulations. Supervision: R. Min & J. Moonen. Retrieved 22nd June 2004, from http://www.gmp.usyd.edu.au/vguide/students/samplew/mscp/learningtopics/Kk9HHkf.html

28. JONASSEN, D., **Computers as Mind tools for Schools. Engaging Critical Thinking**, 2nd ed. New Jersey. Prentice Hall, 2000.

29. JONASSEN, D., ROHRER-MURPHY, L., **Activity Theory as a Framework for Designing Constructivist Learning Environments**. Educational Technology: Research and Development ETR&D 47(1), 1999, pp. 61–79.

30. JOYCE, B., CALHOUN, E., HOPKINS, D., **Models of learning – tools for teaching**, London: Open University Press, 1997.

31. LAPORTE, J., **Technology Education in the United States. A critical Analysis of the Change Process**. Paper presented at the "Technology Education in Practise" –seminar, 2000, 2-5. May, Oulu, Finland.

32. LEFRERE, P., **Becoming Skilled Faster: Why We Need This? - What We Can Do Today?** - Research Issues [keynote]. Paper presented at the Lapland Information Society Seminar Researcher Workshop 2004, 16.-17 September, Rovaniemi.

33. LEHTONEN, M. (2002a). **Toward the Information Age Challenges in Technology Education. Modern learning methods & learning media supported and mediated learning processes as part of the new university technology education curriculum**, In: Looking at the Future: Technical Work in Context of Technology Education, Kantola, J. & Kananoja, T. (Eds.) University of Jyväskylä. Dept. of Teacher Education. Research 76. Jyväskylä. Jyväskylä University Printing House, pp. 99–119.

34. LEHTONEN, M. (2002b). **Online Interactive Curriculum Representation as One Key to Well Structured Students Learning Activity**, In Proceedings of the ED-Media 2002 Conference, 2002 Denver, Colorado USA, June 24–29, pp. 1110-1115.

35. LEHTONEN, M. (2003). **Pedagogical Web Orientation Agent in Orientation and Guiding Studies of the Local Electricity Simulations**, In: Proceedings of 11th International PEG Conference, Powerful ICT Tools for Learning and Teaching. St. Petersburg, Russia.

36. LEHTONEN, M. (to appear**). Simulations as Mental Tools for Network-Based Group Learning**, In B. Thompson & P. Nicholson (Eds.), E-Training Practices for Professional

Organizations. IFIP Open Working Conference, 7-11 July, 2003 in Pori, Finland. New York, Boston, London: Kluwer Academic Publishers.

37. LEHTONEN, M., RUOKAMO, H., TELLA, S., **Towards a Multidisciplinary Metamodel for Network-Based Mobile Education: The MOMENTS Metamodel**. In: Proceedings of the ED-MEDIA 2004 Conference Lugano, Switzerland, June 21-26 2004, pp. 2020–2025.

38. MERRILL, C., **Action Research and Technology Education**, The Technology Teacher, 63(8), 20046-8.

39. MIETTINEN, R., **Varieties of Constructivism in Education. Where do we stand?** Lifelong Learning in Europe. 1/2002, pp. 41–48.

40. MIN, R., **Shortcomings of the Monitor. The Problem of Linear Presentation Media in Learning Situations; the Importance of Parallelism in Open Learning and Working Environments**. Retrieved 22nd June 2004, from http://projects.edte.utwente.nl/pi/Papers/Monitor.htm

41. NARDI, B.A., **Context and Consciousness. Activity Theory and Human-Computer Interaction**, 2nd pr. Cambridge, MA, 1997, MIT Press.

42. NORMAN, G.R., **Problem-Solving Skills, Solving Problems and Problem-Based Learning**, Medical Education, 22, 1998, pp. 279-286.

43. NYKÄNEN, O., ALA-RANTALA, M., **A Design for a Hypermedia-Based Learning Environment**, Education and Information Technologies 3, 1998, pp. 277-290.

44. PODOLSKIJ, A**., Instructional Design for Schooling. Developmental Issues**, In: S. Dijkstra et al. (eds.) Instructional Design. International perspectives, Vol. 2. Mahwah, NJ, Lawrence Erlbaum, 1997.

45. PRENSKY, M., **Digital Game-Based Learning**, USA: McGraw-Hill, 2001.

46. RASINEN, A., **Developing Technology Education. In Search of Curriculum Elements For Finnish General Education Schools**, Jyväskylän yliopisto. Jyväskylä studies in education, psychology and social research 171, 2001.

47. RUOKAMO-SAARI, H., **Mathematical Giftedness and Development of Mathematical Word Problem-Solving Skills in A Technology-Based Learning Environment: A Teaching Experiment**, In T. Muldner, T.C. Reeves (Eds.) ED-MEDIA/EDTELECOM 97. World Conference on Educational Multimedia/Hypermedia, World Conference on Educational Telecommunications. Volume II. Proceedings, University of Calgary; CANADA; June 14–19, 1997, pp. 923–927.

48. RUOKAMO, H., TUOVINEN, H., TELLA, S., VAHTIVUORI, S., TISSARI, V., **Pedagogical Models in the Design and Assessment of Network -Based Education**, In Proceedings of the ED-Media 2002 Conference, Denver, Colorado USA, June 24–29, 2002, pp. 1676 -1681.

49. SWELLER, J., CHANDLER, P., Why Some Material is Difficult to Learn, Cognition and Instruction, 12, 1994, pp. 185-233.

50. TALYZINA, N., The Psychology of Learning. Progress Publishers, Moscow, 1981.

51. TELLA, S., MONONEN-AALTONEN, M., **Developing Dialogic Communication Culture in Media Education: Integrating Dialogism and Technology**, University of Helsinki, Department of Teacher Education, Media Education Centre, Media Education Publications 7, 1998, ERIC ED426620. [Also available online, see http://www.helsinki.fi/~tella/mep7.html]

52. ULJENS, M., **School Didactics and Learning**, Hove, East Sussex: Psychology Press, 1997.

53. WERTSCH, J.V., **Vygotsky and the Social Formation of Mind**, Cambridge, MA: Harvard University Press, 1985.

54. WILSON, B., COLE, P., **Improving Traditional Instruction. Cognitive Load Theory**. Retrieved 22nd June 2004, from http://carbon.cudenver.edu/~bwilson/cog/sweller.html, 1996.

55. DEVEDZIC, V., HARRER, A., **Architectural Patterns in Pedagogical Agents**. In: S.A. Cerri, G. Gouardères, and F. Paraguaçu (Eds*.): ITS 2002, LNCS 2363, Berlin*: Springer-Verlag, 2002, pp. 81–90.

56. VYGOTSKY, L.S., **Mind in Society**, Cambridge, Massachusetts: Harvard University Press, 1978.