EDUCATION ABOUT AND THROUGH TECHNOLOGY

In search of more appropriate pedagogical approaches to technology education

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Abstract

This research thesis aimed to deepen understanding about the nature of technology and its possible correspondence to the constructivist notion of learning. Since technology education is a relatively new subject area in general education and still in an emerging phase in various countries, it provided some interesting opportunities to take into account the latest developments in educational psychology in relation to the development of teaching technology. Moreover, this thesis aimed at finding ways for technology education to provide possibilities to learning environments where the nature of technology could be integrated effectively into the current notion of children as active agents in their learning processes.

The thesis was based on two Case Studies. Both of the Case Studies were carried out on the primary school level. The overall purpose of Case Study I was to consider automation technology and its teaching as a subject-matter area in developing technology education in Finland. In Case Study II the purpose was to explore the influences of socio-cultural interaction on children's thinking and actions in prescribed and open problem-solving situations while they were technologically creating a particular product which used sound for a chosen purpose. Case Study II also involved English schoolchildren.

Teaching methods throughout the thesis were based on the assumption that constructivist-driven, open, and creative problem solving, as well as children-centered approaches, are especially suitable for technology education. This assumption arises from the notions that innovation and problem solving are important in technological processes and that technology has usually emerged as a response to human needs and wants. Consequently, design briefs were developed to provide open, children-centered problem solving based on the acute needs found in the children's own living environment.

In both of the Case Studies multiple data collection procedures were applied. In Case Study I data were collected by means of group observations documented in videotaped recordings, written field notes and project files saved by the students. Moreover, In Case Study II data were collected in terms of photographs of the pupils' final outcomes, including pupils' design folders and product evaluations, the teacher's teaching notes, teacher's lesson evaluation notes, the researcher's field notes based on observations and a questionnaire.

The methodological perspective in both of the Case Studies was qualitative in nature and grounded on inductive and interpretative data-based analysis. The analysis employed an open search for categories, concepts and patterns emerging from the data. The inductive interpretative analysis process enabled the results to be framed as empirical assertions. In addition to the assertions the results of Case Study I detailed content classifications of the substance in the focus were included as well. The assertions and the classifications were supported by evidentiary examples taken from the data. The supporting examples were interpreted from the viewpoint of the research problems.

The results of the thesis suggested that in technology education it is important for children to be able to work and learn in a way that fosters open problem solving with innovation and divergent thinking. In technology education the design briefs and task allocations should be open enough to allow the children to explore their own living environment in order to find problems that need to be solved. Actually, in technology education, according to the nature of technology, there should not be right answers to the posed questions, but rather appropriate solutions to emerging problems. Moreover, teaching methods adjusted according to the nature of technology ensure naturally that the children are treated as active, intentional and goal-directed humans whose activities are driven by human volition.

Keywords: learning environment, technology education, innovation, problem solving, constructivism

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Tiivistelmä

Tämä tutkimus pyrki syventämään ymmärtämystä teknologian luonteesta ja sen mahdollisesta vastaavuudesta konstruktivistiseen oppimiskäsitykseen. Teknologiakasvatus on suhteellisen uusi ala yleissivistävässä koulutuksessa ja se on edelleen sukeutuvassa vaiheessa useissa maissa. Tällainen tilanne antoi mielenkiintoisia mahdollisuuksia ottaa huomioon viimeisimpiä oppimispsykologisia virtauksia suhteessa teknologian opetuksen kehittämiseen. Lisäksi tutkimus pyrki etsimään teknologiakasvatukselle mahdollisuuksia sellaisten oppimisympäristöjen luomiseen, joissa teknologian luonne voitaisiin tehokkaasti integroida nykyiseen käsitykseen lapsista oppimisprosessiensa aktiivisina tekijöinä.

Tämä tutkimus perustui kahteen tapaustutkimukseen (Case Studies). Kummatkin tapaukset toteutettiin peruskoulun ala-asteella. Ensimmäiseen tapauksen (Case Study I) yleisenä tarkoituksena oli tarkastella automaatioteknologiaa ja sen opetusta sisältöalueena osana teknologiakasvatuksen kehittämispyrkimyksiä. Toisessa tapauksessa (Case Study II) tarkoituksena oli tutkia sosio-kulttuurillisen vuorovaikutuksen vaikutusta lasten ajatteluun ja toimintaan avoimissa ja suljetuissa ongelmanratkaisutilanteissa. Tässä tapauksessa lapset tekivät valittavaan tarkoitukseen ääntä tuottavia laitteita ja siihen osallistui myös englantilaisia koululaisia.

Tutkimuksessa käytetyt opetusmetodit perustuivat oletukseen, että konstruktivismiin pohjautuvat, avointa ja luovaa ongelmanratkaisua sekä oppilaskeskeisyyttä korostavat lähestymistavat ovat erityisen soveliaita teknologiakasvatuksessa käytettäviksi. Tämä oletus nousee käsityksestä, jossa innovatiivisuus ja ongelmanratkaisu ovat tärkeitä teknologisille prosesseille ja että teknologia esiintyy vastauksena ihmisen tarpeisiin. Oppilaille annetut tehtävät määriteltiinkin sellaisiksi, että ne mahdollistivat avoimen, oppilaskeskeisen ongelmanratkaisun perustuen lasten omasta elinpiiristään esiin nousevien tarpeiden tyydyttämiseen.

Molemmissa tapauksissa tutkimusaineistoa kerättiin usealla eri tavalla. Ensimmäisessä tapauksessa tutkimusaineistoa kerättiin oppilasryhmiä havainnoimalla mm. videonauhoituksin ja kenttäpäiväkirjaa kirjoittamalla sekä tallentamalla levykkeelle ryhmien projektissa luomat tiedostot. Tämän lisäksi toisessa tapauksessa tutkimusaineistoa kerättiin valokuvaamalla oppilaiden suunnittelukansiot tuotteen itse arviointeineen ja heidän valmistamansa työt. Tässä tapauksessa tallennettiin myös opettajan opetuksestaan tekemiä havaintoja ja arviointeja, tutkimuspäiväkirjaan tehdyt observointimuistiinpanot sekä oppilaille järjestetyn kyselyn tulokset.

Molemmat tapaukset olivat metodologisesti laadullisia tutkimuksia ja perustuivat induktiiviseen ja tulkitsevaan aineistopohjaiseen analyysiin. Analyysissä kiinnitettiin huomiota nimenomaan tutkimusaineistosta esiin nouseviin käsitteisiin, lainalaisuuksiin ja säännönmukaisuuksiin. Tutkimuksen metodologinen valinta mahdollisti tulosten esittämisen empiirisinä väittäminä, joita tuettiin tutkimusaineistosta otetuilla esimerkeillä. Empiiristen väittämien lisäksi ensimmäisen tapauksen tulokset sisältävät tutkimusaineistosta esiin nousseita luokituksia analyysin kohteena olevista painotuksista. Sekä empiirisiä väittämiä, että luokituksia tuettiin tutkimusaineistosta otetuilla esimerkeillä. Esimerkit myös tulkittiin tutkimusongelmien näkökulmasta katsottuna.

Tutkimuksen tuloksista voidaan päätellä, että teknologiakasvatuksessa on tärkeää antaa lapsille mahdollisuuksia työskennellä ja oppia tavalla, joka kehittää innovatiivista avointa ongelmanratkaisua ja divergenttiä ajattelua. Tässä mielessä annetut tehtävät tulisi olla niin avoimia, että lapsien olisi mahdollista löytää omasta elinpiiristään ratkaisua vaativia ongelmia. Itse asiassa teknologiakasvatuksessa, teknologian perusolemuksen mukaisesti, ei tulisi ollakaan vastauksia esitettyihin kysymyksiin, vaan tarkoituksemukaisia ratkaisuja esiintyviin ongelmiin. Lisäksi teknologian perusluonteen mukaiset opetusmenetelmät huomioivat lapsen sisäisesti toimintaan halukkaaksi motivoituneena ja aktiivisena sekä tarkoitus-ja päämäärähakuisena ihmisenä.

Asiasanat: oppimisympäristö, innovaatio, ongelmanratkaisu, konstruktivismi, teknologiakasvatus

Preface and acknowledgements

The research process on which this thesis is based dates back to spring 1995. I was working as a class teacher in the Haapavesi Central Primary School. During that time I became interested to include aspects of automation technology as part of the general school syllabus. Some of my colleagues wanted to participate. Consequently, we set up a teaching “project“ which was included in the normal school routine through a multidisciplinary approach. However, at the start I was not familiar with the concept of “technology education“ and its development. Teaching automation just seemed to be a relevant thing to try with the children. Shortly thereafter, I had the opportunity to become a researcher at the Department of Educational Sciences and Teacher Education in the University of Oulu.

During the course of these hectic research years, I have been immersed in an action research process where my thinking about the nature of technology itself has developed. I have found how in many different ways both technology and technology education can be understood and defined. Also, the more my understanding about the nature of technology deepened, the less I was convinced that instructionally prescriptive teaching methods are suitable for technology education. Moreover, during the research process, I became aware that the Finnish compulsory general education system does not take into a proper account the meaning and importance of the environment made by ourselves. Because of this, something very essential about our culture and ourselves seems to be seriously undervalued in our schools. To my mind, technology is a much too important and essential part of everyday life to be overlooked in general education.

The research years have offered me much more than I initially expected. I have been very privileged to participate in the pioneering work of developing general technology education in Finland. At the moment we still do not have a subject explicitly called “technology” in the general education curriculum, and the future remains unclear in this respect. However, due to the interest of many teachers and developers in this field, an ever increasing number of Finnish kindergarten and school children are taking part in technology education which could be proudly presented anywhere in the world.

Every year has offered me challenges and opportunities that I have never encountered in my life before. During the research process I had the opportunity to work as a visiting researcher in the University of Exeter, School of Education, England. The time in Exeter was truly memorable to our family.

Numerous people have contributed substantially to the research on which this thesis is based. I am deeply indebted to them for their support during these years. I want to thank my supervisor Professor Leena Syrjälä, as well as my advisors Professor Emeritus Olavi Karjalainen and Professor Jorma Kangas. Olavi Karjalainen has also taken part in writing of one of the Studies presented herein. I appreciate his contribution to this work. I wish to thank the external examiners of this dissertation Associate Professor Marc de Vries and Professor Erno Lehtinen for their constructive commentary. Moreover, Marc deVries has offered encouragement for my work in various situations. I am grateful to Associate Professor and Editor-in-Chief James LaPorte and to Professor Erno Lehtinen for agreeing to serve as the opponents in the public examination of my thesis.

The following persons have also shared their expertise with me in many different ways: I am grateful to my colleague Lecturer Matti Lindh who has been a bottomless source of ideas and expertise. Also, a big thank you goes to the late Lecturer Mikko Huhanantti, who supported me substantially during the first research years. Lecturer Jukka Hiltunen has helped me in analyzing the data from the viewpoint of automation technology. Our collaboration in this field is evident in the published articles and conference papers. I thank him for his contribution and hope our work has been bilaterally beneficial. I wish to express my thanks to Professor Juha Perttula who has given me plenty of useful advice concerning the qualitative research methods. I'm also grateful to Dr. Tapani Kananoja for sharing his vast knowledge about the history of the development of technology education, as well as to Dr. Matti Parikka for his valuable advices at the beginning of the research process.

I wish to express my gratitude to Lecturer John Twyford from the University of Exeter, England. Our research collaboration has come to fruition for example in terms of conference papers and published articles in refereed journals. Also, I would also like to thank Director of The School of Education Professor Robert Burden for his substantial support during the time I was in Exeter.

The main part of the language in the thesis has been checked by John Twyford. Vesa Komulainen has helped me with the final editing of the language. Helena Saari made up the text to the format of the Acta Universitatis Ouluensis series. I want to express my thanks to them.

The Case Studies on which this thesis is based would not have been possible without the consent of the Haapavesi Department of Education and Cultural Services. Consequently, I thank Ahti Karvonen, Director of the Department, and Principal Emeritus Matti Hyvärinen. They are among the people who, with their positive attitudes, created the circumstances that enabled Case Study I to be carried out in the Central Primary School. Moreover, I wish to express my special gratitude to Risto Klasila, Head Teacher of Vattukylä Primary School. Case Study II would not have been possible without his outstanding help and support.

I also want to thank all the other teachers and children who participated in both of the Case Studies. Actually, there are so many people who have positively contributed to this work that it is not possible to mention them all by name. Anonymous though they may be, I am grateful for their support and efforts.

Financially, most of this work was made possible by funding from the Finnish Graduate School in Mathematics, Physics and Chemistry Education. Also, many of the international contacts during the work were supported financially by the University of Oulu. The learning environments used to teach automation in Case Study I were acquired by the financial support of the electrical power supply company, Fortum Ltd. All the financial support is gratefully acknowledged.

I wish to thank also my parents Maija-Liisa and Heikki Järvinen. They have encouraged me substantially in my work. Unconventional but inspiring perspectives on education have been a hallmark of my father's thinking.

And the last, but not the least expression of heartfelt gratitude goes to my beloved wife Kaisu and children Topias, Rosaliina, Saraleena, Aurora, Lydia and Tiitus. Without their patience this thesis would not have been accomplished. Too many times during these research years I have been preoccupied with my work and absentminded with my thoughts. You all have given me a touch of real life during the research process, and kept my feet on the ground. Kaisu, also a teacher, has shared her interest in technology education in practice and substantially supported and encouraged me during the difficult times of the work. In this regard, the words fall short in trying to explain how grateful I am.

Haapavesi, September 21, 2001

Esa-Matti Järvinen

List of original articles

This thesis is based on the following articles which are referred to in the text as Study 1, Study 2, Study 3 and Study 4:

Study 1.	Järvinen E-M (1998) The Lego/logo Learning Environment in Technology Education: An Experiment in a Finnish Context. Journal of Technology Education 9 (2): 47-59.
Study 2.	Järvinen E-M & Hilunen J (2000) Automation Technology in Elementary Technology Education. Journal of Indurstrial Teacher Education 37(4): 51-76.
Study 3.	Järvinen E-M & Karjalainen O. Meaningful Mathematics through Technology Education. School Science and Mathematics. (Submitted.)
Study 4.	Järvinen E-M & Twyford J (2000) The Influences of Socio-cultural Interaction Upon Children's Thinking and Actions in Prescribed and Open-ended Problem Solving Situations (An Investigation Involving Design and Technology Lessons in English and Finnish Primary Schools). International Journal of Technology and Design Education 10(1): 21-41.

Contents

Original articles

1 Introduction

1.1 Background

Finland has a valuable and internationally revered history in education. It has been influenced by many contributors and developers. One of the most notable forerunners of his time was Uno Cygnaeus who developed the idea of educative handicraft. The legacy of Cygnaeus seems to be still widely apparent in Finland. Numerous Finns have basic skills to use various tools in order to build, say, summer cottages and even their own houses.

Nowadays Finnish general education still has handicraft education [“käsityö“] as a school subject. In practice, it is divided into two separate subjects: textile work [“tekstiilityö“] and technical work [“tekninen työ“]. They are taught as compulsory subjects from the third grade of primary education. Then, due to the possibility of choosing either “tekninen työ“ or “tekstiilityö“, the first is mostly taken by boys and the latter is widely regarded to be the girls’ domain.

At primary level woodworking is the most common technological area in “tekninen työ“ (Alamäki 1999). However, at secondary level more machines and tools are used in order to produce artifacts and workpieces. Metal, wood and plastics are still the most popular materials, even though electronics and computers have also been introduced recently. (Kananoja 1994b). Similarly, machines, tools and, increasingly, computers are used in “tekstiilityö“ and the outcomes are artifacts and workpieces. Nevertheless, the materials differ from those used in “tekninen työ“. ”Tekstiilityö”, true to its name, uses textiles as the main materials. In this regard, the subject “tekninen työ” undeniably covers a wider spectrum of the materials used in the technological world. Moreover, the contents taught and activities carried out in “tekninen työ” correspond to the idea of technology education in many countries (Alamäki 1999).

However, from the viewpoint of this thesis, translating “tekninen työ“ as technology education (see http://alasin.rokl.utu.fi/) is problematic and cannot be regarded as fully justified. Actually, technology can be regarded a much wider concept consisting of the entire human-made environment. Thus, “tekninen työ“, with all the possible developments in its methods and contents, still represents only a fraction of the technological reality around us. Moreover, the framework of the subject is still in handicraft education focusing more on the learning of specific manual skills within the range of various techniques (sawing, nailing, welding, cutting, etc.).

In fact, from the viewpoint of the present general education curriculum in Finland, no single school subject alone can claim to represent technology in a comprehensive way. De Vries (2000, p. 3) writes that "In Finland, as in a number of other countries, there is a danger that either Technology Education will be equated with crafts or technical work, or that it will be equated with (applied) science. Both are misconceptions and need to be corrected."

From the viewpoint of general technology education, the problem in the Finnish curriculum lies both in contents and methods. The Compulsory education curriculum does not take fully into account the meaning and importance of the environment which we have developed on the basis of our own needs. Children in schools are not systematically made aware of technology around us.

Due to the latest developments related to a Finnish core curriculum, guidelines are rather loose, providing only a brief framework. Because of this, schools can be freer and more flexible in how they orientate their contents, practices and aims. Consequently, there are good opportunities to develop and carry out technology education across the curriculum, especially through a multidisciplinary approach. As a matter of fact, all technology education activities in the studies on which this thesis is based were carried out through technology oriented teaching across several school subjects. In spite of the multidisciplinary nature of the approach, the main focus in all the studies was to teach technology, not for example, simply applied science or handicraft.

Although a general technology education curriculum has been already introduced, for example, in the United Kingdom, Australia and the Netherlands, it is a relatively new concept in the field of general education. It is still in a constant phase of development through revisions and amendments. This is partly due to the rapid pace of development of the subject matter itself.

Environmental education has a widely agreeable position in the Finnish compulsory education curriculum. It is seen as important to know about the surrounding natural environment and the relationship of man and nature in terms of appreciation and caring. Interestingly, in recent environmental and science education teaching materials, there are some references to technology. For example, the principle of the combustion engine is in focus (Aho *et al*. 1995). However, this can be regarded only as a marginal and not satisfactory solution to the present situation. Considering the meaning of the environment that we have made by and for ourselves, it is rather surprising how little attention it attracts in curriculum development. In spite of technology's immense influence on society and individuals, it has not been considered important enough, in its own right, to be taken as an essential subject matter in the Finnish general compulsory education curriculum. Although computer skills and browsing the Internet are widely agreed to be important and relevant in a general education, they only represent a narrow 'using technology'-approach.

The aforementioned problems are illustrated also by the Encyclopaedia Britannica online (1999):

> The recognition of the importance of technological education, however, has never been complete in Western civilization, and the continued coexistence of other traditions has caused problems of assimilation and adjustment. Arthur Koestler put the same point in another way by observing that the traditionally humanities-educated Western man is reluctant to admit that a work of art is beyond his comprehension, but will cheerfully confess that he does not understand how his radio or heating system works. Koestler characterized such a modern man, isolated from a technological environment that he possesses without understanding, as an "urban barbarian." Yet the growing prevalence of "black-box" technology, in which only the rarefied expert is able to understand the enormously complex operations that go on inside the electronic equipment, makes it more and more difficult to avoid becoming such a "barbarian." (http://members.eb.com/cgi-bin/g?DocF=macro/5006/17/75.html&bold=on&sw=education&sw=technology&keywords=technology%20education&DBase=Articles&hits=10&pt=1&sort=relevance&config=config&firsthit=off)

Whether we want it or not, a technological reality surrounds both 'barbarians' and technologically literate citizens. Transportation, communication, construction and health care are just a few examples of the technologies encountered in our everyday life. We carry out most of our daily routines by using various technological products and appliances. (Hacker & Barden 1988)

Technology has changed considerably the world in which we live. In fact, it might be difficult to live without the benefits of technology. Also, the development of technology has substantially changed our habits and routines. Most of us are in a constant “adaptation“ process: a very short time ago we queued in bank halls with a handfuls of bills, now we are paying bills at home through the Internet. Due to the development of WAP (Wireless Application Protocol) technology, in the future we will increasingly do our banking through mobile phones totally regardless of time and place. What comes next? This gives us food for thought; do we really need and want all this? Nevertheless, technology has been considered to be a response to the human needs and wants (Kimbell *et al.* 1996). In short: “necessity is the mother of invention“, but who decides what is necessary?

The development of technology has been quite often dependent on mathematics and science and vice versa. The relationship between technology and mathematics and science has actually strengthened during the past two centuries. For example, the precursory work of Isaac Newton contributed to the Industrial Revolution. Also, it was the findings of sub-atomic particles that gave birth to nuclear power and electronics. Moreover, the origins of modern digital processing are in the binary system developed by mathematicians. All these are still relevant and useful 'ingredients' for further technological development even at the beginning of a new millennium. (Teerikorpi & Valtonen 1994, Spielberg & Anderson 1995)

Skills and knowledge in technology have been transferred through generations in the course of history. The first occurrences in teaching and learning technology could have been very occasional and strongly contextualized activities. For example, 'Stone Age man' could have taken his children on a hunting trip and shown them how to make effective weapons. During the course of time more organized ways to teach technology were developed. The apprenticeship system within the Medieval Guilds was already rather well organized. However, more widespread teaching of technology began with the advent of the Industrial Revolution. Emphases in teaching methods and contents have varied considerably and are connected to their historical contexts. The purpose of teaching has been more or less according to the requirements posed by the surrounding environment, i.e. by society, the industrial life and so forth. However, the notion about general technology education for all has emerged quite recently (Layton 1994, Banks 1994). It is this development that this study aims to contribute to and to support.

1.2 Driving themes for the research

The following issues are presented as the general driving themes for the whole research process. The themes are not yet aims or tasks. Rather, they illustrate the framework in which the research process was carried out. Thus, the themes intend to give the reader an overall grasp about the issues that were influential during the research process.

1.2.1 Education about and through technology

It has been widely agreed that technology teaching should aim to increase knowledge *about* the technological world created by ourselves. The international Technology Education Association (2000, p. 4) writes: “Students who study technology learn about the technological world that inventors, engineers and other innovators have created”. Lindh (1997, p. 133) emphasizes the importance of children’s understanding about the logic and functional mechanisms of 'everyday' technology, and also, the ability to solve technological problems by applying the technological knowledge and skills they have acquired. In short, technology education should reveal the technological world as it is. The fewer “black-box” technologies there are around us, the more familiar and confident we will be with our constructed environment.

It is also important in technology education to make children do technology. According to the International Technology Education Association (2000, p. 5), ”One of the great benefits of learning about technology is also learning to do technology, that is, to carry out in the laboratory-classroom many of the processes that underlie the development of technology in the real world.” Consequently, children should be able to follow, as much as possible, problem solving and thinking typical for technological processes. In short, children should be driven *through* the processes characteristic to technology.

However, it has to be emphasized that just using technology and introducing the latest equipment to the classroom does not meet the idea of educating children about, nor through technology. Neither does limitation to some specific materials and techniques while excluding other essential parts of the technological reality around us. Children should be given opportunities, regardless of the materials used, to act technologically.

They should be supported to use their thinking skills in designing and making things. They should also be given opportunities to participate in innovative problem solving processes in a way that can be considered technological (Harrison 1994).

Moreover, children should be given possibilities to find their “own“ problems to solve and thus experience personally how technology really responds to human needs and wants. This requirement does not seem to be very commonly applied in teaching technology, not even in countries where technology education has quite an agreeable and stable status in the curriculum.

1.2.2 Relevance of curriculum

One influential theme driving the research process was an apprehension about the present curriculum contents tending not to be relevant to the technological world in which we live. Especially in the case of handicraft education there seems to be a risk that a gap is being ruptured between the surrounding reality and teaching in schools. (Benjamin 1975, Stenhouse 1976) Actually, Finnish handicraft education has been a target for criticism (see Opetushalllitus 1994a) and there is a growing demand for more technological-oriented education. Both the methods and contents of traditional handicraft education are being criticized as being out of date.

The contents, and also the working methods in different subject areas need to be flexible enough for adjustments according to current demands and altering situations. There has been a special need for this during the past decade, for example, in the teaching of geography. From the viewpoint of technology education, it should be seriously evaluated whether it would be appropriate any more to carry out reproductive work based on the production of old implements and ornaments that can be found mostly in museums? For example, if children make a spinning wheel plate by meticulously copying the instructional model given by the teacher, the teaching does not relate to the technological world in which we live, nor does it truly relate to the nature of subject matter itself. Actually, children may not even learn the necessary manual skills to cope with the reality outside the schools. Problem solving, divergent production and innovation in action are only marginally present, or in the worst case, totally absent. The making of old artifacts could be very well made part of the teaching of the history of traditions.

In the modern era of enormous and accelerating technological development it is essential to ensure that the necessary technological knowledge and skills come, without forgetting the ethical and moral implications, to the possession of future generations to the largest possible extent. In other words, the school curriculum should be fully relevant also from the viewpoint of the surrounding technological reality, preferably even preceding the technological future.

1.2.3 Meaningful mathematics and science through technology

Mathematics and science have been important contributors to the development of technology. Increased knowledge and skills in those domains can contribute to the preparedness to understand and do modern technology. However, understanding and capability of doing technology are not solely dependent on mathematical and scientific knowledge and skills (Allen 1997). In technology, especially mathematics, but also science is seen from a very utilitarian point of view (Adams 1991). They could be seen as indispensable tools to do and accomplish technology. In this way they could achieve meaningfulness and significance. The potential for successful collaborative projects between technology education and teaching of mathematics and science is enormous and already available (for example Lindh 1996).

Currently, in Finland, there is widespread concern about children’s knowledge, skills and motivation in mathematics and science. The LUMA project has been initiated as a response to the problem and aims to enhance teaching and learning in those subjects (http://www.edu.fi/projektit/luma/). These concerns are important also from the viewpoint of modern technology, especially as its development depends to a great extent on skills and knowledge in science and mathematics.

1.2.4 Collaboration with engineering sciences

Technology cannot be regarded as an activity characteristic only of engineers or the industrial world, but rather as a typical human endeavor that focuses on the satisfaction of human needs and purposes (de Vries 1997). Actually, both engineering sciences and industry originates their existence from this broad perspective. However, especially when modern technologies are considered as a substance area in general technology education, it would be natural to collaborate with people who are professionally dealing with the subject. They have expertise and, according to my experiences, can substantially contribute to the efforts to develop teaching about and through technology.

1.2.5 Modern survival through technology

Throughout history technology has enabled humans to survive (Hacker & Barden 1988). This is very true even today. For example in Finland, the winter temperature can go down to minus 40 Celsius and it would be impossible to survive without appropriate, and sufficient, heating systems.

But, what Finland also faces is a "modern survival" through technology. This means the ability to compete globally is a matter of national survival. In order for Finland to prosper economically and compete with the rest of the world industrially, the workforce of the future must be able to collaborate as a team, to be familiar with the problem solving processes distinctive to technology, to have basic skills in key areas of modern technology and to have capabilities for innovative and divergent thinking and production. However, it should be pointed out that the issue of “modern survival“ should not be viewed only from the perspective of national interests, but rather from the viewpoint of international collaboration on behalf of global survival as well.

The need for school syllabus revision concerning the nature and value of modern technology has been recently acknowledged and voiced by many influential Finnish institutions, interest groups and businesses. These include the Committee for the Future/ The Parliament of Finland, the Confederation of Finnish Industry and Employers (TT), the Federation of Finnish Metal, Engineering and Electrotechnical Industries (MET) and the Finnish Academies of Technology (TTA).

In April 2000, TT sent a memorandum to the Ministry of Education emphasizing the importance of technology education nationally and proposed several activities that would promote it in general education. The research project carried out in Jyväskylä University/ Department of Teacher Education also deals with the expectations and demands related to teaching technology in schools (Parikka 1998, Rasinen 2000).

All this has to be taken into consideration also in the context of general education. An undeniable truth is that the general education school system did not ‘escape’ the effects of the deep economical recession which Finland went through at the beginning of the last decade of the 20th century. The impact was tangible in many ways; materials and resources were reduced and teachers felt overburdened and exhausted in many ways. Although the times have been better in recent years, and some very successful and internationally competitive industries have developed, we should not be too complacent. Rather, we should work hard to secure our future in the world (see Larson 1993, p. 29). Since the teachers are working with our future (children), they bear a great responsibility. The way that responsibility is understood and interpreted is going to have an effect on every one of us.

1.3 Overall purpose of the research

Much has been written about the need for general technology education. Consequently, this research does not aim to substantiate the need for it any more. Rather, the research explores the children doing technology in their school contexts by documenting the learning and problem solving processes that are actually taking place. This overall purpose has been taken partly as a response to the growing demand for research on the children’s learning processes while doing technology.

McCormick *et al.* (1994, p. 32) already maintained seven years ago that “there is surprisingly little empirical research on what pupils actually do while undertaking technology tasks.“ Concerns about the lack of empirical research in technology education are still echoed (de Vries 1999, Custer 1999). Moreover, in spite of the increasing impact of technology on society (see Mottier 1999), there is not enough evidence about the impact of technology education on children’s learning about technology. The current situation is described by de Vries (1999, p. 149) “Although in several countries by now we have had at least a decade to prove the reality of the impact that we claimed Technology Education would make, we do not (yet) have an empirical basis for that.“

The Finnish developmental efforts in technology education operate mainly within the framework of handicraft education, namely in the context of “tekninen työ” (Alamäki 1999, Kankare 1998). However, this research aims to reveal and explore also alternative ways to teach technology, especially through multidisciplinary approaches and, possibly, to explore further ideas through new perspectives.

The above-mentioned general purpose is specified in terms of research tasks (Chapter 1.3.1.) and research questions (Chapter 4.6.1.) hereafter.

1.3.1 Research tasks

The major task of this research is as follows:

How to develop more appropriate pedagogical approaches to technology education?

The above task is contributed to by the following aims:

1. The theoretical aim of this research is to deepen and widen understanding about the nature of technology and its possible correspondence with some of the latest developments in educational psychology.

The above aim arises from the expectation that the true nature of subject matter in the focus of teaching should be understood in order to adjust pedagogical approaches accordingly. This research investigates more appropriate approaches from the perspective of technology as a field of skills and knowledge. The aim is due to apprehension that some basic features in the nature of technology might not have influenced sufficiently the pedagogical approaches in technology education.

2. The empirical aim of this research is to explore in practice the appropriateness of the theoretical considerations.

This aim is carried out through series of activities arranged in the real life school contexts. In this regard, the possibilities to consider above mentioned issues from an empirical point of view are limited to the two Case Studies reported herein. However, together with the theoretical considerations the aims and their reflection throughout the research is intended to contribute to the development of technology education.

While pursuing the above mentioned issues, my interest focuses especially on the following questions:

How can education through technology be arranged in such a way that the activities which the children go through correspond to the nature and processes typical of technology?

How to arrange the learning activities in such a way that the children could feel a spontaneous volition to learn and do technology?

How and what are children learning about technology while they are doing it in the projects described in this research? In this regard learning of automation is in a special focus in Case Study I.

Another question is how could technology education provide a learning context for mathematics and science to appear in a meaningful way to children?

1.3.2 The structure of the thesis

The structure of this thesis is as follows: Chapter 1. “Introduction” describes the background, driving themes, as well as overall purpose and research task and aims for the thesis. Chapter 2. aims to theoretically explore both the nature of technology and current notion of the learner as an active agent of his/her learning processes. Settings and instructional contexts of both of the Case Studies are described in Chapter 3. Chapter 4. describes both the methodological perspective and the data collection, as well as the analysis methods used in the Case Studies. Chapter 5. reveals the results of both of the Case Studies. And finally, Chapter 6. discusses both of the Case Studies as well as the thesis as a whole process.

Empirically this thesis is based on two Case Studies. Case Study I is about teaching automation technology in Haapavesi Central Primary School. Case Study II is about rattles/noisemakers the children designed and made in Finland (Vattukylä Primary School in Haapavesi Township) and England (White Rock Primary School in Devon).

Case Study I yielded three articles, which are treated as Study 1, Study 2 and Study 3 hereafter. Case Study II is reported in the fourth article, which is hereafter called Study 4.

Study 1 can be regarded as a kind of introductory report about teaching automation technology in Haapavesi Central Primary school. It presents initial results of the children’s learning concerning automation, as well as emergence of mathematics and science.

Study 2 goes further in terms of a more detailed analysis concerning automation technology content that the children spontaneously dealt with. This study was done in collaboration with Senior Assistant/Lecturer Jukka Hiltunen from the University of Oulu, Faculty of Technology, Department of Process Engineering.

Study 3 investigates in a more detailed way the mathematical contents that the children spontaneously dealt with. It was written together with Professor Emeritus Olavi Karjalainen from the University of Oulu, Department of Educational Sciences and Teacher Education.

Study 4 was written in collaboration with Lecturer John Twyford from the University of Exeter, School of Education. Although the contents in the focus of this study differ from the first three studies, the overall purpose, on the Finnish side of the case was parallel: to implement open problem solving approach to technology lessons so that the children can work without given prescribed instruction and apply previous knowledge, skills and experiences within the course of the process. Study 4 also aims to prove that an effective learning environment including potential for creative and divergent problem solving can be arranged without sophisticated and expensive learning materials (compare to Studies 1, 2 and 3). Designing and making things by using craft working methods can still be one way to explore and do technology (Black & Harrison 1985), providing that the learning activities are arranged in an appropriate way from the perspective of the subject matter itself.

2 The theoretical stance on the research

Firstly, the nature of technology is explored through the literature review below (Chapter 2.1.). Due to the important role of science and mathematics in the development of modern technology, the relationship between these subject areas is also explored in terms of comparisons from various points of view (Chapter 2.1.1.). The aim of this reflective juxtaposition is to clarify how the nature of scientific inquiry differs from the nature of technological endeavor and what kind of conclusions can be drawn from those differences. The conceptual analysis of the nature of technology and its relations to mathematics and science are summarized in Chapter 2.2.

Secondly, recent developments in educational psychology are considered from the viewpoint of technology education.

Finally, Chapter 2.7. ends the theoretical stance on the research by summarizing both the findings concerning the substance in focus and the educational considerations.

In both of the summarizations I am distilling my own vision from the presented literature review and theoretical considerations.

2.1 The nature of technology

Etymologically, *technology* is formed out of two words that originate in the Greek language. These words are *techne* and *logos*. Techne refers to art and skill. Logos means word, speech, discourse and thought. (Webster's Encyclopedic Unabridged Dictionary of the English Language 1989, pp. 843, 1458). Thus, both skills and thinking are combined in technology.

Although technology has a very influential role in the modern world, in fact, it has been one of the most prevalent features of human endeavor since prehistoric eras. Actually, technology can be claimed to be the oldest outcome of the intellectual capability of human endeavor (Welty 1997, Hacker & Barden 1988, Adams 1991). Chen (1996) also points out the nature of technology as being a unique kind of human intelligence constituting that knowledge can be employed to solve existing human needs and wants. Seen in this perspective, the latest communication systems and computers can be regarded only as a continuation in this ‘chain’ of technological development which began millions of years ago. This perspective is also in accordance with Hacker & Barden (1988, p. 11): “people have been using and creating technology since prehistoric times“. Furthermore, the viewpoint is supported by Barlex & Pitt (2000, p. 12) when they say that “Since the start of civilization we have processed raw materials and fashioned artefacts, to make life better.”

Encyclopaedia Britannica on-line (1999) defines technology accordingly:

> Technology may be defined as the systematic study of techniques for making and doing things....By the early 20th century, the term embraced a growing range of means, processes, and ideas in addition to tools and machines. By mid-century, technology was defined by such phrases as "the means or activity by which man seeks to change or manipulate his environment." (http://members.eb.com/cgi-bin/g?DocF=macro/5006/17.html&keywords= technology&DBase=Articles&hits=10&pt=1&sort=relevance&config=config#4UJI5)

The above reference to technology as a “systematic study of techniques for making and doing things“ can be regarded to be closely related to the notion of “handicrafts“, where the focus of the activities is in using various techniques to make artefacts (see also Alamäki 1999). The early 20th century perspective that technology is not only machines and tools is interesting, because even today it is not uncommon that technology is understood only as physical objects like machines, tools, structures, etc. (Mitcham 1994). However, technology is much more than just the physical objects around us. For example, various kinds of technological systems can also be found in our environment. (In this regard see chapter 3.1.)

Technology has also been defined as “human innovation in action“ (http://www.iteawww.org/A1.html, International Technology Education Association 1996, p. 16). Thus, according to this definition of technology, we need to be innovative and active in order to accomplish technology. Moreover, development of technology is closely connected with the ability to be creative. According to the International Technology Education Association (2000, p. 28) “Technology is closely linked with creativity, which has resulted in innovation.” Although some animals utilize the natural environment to get food and even treatment in the case of illness (Linden 1992), “technology is the practical method which has enabled us to gain a dominant role above the animals“ (Black & Harrison 1985, p. 3).

Mitcham (1994) regards technology as an outcome of a very fundamental phenomenon, the human volition, or will. Thus, a driving force to do technology is essentially influenced by our own will. Moreover, Barlex & Pitt (2000, p. 12) write that “being ‘technological’ is part of what makes us human.” Consequently, from these perspectives purely economical factors, for example, are not fundamentally directing technology. Of course it would be naive to claim that, in the modern world, market forces together with the profit motives are absent in the development of technology (see International Technology Education Association 2000). It is not rare today that the importance and necessity of the latest technological products is advertised to ‘ordinary’ people and, thus, the need to buy and use technology is created by the market forces.

According to the International Technology Education Association (2000, p. 22) “Put simply, technology is how humans modify the world around them to meet their needs and wants or to solve practical problems.” Moreover, Hacker & Barden (1988, p. 21) state that “our biological needs for food and medical assistance, our physical needs for clothing, shelter, and manufactured products, and our need to communicate information are all satisfied through technological means.” (see also Suplee 1997)

In the above quotation “physical need for clothing“ catches attention especially from the perspective of Finnish “Tekstiilityö“ [textile work]. In Finland, “Tekstiilityö“ has not been widely considered as a part of the development of technology education. In spite of this, in textile lessons mostly girls design and make clothes and other useful products. Actually, excluding textiles from technology education does not obtain support for example from the perspective of many Western technology education curricula (for example Hulsbosch 1997, Department for Education 1995).

Considering technology as a response to satisfy the human purposes, it comes close to the idea of Maslow’s systematic categorization of the hierarchy of needs. According to Maslow’s category we have lower needs or deficiency “needs“ (including physiological and safety needs) which must be satisfied before higher “growth needs“ (including the need to know and understand and the need for aesthetics) are attended to. (Hohn 1995) In this regard, technology has played a crucial role. During the course of history it has effectively satisfied primary or “deficiency“ needs and consequently opened possibilities to satisfy secondary “growth“ needs, for example arts. However, from the viewpoint of technology, past and present, Maslow’s categorization is too “restrictive“. Technology overlaps through the categories; while it is essentially related with the satisfaction of “deficiency“ needs, it is also concerned with the aesthetics of designing and making things (see Morrison & Twyford 1994).

Technology and development have always been bound up with work. The nature of work has always involved the use of certain kinds of techniques either to make work easier or even to perform a job. (Kananoja 1994b) According to Alamäki (1999, p. 69) “Technology is also a much broader concept than techniques…Technology solves practical problems via the use of techniques“. Thus, no single technique or mode, crafting for example, can be regarded as a synonym for technology. Rather, they are all included in the field of technology. Consequently, technology (education) is clearly an umbrella concept for handicraft (education) (see Kantola 1997, Parikka 1998).

Most of the technology around us somehow comes from nature. According to Black & Harrison (1985, p. 3) “Technology is a disciplined process using resources of materials, energy and natural phenomena to achieve human purposes“. Consequently, in doing technology we are strongly dependent on nature and its resources; for example, cars are made from different kinds of metals (ore), various forms of plastics and rubber (oil), and so forth. This is true in spite of the increased use of synthetic materials. Moreover, as an ‘addendum’ to the above quotation, technology models nature in various ways. For example, technology models the structures, mechanisms and systems of nature to a very great extent (see Worldwide Fund for Nature 1993). This could provide a fruitful platform for increased collaboration between technological education and biological education.

According to Webster’s Ninth Collegiate Dictionary (1985, p. 1211) technology is “the totality of the means employed to provide objects necessary for human sustenance and comfort.” This interpretation corresponds to the perspective of this research. It would be surprising if technology, when understood to provide human sustenance and comfort, could conjure any negative attitudes against it (as technology being understood solely as concerned with computers or the like seems to do).

Moreover, Collins Cobuild English Language Dictionary (1990) goes a little bit further in defining technology and states it to be:

> 1) The activity of study using scientific knowledge for practical purposes in industry, farming, medicine, business, etc.
>
> and
>
> 2) a particular area of activity that requires scientific method and knowledge. EG...changes in agricultural technology... ...computer technology... ...western technologies of housing, industry, health. (p. 1501)

The above reference emphasizes the importance of a scientific method and knowledge in order to accomplish technology. To some extent, this is undeniably true in modern times. Alamäki (1999, p. 33) says: "Technology utilizes scientific knowledge and laws in solving practical problems." However, if we agree that prehistoric people provided "sustenance and comfort" to themselves via technology, then the role of scientific method and knowledge are to be seen in a different perspective. In the course of the humans' long history much of the technology has been made without any scientific knowledge or method (Fensham & Gardner 1994). Moreover, in countless cases technology has been successful in spite of the many wrong deductions made from the scientific viewpoint. For example, the Montgolfier brothers reasoned that the raising smoke enabled their balloon to fly. Finally, as a complementary consideration, limiting technology only to "western technologies of housing, industry, health" is not in accordance with the perspective of this research.

Webster's Encyclopedic Unabridged Dictionary of the English Language (1989, p. 1458) makes a connection to social aspects of technology as follows: "Technology is the sum of the ways in which a social group provide themselves with the material objects of their civilization." This can be said to be true for technology is rarely an individual enterprise, but rather appears to be a socially interactive collaborative process in pursuing and satisfying emergent needs. Moreover, technology truly has had, and still has profound consequences on the everyday lives of billions of people. (Naughton 1994, Hacker & Barden 1988) Actually, Pytlik *et al.* (1985) consider technology also as a social phenomenon concerning human culture. Thus, technology can be seen as a cultural phenomenon (National Geographic 1999). This view is also expressed by Black & Harrison (1985, p. 3): "Technology is thus an essential part of human culture because it is concerned with the achievement of a wide range of human purposes."

The last, but not the least aspect of technology is the importance of design. Technology without purposeful design would not be useful, appropriate and functional. Morrison & Twyford (1994, p. 11) say: "what, indeed, would be the price of no design at all, to industry, commercial enterprise or our well-being in general". Actually, design and designing are intrinsically part of technology and technological processes.

2.1.1 Technology in relation to mathematics and science

Especially in the last few decades, technology has shifted substantially in industrialized nations from manufacturing workpieces with various tools and machines to various technological systems with a growing demand for new kinds of problem solving capabilities. Moreover, along with this shift, technology has become connected to science and mathematics more than before. (Dugger & Yung 1995, Hacker & Barden 1988, Adams 1991). For example, modern microelectronics and computers, as well as the possibilities to utilize the huge potential of sub-atomic power to create energy, are derived from the scientific findings at the beginning of the 20^{th} century (Rhodes 1986, Teerikorpi & Valtonen 1986).

Consequently, mathematical knowledge and skills are also essential in the practice of technology (Dugger & Yung 1995, Vohra 1988). Actually, there can be found a wide variety of mathematical tasks that are generic in such a way that they arise across an extensive range of technological activities (Sage & Steeg 1993). Thus, the integration of the contents of mathematical subject matter to technology education could be done naturally. As a matter of fact, without mathematics proper teaching of modern technology would be an impossible enterprise (Adams 1991). This is especially true when teaching, say, automation technology. However, the benefits can be bilateral. The teaching of automation can provide a concrete method and meaningful context for mathematical knowledge to appear (Denis 1993).

In the following comparison Dugger & Yung (1995, p. 9) present some differences between technology and science:

Table 1. Comparison between technology and science.

Technology	Science
Concerned with “how to“	Concerned with “what is“
Knowledge is created	Knowledge is discovered
Guided by trial and error	Guided by theory
Oriented toward action	Oriented toward research

There is something in the above table that has direct consequences on traditional science teaching. Scientific inquiry is prompted by the interest to provide an explanation for natural events and phenomena. It is guided by theory, and knowledge of a studied phenomenon is discovered by carrying out experimental research (see Driver *et al.* 1995). Contrary to scientific inquiry, the technological process, as was said in the previous chapter, begins with the identification of a human need or want (Layton 1993). Thus, technology is concerned with “how to“ create our food supply, means of health, habitats, transportation, communication, clothing and so forth (Black & Harrison 1985). In other words, technology is driven by the concern for a solution to a practical problem. The technological process draws on a variety of different sources of knowledge and the new knowledge during the process is rather developed and created (In this regard, see Chapters 2.4.2. and 2.4.2.1.). (Driver 1995)

In many cases scientific inquiry and technological endeavor share common features and aims (Adams 1991). For example, when scientists asked “what was“ the speed of light, the next question was obviously “how to“ measure it. Thus, in the process of finding out the speed of light, both science and technology seem to be present. Also, say, in modern biotechnology both of the questions are driving the work. According to Kurki-Suonio & Kurki-Suonio (1994) in physics, for example, the scientific and technological processes are connected with each other and, as a matter of fact, it is not possible to do modern, experiential research without the help of technology.

However, even though technology helps scientists to carry out research, technology has to be understood as a much wider concept than just a tool to carry out scientific inquiry. It is, as was already said above, essentially one of the most typical outcomes of human culture, both in industrial and individual processes to satisfy our needs, wants and purposes. If the scientific process is triggered only because of the aim to explain the world as it is, it does not end up providing sustenance and comfort to ourselves.

The above-mentioned viewpoint is supported by Mitcham (1994) who makes a clear distinction between technology and science. Firstly, technology is different from science on the basis of the intentions. While science is more about knowing the world as it is, technology aims at controlling, manipulating and using it. Secondly, while in science “laws“ aim to describe reality as it is, technology describes action in terms of “rules“.

As a continuation to the discussion in the above paragraphs, the following comparison by Hacker & Barden (1988) is presented:

> Scientists study how the earth was formed and what it is made from .<--> Technologists use the materials found in the earth to make useful objects.
>
> Scientists study materials under microscope to learn why they have the characteristics that they do. <--> Technologists create new materials with improved characteristics.
>
> Scientists discover the way the human body works. <--> Technologists make artificial hearts and limbs. (p. 3)

The above comparison demonstrates that scientists and technologists often work as a team. Scientific discoveries are made useful by technologists who apply new scientific knowledge to the solution of practical problems. Does this mean that technology is just ’applied science’? It is not the case, as there are plenty of examples supporting the notion that technology has a purpose and character of its own. (de Vries 1994, de Vries 1997, Hacker & Barden 1988, Naughton 1994).

Moreover, Gardner (1994, p. 142) states that “technology has developed throughout the ages largely without the benefit of scientific knowledge; often, when there has been a link between technological capability and scientific knowledge, the technology has *preceded* the science.“ In this regard Barlex & Pitt (2000, p. 12) go even further when they maintain that “Technology has a longer history than science. Humans have always had technology.” These arguments are furthermore reinforced by Allen (1997, p. 315): “It is becoming generally accepted that technology builds on itself and advances quite independently of any link with the scientific frontier, and often without any necessity for an understanding of the basic science which underlies it”.

The processes in technology should be taken into consideration in children's education. The following table presented by Sparkes (1993, p. 36) makes technology and the processes in it distinct from science:

Table 2. Some differences between science and technology.

SCIENCE (Goal: the pursuit of knowledge and understanding for its own sake)	TECHNOLOGY (Goal: the creation of successful artefacts and systems to meet people's wants and needs)
Key scientific processes	Corresponding technology processes
Discovery (mainly by controlled experimentation)	Design, invention, production
Analysis, generalisation and the creation of theories	Analysis and synthesis of designs
Reductionism, involving the isolation and definition of distinct concepts	Holism, involving the integration of many competing demands, theories, data and ideas
Making virtually value-free statements	Activities always value-laden
The search for, and theorising about, causes (e.g. gravity, electromagnetism)	The search for, and theorising about, new processes (e.g. control; information; circuit theories)
Pursuit of accuracy in modelling	Pursuit of sufficient accuracy in modelling to achieve success
Drawing correct conclusions based on good theories and accurate data	Taking good decisions based on incomplete data and approximate models
Experimental and logical skills	Design, construction, testing, planning, quality assurance, problem-solving, decision-making, interpersonal and communication skills
Using predictions that turn out to be incorrect to falsify or improve the theories or data on which they were based	Trying to ensure, by subsequent action, that even poor decision turn out to be successful

Finally, the following perspectives are presented as conclusive remarks for this chapter: Mathematics and science should be clearly taken into account in developing a general technology education curriculum. But how to make sure that the teaching is in accordance with the idea of technology education? From the viewpoint of technology, mathematics has no meaning on its own, but rather can be regarded as an indispensable tool in problem solving. Similarly, science is not only valued because of an interest in natural phenomena and seeking 'the truth', but rather from a practical perspective helping technology, through applying the laws of the nature, in its search to seek appropriate, useful and satisfactory solutions for human needs and purposes. Thus, technology is not seen just as an application of science or scientific knowledge, as there are plentiful examples of activities in 'everyday' technology which do not need scientific knowledge or a scientific way of thinking for their success.

2.2 Summary of the nature of technology

As is evident from the above literature review, technology can be defined and understood in many ways. The relationship between science and technology can also be understood from various perspectives. This inconsistent situation is illustrated also by Hansen & Froelich (1994, p. 179): “Philosophers, antrophologists, sociologists, historians, and teachers educators continue to study the subject, yet a widely accepted definition remains obscure.”

However, the following interpretations of technology are distilled from the considerations above.

Technology is inherently a part of human culture. Essentially, technology is a human-made environment built on the basis of our needs, wants and purposes. In order to do technology people need to be active and willing. Idealistically, human volition, or will, can be regarded as a driving force in the process of seeking solutions to either individual or collective needs, wants and purposes. Thus, volition can be both individual and collective. Importantly, technology does not belong more to western than to eastern culture. Rather, technology is essentially a global phenomenon existing in various forms in different parts of the world.

If technology had been only about the copying of workpieces and producing artifacts, then purposeful development would not have been possible. Thus, innovation and creativity have been, and still are very essential features in technology. Technology consists of skills (techne), but also of intellectual activity and knowledge (logos). In this regard technology includes both techniques, modes and procedures, but also represents a human capability to know and think abstractly. Design and designing are essential features of technological problem solving, as they enable us to make imagination in to reality.

Technology is not represented only through the realm of the engineering sciences. They are only one, albeit a very influential and well-known, facet of technology. Technology cannot be limited to the use of certain materials, methods, techniques, modes or the like. Neither should technology be only about computers or other high technologies. All these are just small pieces in the whole field of technology. In this regard, handicraft is also submitted under the umbrella concept of ‘technology’, meaning that it can be regarded only as one representation of the human’s activity to meet practical needs and purposes. Consequently, handicraft education cannot be translated to mean simply technology education.

Although technology is closely connected with science and mathematics, it cannot be regarded as an applied science. Essentially, technology answers the question “how to“, while science tries to seek answers to “why“ or “what is”. Moreover, while science is driven by the inquiry seeking to answer the truth, the “answers“ in technology are more diverse. In technology, a single starting point can produce various alternative and divergent solutions. In technology “the truth” is relative to useful and functional solutions on the basis of our needs, wants and purposes to provide sustenance and comfort. Much of everyday technology can be accomplished through problem solving which does not require scientific thinking or knowledge.

2.3 Technology and education

A clear distinction should be made between vocational technological education and endeavors to provide technological literacy and capability for all people (Hacker & Barden 1988). Also, just teaching to make use of technology is far too narrow an interpretation of technology education. In this respect, the general notion of technology education also differs from educational technology where technology is widely seen as a medium to enhance and support teaching. (see for example Department for Education 1995, Black & Harrison 1985, Banks 1994, Hulsbosch 1997, Smithers & Robinson 1994, de Vries 1997, http://www.iteaorg/A1.html)

In a way, technology and education have been connected since prehistoric times. Stone age people carried the skills and knowledge essential in survival to their future generations (Hacker & Barden 1988). Much learning undoubtedly took place in real life contexts while pursuing emergent needs, wants and purposes. Otherwise the human race would not been able to live on this planet for such a long time.

The earliest occurrences to teach relevant skills and knowledge in technology are also described by Encyclopaedia Britannica on-line (1999):

> In the early millennia of human existence, a craft was acquired in a lengthy and laborious manner by serving with a master who gradually trained the initiate in the arcane mysteries of the skill. Such instruction, set in a matrix of oral tradition and practical experience, was frequently more closely related to religious ritual than to the application of rational scientific principles. (http://members.eb.com/cgi-bin/g?DocF=macro/5006/17/75.html&bold=on&sw=education&sw=technology&keywords=technology%20education&DBase=Articles&hits=10&pt=1&sort=relevance&config=config&firsthit=off)

The kind of education mentioned above developed into an apprenticeship system. During past centuries skills and knowledge in various areas of technology were taught in apprenticeship situations. The apprenticeship system employed a practical approach to teaching essential craft skills. Learning took place in an authentic real life context and integrated naturally. For example, mathematics, geology, geometry and structural engineering had to be taken into account in the practice of masonry. Thus, problem solving was set in the context of the authentic activity of solving the larger task at hand. (Honebein *et al.* 1993) In the apprenticeship system, skills and knowledge were carried forward to the further generations in the midst of lingering aura of secrecy and mystery. In those days apprenticeship had very little to do with the idea of general education. It was a tight novice-expert-like system, and outsiders of the craft guilds were not allowed to know anything about the skills and knowledge essential for mastering the trade in question.

However, due to its history as a method of teaching essential skills and knowledge, the apprenticeship model had an important role in the early history of technology education. Combined together with the idea of general education, the apprenticeship approach was used as a teaching method in general handicraft education. Necessary manual skills were demonstrated by an expert (teacher) to the children. The children had to practice those skills in order to gain mastery over them. It was essentially a learning by doing method and satisfied its purpose rather well. Moreover, the practice occurred in meaningful contexts, as the end-products were useful and necessary.

Since education became more organized we can also speak about the origins of general technology education, at least in cases where work was in an essential role. For example, the following forms of education can be found:

> Calvin (the meaning of work),
> Comenius (practical education and the meaning of play and concrete approaches),
> Pestalozzi (the importance of the school to prepare children for life after school),
> Fröbel (the meaning of play and hands on concrete teaching methods) and
> Cygnaeus (the idea of educating children to understand the meaning of work, "to educate to work through work"). (Kananoja 1994a, Kananoja 1994b)

More formal teaching in technology began alongside with the industrial revolution. The first technical institutes were founded 1757 in France and during the 19th century tens of technical institutes and universities were founded in the United States. The purpose was to prepare students to participate directly in the labor market or serve as experts in special purposes like in the military. (Adams 1991)

The above-mentioned transition from the apprenticeship system towards a more general notion of teaching technology is also presented in Encyclopaedia Britannica online (1999):

> Craft training was institutionalized in Western civilization in the form of apprenticeship, which has survived into the 20th century as a framework for instruction in technical skills. Increasingly, however, instruction in new techniques has required access both to general theoretical knowledge and to realms of practical experience that, on account of their novelty, were not available through traditional apprenticeship. Thus the requirement for a significant proportion of academic instruction has become an important feature of most aspects of modern technology..…..French and German academies led in the provision of such theoretical instruction, while Britain lagged somewhat in the 19th century, owing to its long and highly successful tradition of apprenticeship in engineering and related skills. But by the 20th century all the advanced industrial countries, including newcomers like Japan, had recognized the crucial role of a theoretical technological education in achieving commercial and industrial competence. (http://members.eb.com/cgi-in/g?DocF=macro/5006/17/75.html&bold=on&sw= education&sw=technology&keywords=technology%20education&DBase=Articles&hits=10&pt=1&sort=relevance&config=config&firsthit=off)

In the above chapters, the context of technological education was more specific and not so much in all-round general education, not to speak of compulsory education for all citizens. However, the present idea of technology education as a part of *general education* in many countries has its roots in teaching connected to technical subjects and industry. During the cold war the Eastern block developed a Polytechnic education, while for example in the United States Industrial Arts prevailed. The idea was to familiarize people with technology, but still the aim was to prepare to children to support their nation's technological endeavors. Nordic countries, especially Finland and Sweden but also Norway to some extent, were oriented towards handicraft education. (Kananoja 1994a, Dugger & Yung 1995)

The above-mentioned orientation is due to the work of the Finnish educator Uno Cygnaeus. He developed the idea of educative handicraft and introduced in 1866, first in the world, a mandatory sloyd education for boys as a school subject for general education. Soon after Cygnaeus's idea about educating children into the world of work was further developed, with a vocational pitch, by the Swedish educator Otto Salomon. Subsequently, Scandinavian sloyd tradition, still widely known among technology educators around the world, was established. In spite of the growing influences of industrial revolution in Scandinavia, most of the population still lived in the countryside far away from the din of the factories. In that environment sloyd education based on producing useful artifacts needed at homes was a fully relevant content of general education. (see Kananoja, 1994b) Interestingly, Uno Cygnaeus was already a proponent of technological creativity, as cited by Kananoja (1994a, p. 47) "The teacher should not give models for everything, but to make pupils think for themselves, to invent and to use their eyes and hands."

Cygnaeus also seemed to understand the importance of 'technological literacy', since one of his ideas was to promote appropriate education in the transition period from the pre-industrial era to the industrial world (Kananaoja 1994a). When and where were these important pieces of Cygnaeus's legacy lost in Finnish handicraft education? Are not innovation and creativity together with demand for technological literacy the very issues that have gained attention among the developers of the technology education curriculum?

Actually, in many western countries craft education has formed a background for developing technology education (de Vries 1994). In its most traditional form craft education was about the production of artifacts through manual training, and the main emphasis was in learning manual skills to use different tools. In this respect the Finnish educational system has nothing to be ashamed of. Actually, our craft tradition and Uno Cygnaeus's work has been recognized all over the world, even in Japan (Yokoyama 1999).

In spite of its valuable contribution especially in the first half of the 20th century, in many countries handicraft education has became increasingly old fashioned at the beginning of the new millennium. Basic crafting techniques have been seen to be inadequate in terms of giving relevant skills and knowledge to cope with the technological world around us. This dilemma has also been noticed among the handicraft teachers. (see Kankare 1998, Alamäki 1999)

In the Netherlands, for example, current developments in technology education curriculum have also been based on craft traditions. The aim is to provide a broader understanding concerning technology and its effects on the modern world, to take into account the social factors of technology, as well as to emphasize the design aspects of technology. (de Vries 1997)

At the beginning of the 20th century polytechnic education emerged in the former Soviet Union. The polytechnic idea to educate children to serve the industrial life on behalf of the nation also spread to the other Warsaw Pact countries. The polytechnic education was strongly bound to serve general aims of communist governments and thus included doctrines of Marxist ideology. Interestingly, mathematics and science were seen as important factors in polytechnic education. Lenin's wife Krupskaya, who was in charge of polytechnic education expressed the following ideas: The basis of national economy is in the children who are interested in technical issues; polytechnic education should deepen the children’s technical orientation and, moreover, “polytechnic” cannot be a separate subject but it has to be closely connected with the natural sciences, especially with physics and chemistry and societal issues as well. (Kananoja 1994b)

In the United States the current notion of technology education was preceded by the Industrial Arts (see Dugger & Yung 1995, Dyrenfurth 1994, LaPorte 2000). The American Industrial Arts Association (AIAA) was established in 1939, but due to the Second World War, its first conference was not held until 1947. The theme of the conference was “A Curriculum to Reflect Technology.“ It was generally agreed that Industrial Arts should contribute more to the general education than merely providing vocational skills. (Dugger & Yung 1995). The name of the American Industrial Arts Association was changed to the International Technology Education Association (ITEA) in 1984. The programs that led to technology education in the United States can be seen to be essentially influenced by the work done in Scandinavia (La Porte 2000). The latest development in technology education in the United States has been the creation of the Standards for Technological Literacy (International Technology Education Association 1996, 2000, see also http://scholar.lib.vt.edu/TAA/TAA.html).

By launching Sputnik, the Soviets gave a boost for curriculum development in the western world. This was especially true in the United Kingdom and the United States. They were concerned that their technological development lagged behind the Soviet Union. Since then, science and technology were given more emphasis in the general education curriculum and the aim was to surpass Soviet Union in terms of scientific and technological superiority. The decisions which were made on behalf of science and technology education can be interpreted to have had a positive influence. The United States, for example, has become one of the most powerful nations in technological, scientific and economical precedence. (see Urevbu 1997)

Is technology education a universally standardized concept and understood in the same way? No, not by any means. As seen in the previous chapter, the concept of technology itself can be defined in various different ways. Thus it is not a big surprise that there are quite diverse interpretations of technology education as well. De Vries (1997, pp. 30-31) has explored different international variations of technology education over previous decades and has come up with the following definitions:

> a) The craft-oriented approach. This approach is the one from which most other approaches have originated. Central to this approach are practical making abilities. Pupils get working drawings in which the design has been elaborated in detail, including the materials and treatments. Most of the time is spent on making work pieces. A variety of materials is used, but wood and metal are found most frequently. Moreover, De Vries (1994, p. 33) says that “In most cases, when conforming to this approach, the subject was taken by boys.“

b) The industrial production oriented approach. This approach can be regarded as a kind of extension of the previous one. Now the practical skills are chosen in such a way that they relate to production in industry. Work preparation in industrial settings is given much attention. According to de Vries (1994, p. 34) in the above-mentioned approach "Both boys and girls take the subject, although for the girls it can be different from the boys."

c) The high tech approach. Although at first sight this approach seems very different from the previous one, it resembles it in a kind of concept of technology that enhances the high status that is given to technology. Usually in this approach the computer plays a dominant role, but it is not always demystified for pupils. In high-tech approach "The subject is seen as relevant for both boys and girls." (de Vries 1994, p. 34)

d) The applied science approach. This approach has been developed by science educators, looking for ways to make their subject more relevant to pupils. Technology is seen as a direct application of scientific knowledge and methods. Historically this paradigm is not correct. De Vries (1994, p. 35) notes that "As science in many cases is mostly taken by boys, this approach tends to be male-dominated in practice, although sometimes issues are chosen that appeal to girls as well."

e) The general technological concept approach. This approach has been developed in close correspondence with the academic engineering disciplines. It often gives the school subject a rather analytical flavor. According to de Vries (1994, p. 35) "usually both boys and girls take the subject when this approach is followed, though it tends to be male-dominated....this approach encourages pupils to develop a concept of technology in which creativity and design is often absent."

f) Design approach. This approach is usually an extension of the craft oriented approach: here not only the making skills but also the designing skills are included. In the Design approach "Both boys and girls can be enthusiastic about this way of learning technology. By using this approach a concept of technology in which creativity is central can be encouraged." (de Vries 1994, p. 36)

g) The key competencies approach. This approach differs from the previous one in the greater emphasis on using theoretical concepts in the assignments. This approach is often promoted by business corporations. Key competencies are for example: innovative thinking and co-operation skills. De Vries (1994, p. 36) states that "both boys and girls are stimulated to take the subject."

h) The STS [Science-Technology-Society] approach. This approach is an extension from the applied science approach, but pays more attention to the human and social aspects of technology. "One reason for implementing this approach is that it can enlist girls' interest in science education" (de Vries 1994, p. 37).

After presenting all the above approaches de Vries (1994, p. 31) continues "In fact every technology teacher makes a choice between one of these approaches or makes a combination of them." Consequently, the following perspectives are taken in relation to the differing approaches listed above:

Skills and materials are in an essential role in technology education, but the focus of the activities is not in just producing work pieces through detailed instructions guiding both working techniques and materials. To some extent, the industrial production approach is acceptable, but technology education which this thesis is concerned about takes place in the context of general education framework. Thus, technology education is not about vocational education, nor does it directly educate the future work force for industry. Information technology and other kinds of high tech play undeniably an important role in today's modern world. Thus, in order to make technology education relevant in relation to the world outside the schools, information technology with computers and the like is important to some extent. However, the "high status" high tech might yield to the schools is not an essential factor. The role of information technology in technology education can be understood only as a tool to enhance and enable teaching, say, if the learning environment is a computer-driven one. On the other hand, the computer itself can be in the focus of learning: What are the main components in it? What are their roles in the whole system? How do they work? and so forth. In this regard, demystifying technology, i.e. to open 'black boxes', is a vital part of educating about technology.

As stated in chapter 2.2., technology is not regarded as an applied science. Consequently, the applied science approach is rejected as well. However, the STS (science-technology-society) approach, with its human and social aspects, is closer to the interpretation this thesis is based upon. Analytical activities should not surpass the possibilities for creativity and innovation in designing and making technology. The co-operation skills also need to be taken into account in technology education.

As a complementary consideration, technology education should be driven by a natural human volition, or will, to satisfy human needs, wants and purposes.

2.4 Teaching methods according to the nature of technology

In this chapter the summarized nature of technology (chapter 2.2.) is viewed in relation to the recent developments in the educational sciences. The purpose is to explore how some current theoretical learning concepts positioning children as *active* agents of their learning processes could be considered in search of more appropriate pedagogical approaches to technology education.

2.4.1 Constructivist viewpoint

In general, this viewpoint derives from the somewhat self-evident notion that humans are not passive, but active constructors of knowledge and meanings as well as intentional and goal-directed agents of their behavior (Schwandt 1994). Constructivism itself cannot be seen as a learning theory, but can be regarded as "a philosophical view on how we come to understand or know" (Savery & Duffy 1995, p. 31). In this regard constructivism is more like a concept of learning, or a framework for education. Although there are various interpretations of constructivism around, they all can be bound together like Ernest (1995), referring to Spivey 1995, says:

> The metaphor of carpentry or architecture (or construction work) is about the building up structures from pre-existing pieces, possibly specially shaped for the task. What methaphor of *construction* does not mean in constructivism is that understanding is built up from received pieces of knowledge. The process is recursive, and so the "building blocks" of understanding are the product of previous acts of construction. Thus, the distinction between the structure and content of understanding can only be relative in constructivism. Previously built structures become the content in subsequent constructions. (p. 461)

Although written within a new nomenclature, the basic idea of "constructivist" learning derives from Piaget's dissatisfaction with the theories of knowledge and epistemological issues available during his time (von Glasersfeld 1995). Piaget (1952) developed two concepts, *assimilation* and *accommodation* to describe the learning process in children's interaction with the environment. Firstly, in the case of assimilation, children's cognitive structure (*schema*) incorporates new experiences and knowledge from the environment. Consequently, quantitative changes take place in the children's thinking. Accommodation is ensued by the full integration of the new information. Cognitive organization is either modified or totally replaced in the process of comparing and manipulating new information to the old information. If the old structure is not compatible in relation to the new one, a more appropriate and useful new structure will be created and consequently qualitative changes take place in the children's minds. Thus, just incorporating new knowledge is not enough in terms of the cognitive growth of children, but rather, the process needs to go through comparisons and manipulations, preferably taking place in a meaningful interactive context.

The implication of Piaget's theory is that the learning is an active process where individuals construct their information structure in interactive settings. As a corollary, this viewpoint emphasizes the notion that the child should be the subject of learning rather that object of teaching (Vygotsky 1997). Moreover, the information that teachers distribute is not necessarily acquired by the learner in a similar form. The same information might engender various interpretations in different children.

Piaget's theory of learning is epitomized in terms of the constructivist notion of learning. It frames learning as an active, continuous process whereby the learner takes information from the environment and constructs personal interpretations and meanings based on prior knowledge and experience (von Glasersfeld 1995, see also Papert 1980). Thus, the learner is not a passive receiver of the information, but rather, an active agent having a substantive responsibility for the learning processes (Savery & Duffy 1995). This idea of learning challenges the behaviorist stimulus-response approach where the distributed knowledge is tested in traditional tests. In order to be successful children need to remember the fact, 'the truth', that was distributed by the teacher. In the test the child is expected to 'return' the same fact back to the teacher in terms of a right answer. Contrary to this, in a constructivist perspective the truth is relative and dependent on the context in which it appears (von Glasersfeld 1995).

It is not only previous knowledge, skills and experiences that children carry on to new problem solving situations. They have their own feelings, expectations, needs, interests and other equivalent factors which they also bring to school, and as a matter of fact, wherever they go. Consequently, the teacher should be sensitive to notice when he/she can make use of those factors. Also, teachers need to orientate teaching practice in such a way that children could be able to sense the spirit of the nature of technology in their school based activities. In this thesis especially the children's needs and interests are considered to be fruitful starting points for technological problem solving. (Biesta 1994)

2.4.1.1 The meaning of the socio-cultural milieu in learning

Piaget had to take into account the role of social interaction in cognitive development (Rogoff 1990). However, his theories of learning have been criticized because he viewed children as lone investigators of the natural world (Fox 1998). It was Piaget's contemporary Lev Semenovitch Vygotsky who substantially emphasized the meaning of the social environment in the development of children.

However, Vygotsky's theories were "hidden" for a long time on the eastern side of the iron curtain and have been relatively recently introduced by the scholars of the western world of psychology (Harvard 1998). Vygotsky's ideas concerning learning developed especially during the time he worked as a school teacher and they can be regarded as the outcomes of his socio-cultural theory in general (Veresov 1998). Vygotsky's thoughts has been welcomed warmly among the educational psychologists (see Moll 1990).

The essential theme of Vygotsky's socio-cultural theory is that a child's cognitive development is difficult to understand without reference to the social world in which the child lives (Rogoff 1990, Harvard 1998). Actually, for Vygotsky, all our internal mental processes, even in their deepest state of privacy, retain the functions of social interaction (see Wertsch & Toma 1995).

As an implication of the socio-cultural theory Vygotsky (1997) emphasizes the importance of the social environment in education in the following way:

> Though the teacher is powerless to produce immediate effects in the student, he is all-powerful when it comes to producing direct effects in him through social environment. The social environment is the true lever of the educational process, and the teacher's overall role reduces to adjusting this lever. (p. 49)

From the socio-cultural viewpoint learning can also be seen as a social phenomenon in which learning is mediated through the social interactions among the individuals participating in the learning activity (Konold 1995, Rogoff 1990, Vygotsky 1986). Knowledge is seen to be social in nature. It is shared through the members of the learning community through the meanings of a context dependent language (Gergen 1995, Björkvist 1994). Consequently, construction of knowledge takes place predominantly in socially interactive settings having a great influence on the individual. However, even though social interaction is important in learning, in the end the knowledge and skills are constructed at the individual level from personal starting points and through spontaneous action (Tudge 1990).

When an assignment or task is done in a collaborative setting it is essential that all the participants share a common understanding about the purpose and goals of the work in hand. At the general level there is an obvious convergence between Piaget's and Vygotsky's theories about the importance of sharing perspectives and thinking. However, true to its preference for social context, Vygotsky's theory emphasizes both the significance of shared thinking and the opportunities to engage in joint decision-making processes. Moreover, children are supposed to gain from the more capable peers.

2.4.2 Constructivism and technology

The origins of technology are in the era when language had not developed. However, nowadays it is an essentially part of our socio-cultural environment and shared through a context dependent language. According to Chen (1996, p 5): "From the evolutionary perspective, technological intelligence emerged within a non-linguistic mind, yet it is centrally nested today within the symbolic language cognitive milieu."

Consequently, technology in itself can be regarded as an illustrative example of socio-cultural theory in practice. The technology around us essentially belongs to our collective consciousness. Technological development has usually been highlighted in terms of remarkable and far-reaching inventions. However, from the socio-historical viewpoint, the development of technology is more like a continuing process which is in constant state of transformation influenced by cultural, economical, political, societal and educational factors. For example, possibilities for further technological development in a certain area or country can be dependent on how successfully the inhabitants have been educated. (Kero & Kujanen 1990, Adams 1991)

As a relatively young field of education, technology education does not have the 'burden' of positivism-driven teaching approaches. Thus, it might give a fruitful background to take into account the latest ideas of teaching and learning. Considering various parallel definitions about the nature of technology itself and technological problem solving processes, the epistemological paradigm of constructivism seems to be a natural, even inevitable approach to appropriate technology teaching. Contrary to scientific inquiry, technology aims to seek practical solutions, not the 'truth', to the emerging problems and the knowledge is created rather than discovered in the process of doing technology. (Dugger & Yung 1995, Welty 1997) Consequently, incorporating the constructivist approach into technology education might be an appropriate and useful procedure to do (see also Lindh 1997).

Moreover, from the ontological viewpoint, technology did not exist before it was made a reality through goal-directed and intentional human activity based on the needs, wants and purposes. Technology has been, literally, constructed out of nothing. We live with it and take it for granted, maybe giving it a thought when some failure occurs, say, if the supply of electricity happens to be interrupted.

It could be fairly justified to speak about constructivist technology education where the human himself/herself is seen as an active, intentional and goal-directed agent driven by the individual and/or collective needs, wants and purposes. What could this mean in practice? Children should have possibilities to create and construct technology, literally to do something tangible and experience the effects of their solutions and outcomes. While doing technology children are in constant interaction with their environment; they use, for example, materials, techniques, modes and rules in order to carry out the process. The materials come from physical environment, but the techniques and modes, not to speak about the rules are fruits of our socio-cultural environment.

However, the above mentioned type of activity can be accomplished through a teaching approach typical for traditional handicraft education; copying prescribed models, patterns, techniques, modes or procedures aim to produce artifacts or workpieces. New experiences and knowledge are incorporated into the children's cognitive structure causing quantitative changes in thinking. However, there are not a lot of opportunities to accommodate and apply incorporated cognitive 'capital' subsequently, because the process is again fairly prescribed by the teacher, worksheets, models or the like. In short, the processes in traditional handicraft education aim at seeking the right answer, 'the truth', which is determined and known also to the children in advance.

How can children be educated about and through technology according to the spirit of constructivism? Literate creation and construction aside, children should have possibilities to assimilate, but especially to accommodate their cognitive structure. Thus, just incorporating new knowledge is not enough in terms of cognitive growth, but rather the process should go through comparisons and manipulations, preferably taking place in a meaningful interactive context. There are many meaningful and interactive contexts that can be found in the field of technology where comparisons as well as manipulations are brought about, providing that the starting point is not too prescriptive. Innovation, divergent thinking and creative production arise better from open problem solving situations.

Constructivist related approaches, with various interpretations, have actually been applied in several research experiments related to the teaching of technology. For instance, in the University of Joensuu, Lego/Logo learning environments have been used from the viewpoint of cognitive apprenticeship methods emphasizing the authenticity of the learning processes (for example Enkenberg 1995, Järvelä 1996). Suomala's (1995) research experiment also relates closely to both technology education and teaching methods deriving from the constructivist idea of learning. (see also Futschek 1995, Järvinen 1998)

2.4.2.1 Constructivism and learning environments in technology education

A learning environment should be based upon something where children want to 'enter'. Children should have a positive feeling and sense of usefulness of the learning environment that they are supposed to work with. Effective teaching requires the creation of optimal learning opportunities through pedagogical means, including the encouragement and maintenance of a positive willingness to learn. Here again the keyword is 'volition'. Thus, a teacher's role changes to the role of a facilitator of learning and co-ordinator of learning environments. (Opetushallitus 1994b)

As for the instructional principles of designing learning environments according to constructivist idea of learning, the following guidelines are offered by Savery & Duffy (1995):

> 1. Anchor all learning activities to a larger task or problem.
> 2. Support the learner in developing ownership for the overall problem or task.
> 3. Design an authentic task.
> 4. Design the task and the learning environment to reflect the complexity of the environment they (*learners*) should be able to function in at the end of learning.
> 5. Give the learner ownership of the process used to develop a solution.
> 6. Design the learning environment to support and challenge the learner's thinking.
> 7. Encourage testing ideas against alternative views and alternative context.
> 8. Provide opportunity for and support reflection on both the content learned and the learning process. (pp. 32-35)

Thus, when planning and utilizing different learning environments from the constructivist point of view, it is essential that children are provided with possibilities for personal cognitive construction processes and authentic activities connected to real-life environment, preferably to their own living environment (Duffy *et al.* 1992). An effective constructivist learning environment gives many possibilities to apply previous skills, knowledge and experiences in a large platform including also the world outside the school. (Savery & Duffy 1995).

Whilst social interaction can be seen as something essential to the learning processes, it should also be given an important role in designing learning environments for technology education. A natural part of child-centered activity is social interaction in small group settings, where the skills and knowledge are transferred through apprentice-like situations. (Honebein *et al.* 1993, Savery & Duffy 1995) According to Rogoff (1990) social interaction in cognitive development quite often resembles an apprenticeship situation, where the novice and the expert are engaged in the same problem solving situation, thus enabling assistance by experts (Gallimore & Tharp 1990, Järvelä 1996).

A traditional wood shop, metal shop or textile classroom can also be understood as an efficient learning environment in which learning of many skills and knowledge can take place. Broadly defined, the whole school, even our daily living environment, can be seen as a learning environment, in which constant social contacts support our personal construction processes and, moreover, often make learning possible in the first place. (Wilson 1995). Actually, even before children start their formal schooling, they have already learnt a wide variety of skills and knowledge through informal learning situations.

What does the concept of "learning environment" mean in the context of this research? In Case Study I the concept of learning environment is 'narrowed' to ready-made environments having features of construction kits used in technology lessons (Parkinson in press, Järvinen 1997, Järvinen 1998). In some instances the term 'device-environment' has been used (for example http://www.vaala.fi/~lml/Teknologia1.html), and even just 'environment' (see Enkenberg 1993). These definitions can be seen to be more appropriate, as it is not necessarily the learning environment itself that guarantees that learning does take place. The point is that in education all the learning environments have to be used in a pedagogically appropriate way in order to make them real learning environments. Although the term "learning environment" might be too promising, it has been used by many of the researchers in education (for example, Järvelä 1996, Suomala 1993). Consequently, the Lego Dacta Control Lab is called a Lego/Logo learning environment also in this research.

In Study 4., the learning environment consisted mainly of a wood shop in which conventional tools were used by the children. However, as the results of this study indicate, a learning environment in teaching technology alongside with the possibilities for constructivist learning could be arranged with relatively cheap and simple materials and equipment. It is important, that the teaching strategies in technology lessons are in accordance with the nature of the subject matter. Due to many parallel definitions of technology, it is natural to observe practical child-centered problem solving, divergent production with creativity and innovation. Moreover, the significance of creating a personal, as well as collective, need and volition to do technology should not be forgotten. These views need to be taken into account when designing effective learning environments for technology education. These considerations are in accordance with Alamäki (1999, p. 152): “The central duty of technology education is to develop the students’ technological higher thinking skills and attitudes. Therefore it is not so decisive which matters are studied, but rather the means by which the students’ technological thinking and conclusions develop.“

2.5 Authenticity and enculturation in teaching technology

Technology is inherently a part of us (Barlex & Pitt 2000). Thus, the ideas of authenticity and enculturation are naturally applied to technology education. As has been demonstrated earlier, learning is understood to take part in a social context and it is part of the process of enculturation, where the learner increasingly participates in an authentic and context dependent activity (McCormick *et al.* 1996, Koulaidis & Tsatsaroni 1996, Wertsch & Toma 1995). In technology education this kind of activity can generate understanding and knowledge at procedural level, referring to the notion of ‘device knowledge’, which is related to action and inserted to objects within it (McCormick 1998). In Vygotskian theory, spontaneous, or everyday, knowledge is explained “in terms of perceptual or functional or contextual properties of its referent“ (Panofsky *et al.* 1990, p. 251)

In authoritative teaching methods (Wertsch 1991), whereby the teacher controls the social interaction and other classroom activities, the actions of many children are often in response to what they perceive to be the teacher's expectations and traditional school evaluation in terms of examinations and tests (Edwards & Mercer 1987, Vygotsky 1997). In this kind of school setting children do not necessarily feel the teaching and its contents to be personally important or useful. This also militates against children's collaborative construction of understanding and individual children may feel that they are outsiders in the learning activity. Nevertheless, personal interests and needs that arise from the learner have a great influence on the learning process. Moreover, it is essential to give children a sense of ownership over the problem (Savery & Duffy 1995). In this regard, von

Glasersfeld (1995, p. 14) says aptly: “Problems are not solved by the retrieval of rote-learned ‘right’ answers. To solve a problem intelligently, one must first see it as one’s own problem”.

Excessively authoritative teaching methods can be regarded as unsuitable approaches especially in technology education. Actions of children should not be in response to the expectations of the teacher or traditional school evaluation practices, but rather, they should be in response to the emergent needs, wants and purposes preferably raising from the children’s own living environment. In technology, the outcomes are more or less appropriate solutions, not right answers, to emergent needs or/and wants (see Sparkes 1993, Layton 1993).

Problem solving should relate to the children’s real life, with the authentic environment (Schwarz 1996, Lehto 1998) allowing them to make appropriate and meaningful connections. Importantly, children should actually be supported to notice problems, even deficient features in their everyday environment. Moreover, they should be given chances to apply the technological knowledge and skills that they have acquired in subsequent problem solving (Adams 1991, Lindh 1997). In this regard, the question is about enculturating children through technology education to the constant process of modification of the environment created by ourselves.

2.6 Problem solving in teaching technology

This chapter explores the importance and nature of problem solving in technology. Through comparisons with problem solving in science some differing characteristics are derived. The comparisons are also intended to give food for thought to those teachers who are teaching technology through the multidisciplinary approach. In the multidisciplinary approach, it is essential that the essence of technology, and the characteristics of its problem solving processes are not missed within cross-domain activities. They should be clearly in the focus regardless of the procedures or approaches taken. This means, for example, that balance/counterbalance is not explored just because of an interest in the phenomenon itself, but rather by solving technological problems where the effects of balance/counterbalance need to be used in real solutions for identified purposes.

The problem solving method can be seen to be central in technological processes (McCormick & Davidson 1995, Layton 1993), even to the extent that it is regarded as a main part of the ‘technological method’ (Savage & Sterry 1990). Although the problem solving processes in technology were already discussed to some extent in chapter 2.1., the nature of the problem of innovation and creativity in problem solving, as well as motivation with volition are explored further below.

There is a broad agreement among psychologists that the term “problem“ refers to a situation in which an individual is called upon to perform a task not previously encountered. Moreover, when dealing with a true problem, externally provided instructions do not specify completely the mode of solution. The particular task, in other words, is something new to the individual, even though the processes or knowledge already available can be called up for solution. (Resnick & Glaser 1976)

Problem solving with openness is closely related to creativity and divergent thinking and production. According to Feldman (1993, p. 293) divergent thinking is “the ability to generate unusual but appropriate responses to problems or questions.“ Interestingly, creativity and intelligence do not seem to have a strong correlation between them (Cage & Berliner 1992). In most of the IQ tests the problems are rather defined and usually have only one right answer. In order to be successful in these tests, one needs to have convergent thinking skills; “a type of thinking which produces responses based on knowledge and logic“ (Feldman 1993, p. 293). In order to do technology, one also needs to have sheer knowledge about “rules“ and logical thinking. However, and importantly, also divergent thinking with innovative abilities is needed. In technology, there can be various appropriate and useful solutions that can be reached through creative and divergent problem solving processes, not through a “habitual way of doing things“ (Cage & Berliner 1992, p. 152).

Problem solving involves ‘a gap’ between what the child already knows and what he is required to find out. However, a problem in itself does not necessarily mean that the child is willing to solve it. What is required is motivation to act, the need to do something. This motivation could also be described as a cognitive drive including a desire to know and, importantly, also a desire to solve problems. (Ausubel & Robinson 1973). Since doing technology has been and still is driven by human needs and wants, children should also be given an impression of that drive in technology lessons. Here the question is essentially about the human volition or will. It is the cognitive drive that needs to be triggered in order to start the process of technology.

The activities in which scientists and technologists engage are claimed to be simply particular illustrations of general problem solving processes and actually have much in common. This is presented in the following table:

Table 3. Problem solving processes by Layton (1993, p. 46).

General model for problem solving	Science process	Technology/Design
Understand the process	Consider the natural phenomenon	Determine the need
Describe the problem	Describe the problem	Describe the need
Consider alternative solutions	Suggest hypotheses	Formulate ideas
Choose one solution	Select one hypotheses	Select one idea
Take action	Experiment	Make product
Evaluate the product	Does result fit hypotheses	Test product

Science typically focuses on analysis. This means that the problem at hand is broken down into its parts in the process with the objective of discovering the laws of nature and explaining natural phenomena (Driver *et al.* 1995). Due to its focus on analysis doing science requires and might help to develop convergent thinking skills. Quite on the contrary, the essence in the technological process is a synthesis with the aim to bring together separate elements into a whole. Thus, doing technology requires and might help to develop divergent thinking skills. (Dugger & Yung 1995, Harrison 1994, Sparkes 1993, Feldman 1993)

Although the above model for technology/design problem solving is not the only one available (for example Savage & Sterry 1990), it can be applied in practical technology education, as it gives a well defined and even natural structure for problem solving when doing technology. However, the reality in the schools does not necessarily follow Layton's problem solving model. If the learner is a beginner and has no experience about problem solving processes in technology, his/her process can go through quite a different route. Actually, in that case, the process can even be a regressive and frustrating endeavor. The child might have acquired so little experience and knowledge that formulating various ideas can actually be impossible, not to speak of selecting the most appropriate one as the final outcome. These kind of inadequate problem solving skills easily lead to situations where the learning process is slowed down or even hindered. Consequently, the teachers' role in terms of intervention is again essential to guide the process into the right direction. On the other hand, children might have a lot of previous experiences and knowledge, and, subsequently more potential to proceed according to the problem solving model in technology. However, the child's thinking is restricted or regulated by the expectations and demands of schools, teachers, and sometimes even parents. In this case the most appropriate or useful idea is not necessarily chosen, as the outcome has to be in accordance with these expectations (Adams 1991).

While solving the problem children bring background information and strategies to the process. If the children are working in a group, the individuals also bring their personal background information and strategies to the situation to form a common 'pool' of contribution on behalf of the collaborative problem solving. The possession of relevant background knowledge and skills facilitates problem solving. As a matter of fact, without such knowledge no problem solving is possible, aside from purely logical or 'content-free' problems. (Novak 1986) In general terms, a problem solving strategy is a set of rules for selecting, combining, modifying or otherwise manipulating background propositions in order to fill a gap inherent in a problem. The function and aim of the strategy is to reduce the randomness of trial and error in problem solving processes, and also in the technology process (cf. Dugger & Yung 1995), thus reducing the time required for and increasing the probability of a solution (McCormick *et al.* 1994).

Importantly, before engaging in problem solving, children should be made sensitive to *notice* problems which need to be solved (see Adams 1991). When doing technology children should be given opportunities to solve problems through discovery and innovation. As a matter of fact, the discovery approach to learning is naturally implied in problem solving. In the context of technology, this could mean real creative and divergent production, not marginal and would-be problem solving where, in the worst case, the final solutions are actually prescribed beforehand in terms of right answers. (Järvinen & Twyford 2000, McCormick & Davidson 1995)

"When the problem is not the question and the solution is not the answer" kind of thinking (Lampert 1990) has been under consideration even among the researchers in mathematics teaching. In this regard, Lampert (1990, p. 32) challenges the traditional notion that "*Doing* mathematics means following the rules laid by the teacher.....and the mathematical *truth is determined* when the answer is ratified by the teacher". Actually, it is not very rare even today that technology education follows these traditional notions of mathematical teaching. However, as shown earlier in this thesis, the above mentioned traditional notion does not seem to obtain support from the nature of technology itself.

It has to be noted that even though creative problem solving is essential in technology, convergent thinking is also needed during the course of technological processes. Moreover, knowledge and skills taught by the traditional teacher-centered approaches could become useful and utilizable when the learner attempts to apply them in novel, open-ended problem solving situations.

2.7 Summary of the theoretical stance on the research

This chapter summarizes the nature of technology with respect to the pedagogical considerations as follows:

The basic idea of children as active agents of their learning processes and as problem solvers using their previous skills, knowledge and experiences in a novel learning situation seems to provide a fruitful pedagogical approach to the nature of technology. Children being willing and active agents in their technology learning is a crucial factor in their success. Moreover, personal experience of technology as a response to human needs, wants and purposes is also vital. Consequently, children need to notice problems closely connected to their own living environment. In this way they can have an ownership of the task at hand. This is not possible in the ‘recipe-like’ teaching materials where the final outcomes are predetermined.

The above assumptions arise from the fact that technology has emerged as a response to both individual and collective human needs and wants during its long history. In this development problem solving has played an essential role and it has usually been practical, strongly contextualized and an open endeavor in order to satisfy human purposes. (see for example Adams 1991, Dugger & Yung 1995, Hacker & Barden 1988, Driver *et al.* 1995, Welty 1997, Black & Harrison 1985, Gardner 1994, McCormick & Davidson 1995)

From the viewpoint of skills (*techne*) the traditional notion of educational handicraft, with prescriptive copying of work pieces and artefacts, could have served quite well. However, from the viewpoint of knowledge and thinking (*logos*), another perspective is also needed to speak about *technelogos* education. In this regard, taking into account the modern notion of the learner as an active agent and contributor to his/her own learning process, the outcomes of learning produced in technology lessons do not necessarily need to be copied and well finished work pieces and artifacts, but improved thinking skills and capabilities to solve technological problems through human innovation in action.

Problem solving is an essential feature of the technological process. When engaged in problem solving, the individual or the collective group, faces a new situation which needs to be solved. Although the solution to the problem can be novel and innovative, in the process of solving it knowledge and skills already available are called upon for solution. In the process of technological problem solving there is rarely a single right answer, “the truth”, defining the solution, but rather a wide variety of possible alternatives from which the most appropriate and useful one is selected. And, provided that the circumstances are different, the alternatives selected can vary considerably.

In solving problems children are rarely working entirely on their own and in isolation from the surrounding world, but rather within the context of the socio-cultural milieu. This milieu has provided them with a considerable amount of thinking and making skills as well as experiences which can be utilized in the process of problem solving.

Authenticity and enculturation are especially important from the viewpoint of technology. Thus, if technology lessons are arranged according to the true nature of technology, they naturally include a strong inclination to authenticity. Moreover, since technology is inherently part of our culture, children should be enculturated into an active and contributing part of that culture.

Although the main focus of activity in technology education is not on mathematics and science (chapter 2.1.1), they constitute an important factor in the process of technology. From the constructivist point of view, children should have previous skills and knowledge on these subject areas and make use of that potential as a problem solving tool in technology education. On the other hand, technology can provide an authentic context for these subjects areas to appear meaningfully.

The connection between the constructivist theory of learning and technology education seems not to be taken into consideration to the extent that it might deserve. This research thesis considers constructivist driven teaching methods in relation to the nature of technology as a human construction in both a concrete and abstract sense. According to the constructivist idea of learning, it is vital to enable children to take information from the environment and use it, as well as their previous knowledge and experiences, in a problem solving situation and also to create new knowledge and skills in a personally meaningful leaning activity. (von Glasersfeld 1995, Tudge 1990)

3 Settings and instructional contexts

This chapter describes the settings and instructional contexts in both of the Case Studies: Case Study I (Studies 1, 2 and 3) and Case Study II (Study 4).

3.1 Case Study I

Case Study I reported in this thesis was primarily concerned with automation technology as a content area in the whole field of technology. Thus, a more detailed and extensive rationale for teaching automation technology in general technology education is presented as follows:

Why automation technology in technology education?

Automation is a prevalent feature of the human made environment. It surrounds us every day and night. For example, thermostats control temperatures in homes, freezers, car engines, etc. A wide variety of other kinds of automated systems can also be found. They are all constantly operating on our behalf. Actually, our life would be essentially different without the help of automated systems. Advanced automation systems represent a level of capability and performance that surpasses our abilities to accomplish the same activities. Automated systems are used to control a variety of processes that ease, speed up, and enable many functions that are otherwise impossible, difficult, excessively repetitive, or even dangerous to ourselves (Norman *et al.* 1995, Suplee 1997).

The concept of systems thinking relates essentially to the principles of automated systems. According to the International Technology Education Association (2000, p. 39) “Systems thinking involves considering how every part relates to others”. Actually, automation is largely based on control and systems theory, which is not limited to technical systems only but also covers economic, biological, sociological, and other types of systems. As a matter of fact, probably the most sophisticated control systems are found in ourselves and other living creatures (Norman *et al.* 1995, p. 698). These are, for example, balancing when walking or cycling, as well as the system that regulates our body temperature.

When dealing with automation in a technical sense, computers are widely used as an implementation environment for control functions, as well as a tool for human operations and supervisory control of the system. Control systems are important features of automation technology. Basically, the control systems are divided into open loop and closed loop control systems (Norman *et al.* 1995).

Open Loop Control System:

The principle is that the system, having received an input signal, responds to it with an expedient function (output). The output variable is controlled by the input to the system, but it is not used for further control of the system. Thus, the open loop control system is not influenced in any way by the output. This kind of system is limited in that it does not make any adjusting action if the output is altered or incorrect.

Fig. 1. The principle of the open loop control system (Norman *et al.* 1995, p. 699).

Examples of an open loop control system would be a fire alarm that activates the alarm when the sensor detects a sufficient amount of smoke, or the ‘guard’ that switches on the lights if it detects any movement, say, in the vicinity of a house. A very simple example of the open loop control system would be an ordinary light switch.

Closed Loop Control Systems:

A closed loop control system functions in a self-regulating manner, meaning that the output is used for further control of the input by means of the feedback principle (Hacker & Barden 1988, p. 51, Phillips & Harbor 1988, pp. 1-3). Feedback is an essential feature of closed loop control systems allowing comparison of the output to the input in such a way that the relationships between the two can be used to control the desired function or to maintain the desired state. In this regard, the system is truly automatic.

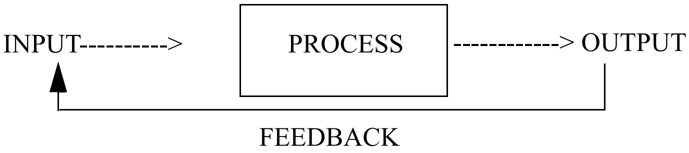

Fig. 2. The principle of the closed loop control system (Norman *et al.* 1995, p. 701).

An example of a closed loop control system would be the room temperature control system, in which the temperature can be kept within the desired limits using a thermostat. A car driver that is driving carefully at an even speed is another descriptive and practical example of a closed loop control system. The driver accelerates the car keeping an eye on the speedometer. If the speed of the car exceeds the desired limit, the driver throttles down and thus ensures that the speed remains within the limit. Similarly, if the car is running at less than the desired speed, the driver will accelerate to increase speed (see Hacker & Barden 1988, p. 51). Actually, from a technological point of view, the speed of a car can be set to remain constant by using the cruise control system.

In both of the systems it is essential that the system needs to sense, or feel, the input and consequently accomplish the expedient output functions. In this regard one of the essentials of the automated system is 'sensing the world around us" (Deal 1997, p. 11). Thus, the system needs sensors in order to sense the input. The sensors are literally the senses of the system.

In spite of the above-mentioned prevailing role of automation in the technological world, it does not belong to the core curriculum of Finnish compulsory education system. Thus, automation technology has not been accepted as a broadly agreed content area in the general education syllabus and it is not required to be taught in either primary or secondary education. This is the prevailing situation even though in the latest Finnish curriculum revision control systems were taken shortly into account within the framework of handicraft education (Opetushallitus 1994a, pp. 108-111). However, in many countries, automation with control systems has been regarded as a relevant content of modern technology education (e.g. Department for Education 1995, Norman *et al.* 1995, International Technology Education Association 2000).

Also, in Finland, the profusion of automation would be a fruitful background for making it authentic to the real life experiences of children. As indicated above, there are plenty of examples of automated systems to which children can be introduced.

Actually, automation is taught, with various interpretations on methods and contents, in some schools around the country. These schools have usually participated in special projects or have been otherwise active in developing their school syllabus further. The Haapavesi 'project' described below serves as one practical example.

Setting and Instructional Context

The Lego/Logo learning environment was selected for the project with the costs underwritten by a national electrical power supply company, Fortum Ltd. The materials and equipment were part of the Technic series of the Lego product line which includes sensors for light, touch, angle and temperature (Lego Dacta Control Lab 9701); the process interface connected to the computer serial port (Lego Dacta Multi-interface 8+8, 9751); and the Lego/Logo programming language software which allowed the children to write control programs (Lego Dacta Control Lab Software for PC Version 1.0). (Lego Dacta 1993b)

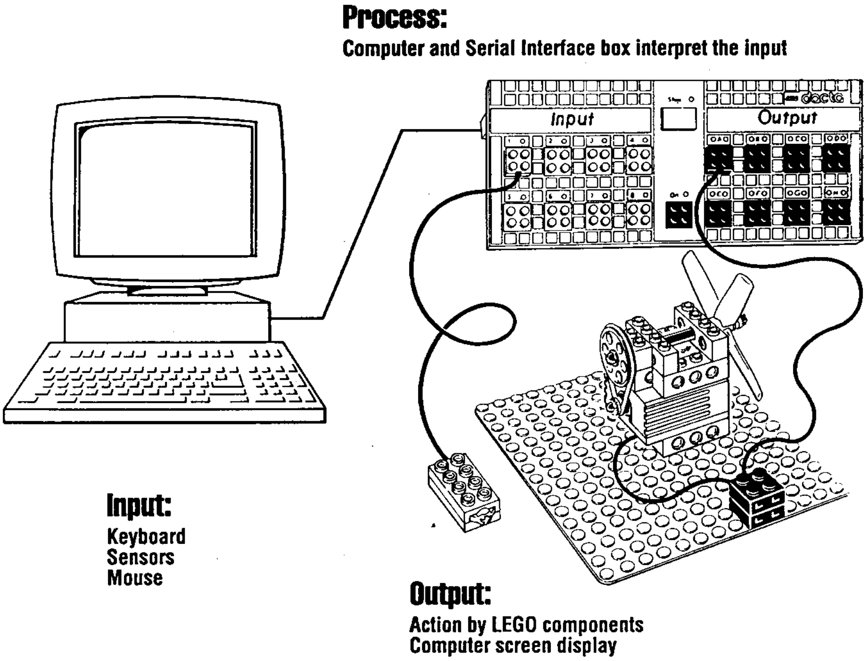

Fig. 3. Principle of Lego/logo-learning environment (Lego Dacta 1993b, p. 5).

The teachers who decided to take part in the project participated in a special in-service training session arranged at the end of the spring term 1995. Due to his expertise and previous experiences with the Lego/logo learning environment, class teacher Petri Lounaskorpi from Vaajakoski was invited to introduce and educate the group of Haapavesi teachers, including myself, to use the Lego/Logo learning environment. His contribution served as a good starting point. However, Case Study I was connected later to the larger context of developing technology education.

Teaching automation technology started at the beginning of the fall term 1995. All the classes were given similar instructions and arrangement and followed a similar class schedule. Children's work was arranged to fit into normal school routines by means of a workshop-like environment. The computer laboratory was reserved for the construction of projects. A work station was provided to each group and consisted of a computer (Intel 486-66 MHz), the Lego/logo Control Lab -materials, and adequate space to work. The children were given a handout sheet consisting of the main commands and some principles of programming. The handout sheet was designed by Lounaskorpi, but was later amended, by myself, with the third page explaining in a more comprehensive way the relationship between main- and sub-procedures. Importantly, the delivered handout sheet did not contain any design challenges, tasks or problems to solve (see appendix 1). Moreover, Lego Dacta manuals were put aside in order to avoid the children to copy and model ready-made outcomes and solutions.

I coordinated the setting up of the activities and also took part in the teaching together with the class teacher. However, my role was limited, because of the research interests, to that of a tutor in need, and the class teacher was mainly responsible for the children.

The children worked in groups of three to four and were assigned to the groups by the teacher based on diversity rather than pre-established friendships. Both boys and girls were represented in nearly every group. The practice was to follow the modern teamwork model whereby the members of a team have to cooperate in order to accomplish the given tasks (Mortimer 1996). While working in a group, however, the children were free to decide the assignment of roles, i.e., programmers and constructors. Moreover, social interaction in the groups was not controlled by the teacher, but was dependent on the children themselves.

In all, the children went through activities that consisted of four six-hour instructional time blocks. This time was taken from science with environmental issues, mathematics and technical/textile work lessons. Since the duration of one school lesson is 45 minutes, the effective working time was approximately 6 X 45 minutes = 270 minutes. During the first time block, the six hours were divided between three consecutive days. Thus, on each of these days the children had two hours to work on the project. During the second time block the working time was divided by two, making three hours during two consecutive days. Encouraged by the children's tenacity and enthusiasm to work, time blocks three and four were arranged during one day.

The work of the children was not required to proceed at a certain pace. There were no requirements for the children that they should have specific tasks accomplished within any given time limits. The children knew the overall time reserved for working in each of the time blocks, and they were free to decide how they used the time. In fact, the working groups did not progress at the same pace; some of the groups used more time on brainstorming and developing the idea, while others began to work almost immediately.

However, there were two occasions where the overall time in the time blocks was regulated more closely. Firstly, at the beginning of time block one, the children were given the task to construct a 'soapbox' car in twenty minutes. Secondly, the excursion to the local peat power plant was scheduled to last two hours.

The first three of the time blocks took place over a one-year period, i.e. from 1995 to 1996. Then, due to the continuing interest of the class teachers and partly because of my research interests, one more six-hour time block was arranged. It was carried out one year later in the spring term of 1997. This time the sixth grade from the previous year had already gone to the secondary school and did not take part. Thus, in the fourth time block the only remaining class was now in the sixth grade.

Time block one: At the beginning, the children were told about the experimental project and its general aims, i.e. to make children familiar with some essential features of modern automation around us. After the introduction the children were divided into their working groups. The Lego components of the learning environment were introduced through a competition to construct a Lego 'soapbox' car which runs as quickly as possible. Once this was complete, the children moved to the computer lab where the Lego/Logo- learning environment was shown as a whole system. The handout sheets described above were distributed. The children were then allowed to investigate freely the possibilities of the learning environment.

Time Block Two: The children visited a local peat-fired power plant. They investigated the functions of the main gate of the plant and the peat conveyors. The rest of the time was spent in the computer laboratory. The visit to the peat plant yielded a theme for their work. Instead of making just a model, they were encouraged to use their creativity and imagination to improve on what they had seen. The gate appeared to be a particularly fruitful source for authentic problem solving, as it was seen not to function well in a snowy winter. The conveyor belts and the gate were then used as a theme for the work at school.

The above-mentioned case of the gate authenticates the perspective that in technology there are no right answers, but rather, more or less appropriate solutions. However, the "gate problem" was more like an incidental, albeit effective and descriptive example of a task which should be given to the children to adjust teaching methods according to the nature of technology.

Especially in the following time blocks, theoretical considerations about more appropriate teaching approaches to technology education are taking more tangible and practical forms.

After participating in the above mentioned activities, the children were supposed to get rather familiar with the possibilities of the Lego/logo -learning environment. In subsequent time blocks the tasks given to the children allowed them to explore more their own needs and wants, for example to notice problems in their own everyday living environment that need to be solved (Amram & Brick 1996). They were allowed to work almost entirely on the basis of their own needs without ready-made answers, 'the truth', found in the teacher's manuals or answer books. Consequently, the children were expected to experience a feeling to "own" the task at hand (see Savery & Duffy 1995) and make the work meaningful and significant for them.

Time block three: The children were given an open-ended design challenge. This time their challenge was to design and build a system that would enable a pet to survive at home while the family was away on vacation. Even the teachers did not know beforehand what the groups might accomplish. Consequently, there were no predetermined right answers or solutions. Rather, the viability of the solution was relative to what the children knew about the needs of their pets as a priori process knowledge.

Time block four: The children were given a short imaginary notice that there are burglars going around in the town. There was some emphasis on the fact that the burglars are also a reality and occasionally encountered. Then, children's personal concerns were raised by asking them to think their own home was to be robbed. The children were expected to know their home conditions and needs best, and by raising their personal concern they were expected to be emotionally engaged in problem solving (Lave 1988). Like in the previous time block, the children were told that there are no wrong answers to the problem, but rather only appropriate solutions (Lampert 1990). They were encouraged to use their imagination and creativity without concern of being submitted to the traditional school evaluation practices. Again, viability of the solution was relative to what the children knew about the needs of their home as a priori process knowledge (Järvinen & Hiltunen 1999, 2000)

There were no tests administered before, during, or after the study. It was assumed that multiple kinds of qualitative data collection would provide enough information relative to the research problems. Moreover, this procedure was believed to enhance the motivation and relaxation of the children and thus supported the "authentic" nature of the work void of expectations connected with the study or traditional school evaluation. (Patton 1990, Honebein *et al.* 1993).

Participants

Six classes in all from the Haapavesi Central Primary School took part in the activities. These were all classes from the fifth and sixth grades, making six classes altogether. However, not all the classes were submitted to the research purposes. Case Study I consists of four classes: two fifth-grade and two sixth-grade classes (the total number of children was 90; 45 boys and 45 girls). The rationale for this procedure derives from the nature of qualitative inquiry, where the methods usually produce an affluence of detailed and in-depth information about a relatively small number of people (Patton 1990).

3.2 Case Study II

Setting and Instructional Context

The study itself - a Design and Technology Education project in Finland and UK:

The children's technology experience in designing and making a 'sound device' was explored by means of a mutual decision by the authors to use the Nuffield Primary Design and Technology Project materials (Twyford 1997) in a UK and a Finnish context.

The two teaching contexts took as their standard idea that of encouraging the children to make use of sound for a purpose. However, as noted, due to the different cultural and curriculum interpretations of this teaching and learning project, several different teaching interpretations occurred. Both groups were taught the everyday physics of sound, and both groups provided opportunities for children to play their own part in the making of devices, including reviewing an assortment of existing rattle designs. The choice of design routes was the major difference between the groups.

The Finnish context:

In Finland the project was introduced to Vattukylä Primary school, located in the Township of Haapavesi. The study included pupils, aged 11-12/ grades 5-6. It was arranged to fit into a normal school routine and workshop facilities. The researchers agreed with the head teacher Risto Klasila to apply an open-ended teaching approach to the Finnish side of the study. Firstly, the formal concept of sound was taught through open discussion of the nature and physics of sound. From this work the children were directed to explore where sound could be used purposefully. Importantly, pupils were challenged to use their knowledge of 'what sound is' and 'how it is made'.

The teacher then presented the open brief: "You have to create a mechanical device, which makes a loud noise for a given purpose, and the construction should be easy enough to use by only one hand." Throughout, the teacher negotiated with each pupil about their ideas. Also, during classroom discussions pupils presented their ideas to each other.

The UK context:

The UK teaching used the UK National Curriculum concerning how pupils develop their D&T capabilities through ".... focused practical tasks in which they develop and practise particular skills and knowledge." (Department for Education 1995, p. 2) The project also incorporated a design and make activity for pupils to create a noise maker from found materials as a precursor to discussing how sound is used purposefully.

This task was timetabled to be an opportunity to learn basic craft skills in handling resistant materials, within the ambit of the formal curriculum. As a focused task it involved acquiring making skills and the notion of the logic required in product component assembly, especially prior to decorating the rattle product.

In the UK project discussion of making something to create a noise for a special purpose was based upon pupils using the term rattle. Thus, the term rattle was used as a form of synecdoche to mean a range of devices which makes a noise for a specified purpose. This applied to the personalised design created by each pupil whereby the ‘rattle’ was made up from sliding components which banged together to make a sound.

The teaching goals of the study were to develop pupils' D&T capabilities, and for them to grasp the meaning of technology in their everyday lives, especially so that their work was authentic in character by making something which worked in a particular way for a given purpose.

4 Method

4.1 Methodological perspective

Constructivism and socio-cultural theory as a background for teaching strategies in both of the studies also had an influential role in the whole research process. The socio-cultural constructivist perspective relative to learning enables a theoretical background that draws on both constructivism and interpretivism. Constructivism and interpretivism aim to understand the meanings constructed by the children taking part in context-specific and socially situated activity through social interaction (Schwandt 1994). This theoretical background required that the methodology of the study take into account the actions of individual children toward others and also toward physical objects in the socio-cultural context, the social interactions between the children, as well as the context and substance of the actions and social interaction.

4.2 General methodological overview for both Case Studies

All the research on which this thesis is based was developed according to the nature of qualitative inquiry. It was based on the notion that there is no human behavior and characteristics that can be predicted and generalized. (Borg & Gall 1989) Contrary to the natural sciences where research assumes general laws to determine phenomena, qualitative educational research, dealing with complex and sometimes even irrational actions of humans, cannot rely on any kind of 'set of laws'. As a matter of fact, even in the long and dominant history of positivistic educational research, search for laws that would completely determine human behavior has not been very successful, not to speak about predicting and controlling educational situations. (Carr & Kemmis 1986)

In the naturalistic inquiry, also known as ethnographic research, human actions are interpreted always to happen in the specific context of time and place (Guba & Lincoln 1988). Moreover, human behavior and actions gain significance only through the insights of how the participants have understood the situation in which they act, including what their motives, goals and aims are in the process. (Erickson 1986, Guba & Lincoln 1994, Rogoff 1990) Since the research was carried out in the school environment within the context of teaching technology and the researcher ‘immersed’ himself in the natural setting it can be understood to be parallel with the characteristics of qualitative inquiry (Sherman & Webb 1988).

This research report did not produce an affluence of statistical data from a large research sample, but rather, enabled researcher/s to study selected issues in depth and detail amidst a relatively small group of children (see Patton 1990, p. 13). Neither did this research make use of specific measurement instruments or pre-determined imposing categories upon the observations of actions and happenings taking place in classroom settings (Hitchcock & Hughes 1989). In this thesis, the researcher himself is the instrument and therefore the credibility of this whole report hinges to a great extent on his personal skills and competencies to do qualitative inquiry (Patton 1990).

The requirements for the instrument, the researcher, are also stated by Guba & Lincoln (1988):

> The naturalist prefers humans as instruments, for reasons such as their greater insightfulness, flexibility, and responsiveness, the fact that they are able to take a wholistic view, are able to utilize their tacit knowledge, and are able simultaneously to acquire and process information. (p. 83)

In short, this research report stands on my personal capabilities to carry out this type of research practice. This also means that although other researchers have been involved in the process, in the end I am wholly responsible for the thesis and its results.

In general, the whole research process can be defined as an action research. The starting point was an apprehension about the need for a revision of the pedagogical approaches to technology education. (see Syrjälä 1995) During the research process I was aiming to develop my understanding about the subject matter and prevailing theories of learning in order to make appropriate connections concerning technology education in praxis. (Cohen & Manion 1986, Kemmis 1988, Altrichter *et al.* 1996) A starting point also for this research process is aptly described by Hustler *et al.* (1986, p. 73): ”...the motivation for action research is personal....The teacher’s sense of dissatisfaction or frustration with certain aspects of the existing situation is the starting point.”

The fieldwork of the research was done within two Case Studies: Case Study I to teach automation technology and Case Study II to explore rattles and noisemakers. Both of the Cases served as a fruitful field connection for the research and, actually, they became a joint project between the practical field and the University, providing valuable cases of authentic educational context (Syrjälä 1995). Moreover, both of the Cases provided a valuable data source for the research and, on the other hand, insights of the research process contributed to new perspectives on technology education in practice, as well as on curriculum development (Stenhouse 1988).

The *case study* approach enabled the researcher/s, in the role of a teacher as an action researcher (Carr & Kemmis 1986), to investigate authentic classroom activity in depth and detail (Stenhouse 1988, Patton 1990), and as a corollary of this, to experience educational practice in its full-fledged unpredictable complexity.

Bell (1993) describes the case-study method as follows:

> The great strength of case-study method is that it allows the researchers to concentrate on a specific instance or situation and to identify, or attempt to identify, the various interactive processes at work. These processes may remain hidden in a large scale survey but may be crucial to the success or failure of systems or organizations. (p. 8)

Typically to the qualitative case study approach, both of the cases reported herein are unique in nature. They are characteristically singular, specific instances and cannot be re-generated. Thus identical situations are impossible to arrange any more, only ones that might bear some similarities. (Golby 1999, Bell 1993)

Also, due to the fact that the research was conducted in a natural educational setting it can be claimed to have features of the field research approach (Wiersma 1986, also Le Compte & Preissle 1993). Because of this approach it was possible to explore the children's use of context-specific language while working in socially interactive settings. Moreover, it provided insights to that particular process whereby the aim of the teaching was to educate the children about and through technology.

4.3 Data Collection

Characteristically of the field work of qualitative case study, the multiple and extensive data gathering procedures were applied in order to provide a fruitful, in-depth database (Stenhouse 1988, Borg & Gall 1989), which was subsequently submitted to an interpretative analysis process (Erickson 1986, Cohen & Manion 1986). The data gathered appeared to be rich in nature; close to the real world of teaching and containing in-depth information which actually was not visible at first glance (Sowden & Keeves 1988). In this sense the data first emerged like the fuss of a great city, full of different actions taking place and an amass of detailed information seemingly chaotic in the first place, but gradually, during the course of the analysis, taking more understandable and comprehensible forms.

I assumed, especially in the Case Study I, the role of a participant observer and actually engaged in practical teaching in the role of a 'tutor in the need'. This procedure enabled me to be in the midst of school activity and carry out data collection from "naturally occurring, ordinary events in natural settings" (Miles & Huberman 1994, p. 10), true to the nature of qualitative research (Erickson 1986).

In data collection I was interested to establish answers to some of the questions stated by Borg & Gall (1989):

> *What* are the people in the group or scene doing and saying to one another?
>
> What is the content of their conversation? What language do they use for communication, both verbal and nonverbal? What formats do the conversation follow? What processes do they reflect?
>
> What physical setting and environments form their context? What (natural) resources are evident and what technologies are created or used? (pp. 394-395)

In the analysis, the broad ideas in above-mentioned questions were ‘narrowed’ and contextualized by the influence of theoretical considerations contributing to the research interests. Consequently and finally, the whole database was analyzed by using stated research questions as a kind of lens in order to put the focus on the process. (see Figure 4)

4.3.1 Data Collection in Case Study I

All the studies within Case Study I focused mainly on small-group social interaction and its effects at the individual level. Therefore, I aimed the data collection procedures at capturing children’s social interaction and actions in small-group settings. I collected data by means of group observations documented in videotaped recordings, written field notes and also as project files saved by the children. In this way, the data are all about the activities the children went through during the experiment. The data were collected in accordance with the idea of “local groundedness“, that is, the collection was carried out in the actual place where the activity occurred (not through mail or phone, for instance) (Miles & Huberman 1994). Importantly, the data does not contain any exams or reports written by the children, but rather reveals spontaneous activity itself. The aim of the data collection was to document the whole working of the children as authentically as possible.

Primary data source consists of video recordings. Video recording was chosen to be a primary medium of data collection because of its capability to document both audible and visual information in a rather detailed manner. Moreover, in terms of video recordings the data was thought to be quite accessible, i.e. it is rather easy to view the tapes again. Video recordings were aimed at several working groups in the first time block, but in the second, third and fourth time blocks video recordings were aimed at a single group throughout the time block. In each class, one group’s work was selected to be recorded as a whole, continuous process in the second, third and fourth time blocks.

Thus, the other groups were not video recorded during the process in the time blocks two, three and four. However, when all the groups had to present their outcomes to whole class at the end of the time block, all the presentations and outcomes were documented as carefully as possible. The groups selected to be video recorded during the process were not chosen on the basis of their expected better performance, skills, knowledge, etc. compared to the other groups. Rather, the randomly chosen groups consisted of ‘ordinary’ children.

In the first time block the groups that were video recorded worked among the other groups in the computer class. Due to overall turmoil in the class, in the second time block the video recorded group was separated from the other groups with a partition. In order to make the capture of video recording even more sensitive, in the third and fourth time blocks the group that was video recorded was separated totally from the other groups by being placed in an empty classroom.

In spite of the above-mentioned procedures, the video recorded groups did not have any privileges; they were given similar instructions, they had the same materials and equipment, and importantly, they were not required to work harder or better than the other groups.

The field notes were written on all of the groups in the time blocks one, two and three. I visited every group several times during the time blocks. Equipped with paper, a pen and a dictating machine I observed, listened to and interviewed the group members, and occasionally even participated, if needed, in the group's process, true to my role as a participant observer and tutor in the need. I documented these experiences in the field diary, mainly at the end of the day, but sometimes even during the day. The dictating machine recordings were transcribed in order to support the diary entries.

In the fourth time block the data were collected in terms of similar video recording procedures as in the previous time blocks. The dictating machine was also used to make quick notes during the groups' work. However, from the fourth time block I did not write a field diary any more, because I thought video recording and the dictating machine would provide enough information. Actually, in retrospect, I consider the dictating machine to be a much better medium to create the field diary in an audible form, which if needed can also be easily transcribed into a readable form.

Moreover, in the time blocks two and three almost all of the groups' project files, including the written programs, were saved on the hard discs of computers and subsequently copied to floppy discs. These saved project files supplemented essentially the video recorded information collected from the presentation rounds at the end of each time block.

The data gathering methods developed during the course of the research. For example, I did not use the dictating machine in the first two time blocks, but introduced it for the last two. And, from the second time block onwards I numbered the working groups with stickers on the computer cases. Because of this, it was much easier to refer to the work of a particular group.

However, there were situations that caused unexpected difficulties when collecting data. For example, some of the groups shut down their computers before I had requested them to save their project files. And, sometimes the class worked overtime which consequently caused busy and hectic presentation round at the end of time block. When some of the children, for example, were worrying that their school bus was about to leave in five minutes, it was impossible to ask the whole class to be patient while I was setting up the video camera to make it ready for the next group's presentation. In spite of these difficulties, most of the group's activities were documented according to the original plans. Moreover, it was helpful that other data sources effectively supplemented the lost data.

Observational field notes, together with the dictating machine recordings and the groups' project files, formed secondary data sources. Secondary data sources were then used to supplement the information in the primary data source. They also enabled me, together with my colleagues, to have a profile of activities within all the groups and not just within the video recorded group. Thus, to enhance the credibility of the research, multiple data collecting sources and strategies were employed in accordance with the concept of triangulation (Miles & Huberman 1994).

4.3.2 Data Collection in Case Study II

Case Study II involved direct observations of the children in action and employed a search for how children brought their previous experiences to the making of the sound producing device (Patton 1990). Therefore, data collection procedures were aimed at empirically observing what the children did for the given problem, at the individual level, as well as including actions taken in small-group settings.

Data were collected by means of the teacher's written reports of the project, photographs of the pupils' final outcomes, including pupils' design folders and product evaluations, teachers teaching notes, teacher's lesson evaluation notes, the researcher's field notes based upon observations. Moreover, in a Finnish side of the study data were also collected by means of videotaped recordings and, due to the more open problem solving approach, by a questionnaire where the pupils were asked to answer the following questions:

i) What did you make?

ii) Why did you make it?

iii) Where did you get your ideas from?

The researchers assumed the role of impartial participant observers. This procedure enabled the researchers to be 'inside' the study, true to the nature of qualitative research (Erickson 1986). The researchers' participation was further reinforced by the means of qualitative data gathered from the study, especially in terms of video recordings.

Also, in this study there were no tests administered before, during, or after the treatment. It was assumed that multiple qualitative data collection would provide enough information relative to the research problems. Moreover this procedure was believed to enhance the motivation and relaxation of the pupils and thus supported the 'authentic' nature of the work, separate from expectations connected with the study or traditional school evaluation (Patton 1990, Honebein *et al.* 1993).

4.4 Data Analysis

4.4.1 Data analysis in Case Study I

Video recordings were transcribed from the viewpoint of the research focus, i.e. situations in which the students spontaneously generated problems related to the contents of automation technology. The situations in which mathematics or science were used as tools in technological problem solving were also included in the transcriptions. During the transcription process, irrelevant data, such as discussions about 'boy and girl friends', were excluded (Miles & Huberman 1994). All the names in the transcriptions were treated as pseudonyms.

Verbatim transcriptions derived from the video recordings were combined with the secondary data sources. Secondary data sources were used to supplement information in the search for emergent patterns in the data. In all, combined primary and secondary data sources constituted the data corpus. I focused, together with the contributing co-researchers, the analysis process on socially interactive settings where the children worked spontaneously with some essential principles of automation technology, as well as mathematics and science. Moreover, the theoretical issues about learning and teaching presented in this thesis were also in the point of the research interest.

During the first round of analysis I began to form an idea of the emergent phenomena relative to the theme of the research (LeCompte & Preissle 1993). In subsequent analysis rounds the data corpus revealed more organized, pervasive patterns from the viewpoint of automation technology (Study 2) and from the viewpoint of mathematics (Study 3). These emergent phenomena indicated that the children were spontaneously dealing with some essential features of automation technology and mathematics. This prompted me, together with the contributing co-researchers, to investigate the data further in order to specify these emerging features. At the final stage of the analysis, emergent findings were specified in to detailed classifications of the content of automation technology and mathematics, supported by the illustrative data examples with interpretations (Järvinen 1998).

During the analysis process we were continually open to re-explore the relationship between data and emergent findings and making revisions correspondingly. I was helped substantially by the colleagues, and we discussed and shared thoughts on several occasions. Data examples presented in this research were analyzed both individually and also in collaborative discussion in which the final interpretations were developed. (see Ritchie & Hampson 1996) Finally, the analysis reached the stage where it was considered that the whole data corpus had been investigated sufficiently from the viewpoint of research problems. From this point of saturation we went forward to present the results with interpretations.

4.4.2 Data analysis in Case Study II

The study's methodological perspective was continually open to review. This is consistent with qualitative analytical techniques concerning the relationship between data and research issues, as well as a contributor to the continual revision of the assertions emanating from the study (Ritchie & Hampson 1996). It involved direct observations of the children in action and employed a search for how children brought their previous experiences to the making of the sound-producing device (Patton 1990).

Verbatim transcriptions were derived from the initial viewing of the videotapes and were combined with the observation field notes, as well as other data sources. During the transcription process, irrelevant data were excluded, such as children talking outside of the project (Miles & Hubermann 1994).

During the first viewing of the data the researchers formed ideas about the emergent phenomena in the form of tentative assertions formulated throughout the course of the analysis, and were confirmed to be presented as concluding results (Ritchie & Hampson

1996, p. 394). In this regard the analysis process was similar to the analysis in the Case Study I. The structure of the research process in both of the Case Studies is illustrated in Figure 4.

4.5 Triangulation

The idea of triangulation derives from navigation techniques to use several location markers in order to pinpoint a single objective. According to Cohen & Manion (1986, p. 254), in social sciences triangulation “attempt to map out, or explain more fully, the richness and complexity of human behavior by studying it from more than one standpoint“. In qualitative research triangulation aims to enhance the credibility and validity of the results. Altrichter *et al.* (1996, p. 117) say that “it [triangulation] gives a more detailed and balanced picture of the situation.“

In the research process on which this thesis is based, triangulation was achieved mainly through two kinds of ways. Firstly, so-called data triangulation was achieved through multiple data collecting, sources, procedures and strategies. These various sources and procedures were explained for both of the Case Studies in chapters 4.3.1. and 4.3.2. (Miles & Hubermann 1994, Wiersma 1986)

Another kind of triangulation that was applied during the research was the concept of researcher or investigator triangulation. Since the data was analyzed through shared expertise of other researchers, the final interpretations are outcomes of an interactive and collaborative process. However, the data were analyzed both individually and also in the collaborative discussion where the final interpretations were developed. For example, in Study 2, Jukka Hiltunen independently viewed the examples I had already analyzed and contributed with new perspectives and insights into the interpretations. He wrote his contribution input directly to the interpretations and e-mailed the text back to me. Renewed interpretations were also discussed and agreed on collaboratively. In this way, my initial misinterpretations and misconceptions were corrected. The data also revealed interesting phenomena that I would not have been able to realize by myself. (see Ritchie & Hampson 1996) The results of collaborative data analysis were also submitted to the scrutiny of (journal) reviewers, thus allowing even more ‘investigators’ to take part in the process of interpretative analysis. (Denzin 1988)

4.6 The structure of the research process

The following figure illustrates the research process that I have gone through together with my colleagues. Importantly, the figure has emerged as a coherent diagram as a result of the overall research. (cf. Lindh 1997, Erickson 1986)

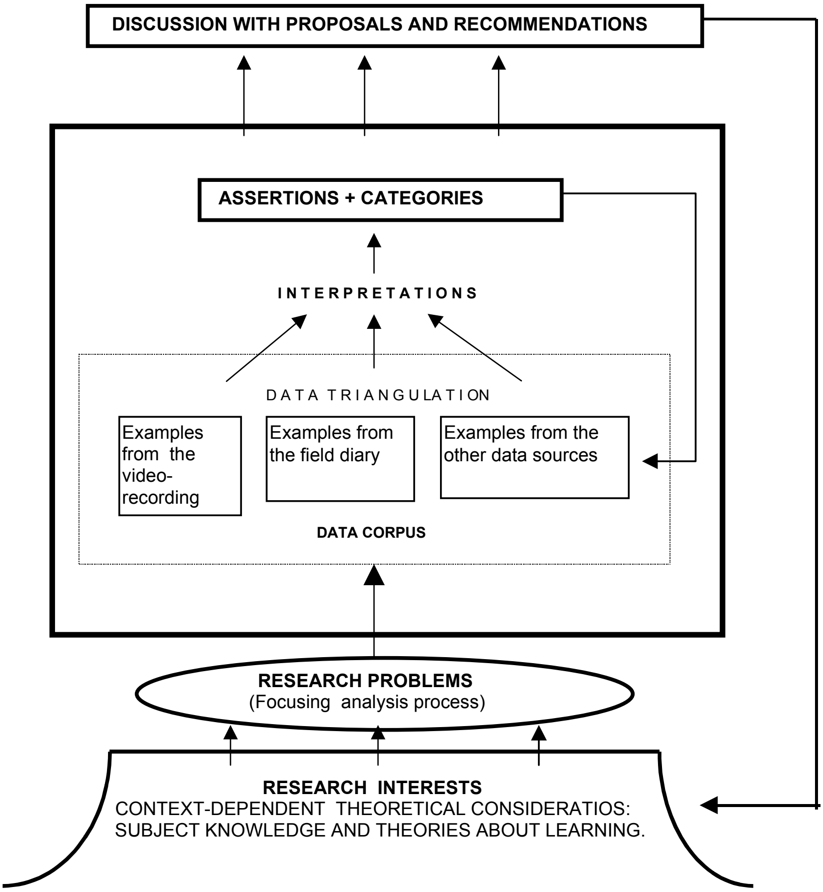

Fig. 4. The structure of the research process.

The contents and structures of the above figure are strategically placed throughout the thesis. For example, my research interests were influenced both by the breadth of the subject knowledge, as well as by my considerations of the theoretical issues in current learning concepts. The collected data corpus was analyzed from the viewpoint of the specified research problems. The results, together with my/our interpretations, are found in chapter 5. The discussion (chapter 6), together with the proposals and recommendations, concentrates on the issues arising from the whole research process. Thus, the discussion can be regarded as a main outcome of the research on which this thesis is based.

In all of the studies reported herein, the data was investigated through a context-dependent theory. This context-dependency means that technology was considered as a distinct subject matter for educational purposes. In this respect, the method was not entirely a data-based inquiry, because the analysis was also guided by certain assumptions and stated research problems. (Patton 1990, Syrjälä *et al.* 1994, cf. Glaser 1992)

The theoretical background and my research interests are identified as influential factors in the data interpretations, as epitomized by LeCompte & Preissle (1993, p. 267): "Interpretation of data varies according to the purpose of the study, its conceptual and theoretical frameworks, researcher experience and background, and the nature of the data collected and analyzed."

I regard this model as a useful guiding tool, and it will also be pertinent when structuring similar research endeavors. Moreover, I regard it as an important outcome of the research process, because I think it provides a useful structure to carry out qualitative research through interpretative, data- based analysis techniques.

4.6.1 Specification of research questions

The focus of the inquiry varied in the four studies presented in this research thesis. However, due to the previous theoretical considerations similarities can be found in the questions. Thus, all the questions are shortly discussed from the perspective of the theoretical considerations presented in this thesis. In this way the reader can see how the previous considerations have influenced the specification of the research question.

The specific research questions of each study are presented as follows:

Study 1:

The study was directed by the following main questions:

1) to what extent do primary level students spontaneously generate problem solving situations and thereby create possibilities for the transfer of knowledge and skills within a group? and,

2) to what extent do primary level students learn technological content?

Secondary questions included:

1) to what extent and in what way does group work include the elements of science and mathematics? and,

2) what is the contribution of the teacher in group-oriented learning environments?

The key word in the above main question number 1 is "spontaneously". Importantly, it indicates that teaching technology should not merely follow detailed instructions and prescribed solutions or answers to design problems, but that it should be characterized by a more open approach in the spirit of authentic and spontaneous technological inquiry.

"Transfer of knowledge and skills within a group" indicates the importance of social interactions in learning processes. The main question number 2 is concerned with the technological content to be learned by the children. The content in this case was automation technology, although "automation" was not yet mentioned. In spite of the value of openness in instruction, activities in technology lessons should not be aimless or without direction. Rather, children should be made aware of the technological ideas and subject matter to be learnt.

The secondary question, which refers to number 1, indicates the widely agreed notion that science and mathematics are important areas in a contemporary technology education and need to be taken into the consideration accordingly. The secondary question, number 2, explores the role of the teachers in a group-oriented learning environment. The question begs further questions concerning the role of the teacher: Are they needed and importantly, what is their role in children's learning in technology?

Study 2:

1) What contents of automation technology spontaneously emerge in the children's work while they work in groups, at solving problems from their own living environment?

2) How successfully do the children solve problems that involve automation technology?

Due to the progress in the research process, "automation" is now mentioned as a focused subject matter of the Study 2. Moreover, further theoretical considerations about the nature of technology have been influential in the formation of the latter part of the question number 1. The wording "…solving problems raising from their own living environment?" indicates the true need for authenticity in technology education. Due to the theoretical considerations of this thesis, it is also essential that the children experience technology as a response to the human needs, wants and purposes, rather than responding to technical, factual issues alone.

The second question of the Study 2 focused on successful problem solving outside the traditional notion of school evaluation. Successful learning is in the focus, especially in activities where the design solutions or product outcomes are not predetermined. The wording "How successfully…" refers to the functionality and appropriateness of the solutions in relation to the specific problems formulated by the children themselves. In both of the questions the content of automation technology was in the focus, as the purpose of the whole Case Study I was to familiarize the children with the world of automation.

Study 3:

1) What contents of mathematical-subject matter spontaneously emerged in the children's work while they were working with automation technology?

2) How successfully the children solved problems which required mathematical thinking?

The formation of the research questions in the Study 3 resembles the questions in the Studies 1 and 2. However, mathematics was not 'secondary' (as it was in the Study 1) any more, but the main issue of interest in this particular study. This study focused especially on how children naturally and spontaneously used mathematics whilst dealing with automation technology.

Although it is not directly obvious in the first question, the children were (as they were in the Study 2), solving problems arising from their own living environment. In this regard the possible appearance of mathematics was not emphasized to the children. Rather, they were expected to encounter naturally some mathematical ideas during their (automation) technological problem solving. This expectation arises from the notion that technology and mathematics are in many ways connected and this should be taken into account in technology education as well.

The question number 2 was intended to reveal information about children's successes in problem solving in situations containing mathematics. In this regard the success was not achieved by solving mathematical problems per se, but by applying mathematics to functional and appropriate solutions situated in the children's own living environment.

Study 4:

> How the socio-cultural context of pupil's learning, which includes the effect of teaching, contributes to pupil's personal D&T outcomes, with special regard to the meaning and value of open problem-solving in D&T learning?

This research question includes essential issues which were prevalent throughout the thesis. Firstly, the question points out to the meaning of the socio-cultural context, to which the school environment and teaching are also considered to belong, possibly contributing to the child's personal outcomes in problem solving. Actually, the question was devised to illicit information about the processes involved in personally constructed knowledge, skills and experiences from the socio-cultural context in which they operate. In this regard the question refers to the essential role of constructivism as a background for pedagogical considerations in this thesis.

Secondly, the latter part of the research question: "…with special regard to the meaning and value of open problem solving in Design & Technology learning" reveals again how open problem solving had an essential role throughout the whole research process.

5 Summary of the results

The results of this research are based on the findings of the four studies reported unabridged at the end of this thesis (Case Study I: Studies 1, 2 and 3; Case Study II: Study 4).

The inductive interpretative analysis process used in both of the Case Studies enabled the results to be framed as empirical assertions, with data as evidentiary warrants(Erickson 1986) including more detailed content classifications of automation technology (Study 2) and of mathematics (Study 3). Throughout the results the assertions as well as the classifications are supported by evidentiary examples taken from primary and secondary data sources (Miles & Huberman 1994). Examples are also “microanalyzed“ in terms of Interpretations/Comments in order to clarify the interpretative analysis process. (Erickson 1986)

The information in the examples overlaps considerably throughout the classifications. In spite of this, it has been chosen to present the classification and microanalysis. Generally, the examples illustrate information contained in all of the data that I, together with my colleagues, went through during the analysis.

The purpose of this chapter is to present the results as a summary. Thus, not all examples with interpretations are presented in this chapter. However, all examples and interpretations are to be found in Studies 1, 2, 3 and 4. Moreover, further reflection on some of the results will be provided. This does not mean that the results presented in the four studies are invalid. Rather, retrospective thoughts are intended to add to the depth and quality of my argument.

At the end of each example there is an indication of the data source from which the example was taken. All of the data corpus has been stored and is available if required.

The results taken from the studies are indented to make them clearly distinct from the other text.

5.1 Case Study I

The following three chapters summarizes the results of Case Study I:

5.1.1 Study 1. The Lego/logo Learning Environment in Technology Education: An Experiment in a Finnish Context

This study has been published in the *Journal of Technology Education (1998 9(2))*. It can be regarded as an introductory report of the Case Study I. The results in this study are presented generally. At this stage of my argument there are no detailed classifications of the contents of automation technology and of mathematical or scientific subject-matter.

The results of the Study 1 are as follows:

> *Assertion 1. (Main problem 1 and Secondary Problem 2)*
>
> *The working of the pupils was controlled and guided mostly by themselves and the teacher's role was more like tutor and adviser as needed.*

Table 4. Emergent Categories and Operational Definitions.

Categories	Definition
Actors	Pupil as an individual actor or the pupils in mutual social interaction. Includes also the teacher or the researcher participating in social interaction.
Technological content	Content consistent with the theme of the experimental project.
Mathematical-scientific content	Content emerging from the group work as a natural tool to solve technology-related problems.
Group action occurrences	Discourse, mainly verbal, but also includes other noticeable action, which focuses on technological, or scientific content. Also includes the pupil's independent action on behalf of the group and the final accomplishment (see Vygotsky in Wertsch and Toma, 1995, p. 163)

Table 5. Number of Group Action Occurrences by Time block: Teacher or Researcher Not in Group (TA) Versus Teacher in Group (TP).

	Time Block 1		Time Block 2		Time Block 3	
	TA	TP	TA	TP	TA	TP
Technological Content						
Pupil Acting Alone	5	9	19	2	23	8
Pupil to Pupil Interaction	20	9	45	11	45	21
Pupil to Pupil to Pupil Interaction	2	1	20	10	11	15
Mathematical-Scientific Content						
Pupil Acting Alone	1	3	0	0	3	3
Pupil to Pupil Interaction	7	6	3	1	10	5
Pupil to Pupil to Pupil Interaction	5	1	1	0	1	1

> The data in Table 5 clearly show that during the project work the pupils tended to handle technological and mathematical-scientific content mostly by themselves. This phenomena is especially obvious in action with the technological content and leads to the second assertion. (Järvinen 1998, pp. 52-54)

In order to clarify the rationale behind the use of the above tables the following explanation is presented:

During the first viewing of the video recordings, I began to form an idea of the emergent categories relative to the theme of the study. The resultant categories are reported in Table 4. The formation of these categories helped me to make the research process much clearer and structured. Moreover, and importantly, the categories were used to develop a matrix into which the number of Group Action Occurrences (GAO hereafter) could be logged during the subsequent rounds of data analysis.

One GAO stands for a one noticeable action occurrence between the children (TA) or between the teacher/researcher and the children (TP) that focused on technological or mathematical-scientific content (see the definition of the GAO in Table 4). Importantly, these occurrences are presented in terms of examples taken from the video recordings. One example stands for one GAO.

While logging the GAO, time was not the most important criterion. The most important criterion was that the logged GAO included either technological or mathematical-scientific content. As was written previously, the working of the children was not required to take place at a certain pace. The children knew the overall time reserved for working and they were free to decide how they used the time. Thus, there were periods in the children's working which included only a few GAOs. On the other hand, a lot of activity could take place within relatively short periods of time.

Table 5 reveals the tendency for spontaneous child-'centeredness' in the project. This in itself can be said to be a result on its own right, for the use of a child-centered approach does not necessarily guarantee that the children are really doing something meaningful and important independently. The assertions and examples below demonstrate the GAOs logged in the table, and importantly, with the preliminarily emerging technological and mathematical-scientific content.

I think that the table presented above was a kind of quantitative diversion from a qualitative research process and I decided to limit its use to this study only. The results below, as well as the results of Studies 2 and 3, are more like outcomes of inductive, interpretative analysis. It is not any longer the amount of activity, but rather the meaning of the activity that is in the point of interest hereafter.

> *Assertion 2. (Main Problem 2.)*
>
> *Technological content spontaneously handled by the pupils consisted of the elements of control technology, system planning, and at least rudimentary programming skills; this content can be commonly understood and transferred among the pupils acting in the social interaction.*
>
> The following example illustrates the situations where the pupils handled the content in accordance with the above assertion.
>
>> Ulla is sitting in the front of computer and says: "Now we have to write those commands...motorb.." Kati advices Ulla and says: "Talkto motorb!" Ulla begins to write and speaks to herself, "Talkto.." Now Kati interrupts and writes

> the quotation mark in the right place (Talkto "motorb) and then she begins to ponder the connections made in the interface: “Motorb...is it really motorb?“ Now the third member of the group, Juuso, says: “It’s motorc“ Kati investigates the wires and agrees with Juuso: “Yes it’s motorc...hey Ulla it’s motorc!“ (Time block two; 5.B-class, 5th group. Transcription from the video recording)

Interpretation
Ulla evidently understands the meaning of the commands in order to get the desired functions out of devices connected to the output section of the interface. Kati seems to know better the syntax of the programming language and thus helped Ulla in her writing. The whole group is involved in attempting to get the motor to operate in the desire manner. (Järvinen 1998, p. 54)

The above example and interpretation can be said to be in accordance; the example is a direct referent for the interpretation. However, the interpretation could have referred more to the assertion 2. Apparently, the general problem seems to be that the claims stated in assertion 1 are not very well substantiated in this particular example, nor in other examples intended to support assertion 2.

Assertion 3. (Secondary Problem 1.)

Mathematical-scientific content appeared to be used as a tool in technological-oriented problem solving and it was naturally applied by the pupils.

Considering mathematics, the focus was now only in situations where the pupils used arithmetic. Although situations dealing with higher order mathematics concepts such as spatial perception, proportionality, inverse proportionality, and symmetry were not included in this study, they were clearly in evidence among the children. Mathematics and science tended to be naturally used as tools for problem solving in the context of technology. Contrary to the normal situation in mathematics lessons, the children never asked why they were expected to learn certain content.

The following two examples illustrate the situations where scientific-mathematical content was used as a tool in problem solving.

> Marko looked toward the girls and said, "Hey...do you know what? Let's put more weight on this (Lego-car) and will accelerate better while going down the hill... and it would be nice to have some oil on the axle also." (However, oil was not used because of it's messy nature.)
> (Time block one; 5. B-class. Transcription from the video recording)

Interpretation
In this example Marko's statements indicate understanding of the meaning of increased mass in order to increase the speed of the vehicle, a scientific concept. He also seemed to know the significance of the lubrication in decreasing the friction, something he may have learned from science or from practical experience. He clearly applied his existing knowledge and experience to this particular situation as tools for technological problem solving. The girls are passive participants but they intently follow Marko's reasoning and knowledge transfer can be interpreted to have taken place. The pupil's deeper understanding of the phenomena behind the increased mass or lubrication is difficult to prove, however.

> Pirkko looks at the commands Marko has just written and stated, “Ten...you have programmed it (the motor) to operate for one second (ten equals ten tenths of a second or one second)“. Then Pirkko investigates the movement of the gate using her hand and measures the time by speaking aloud, “One, two…“ Marko also tries the gate with his hand and then continues writing the program while speaking aloud, “Onfor 10...wait a minute...oh yes...talkto motorb onfor ten.“ (Time block three; 5.B-class, 7th group. Transcription from the video recording)
>
> *Interpretation*
>
> Here the conversation between Marko and Pirkko indicates their mutual understanding of the principles of the decimal system. Mathematics can be seen as an indispensable tool in technological problem solving dealing with programming. In this way mathematics appears to be natural and meaningful for the pupils; they do not question the need for it. (Järvinen 1998, pp. 55-56)

The first example and interpretation concerning scientific content are informative in many ways. Also, the interpretation is targeted to the main points. Marko’s understanding of the meaning of increased mass and lubrication in order to increase the speed of the vehicle indicate application of his existing knowledge and experience to this particular problem solving situation. In retrospect, the example can be interpreted a little bit further. Firstly, rather than learning the idea of lubrication in science lessons, Marko appears to have used the idea from his practical experience. In this regard “a scientific concept“ should be viewed in relation to the procedural knowledge and understanding of the phenomena (see McCormick 1998), which is obviously the case in this example.

Secondly, the example is interesting from the constructivist viewpoint. Marko has obviously acquired the practical knowledge that he applies from his socio-cultural environment and now, in this novel problem solving situation, he is constructing personal interpretations and meanings based on that information. These additional comments do not undervalue the original interpretation, but rather support it further.

In the latter example and interpretation there is some emerging evidence of the importance of mathematics as a vital problem-solving tool in technology. This time the ‘chain’ of assertion, example and interpretation works the way it actually should: The assertion claims, the example provides evidence and the interpretation reveals how the researcher(s) is/are able to interpret the data from the viewpoint of research focus. Interpretation is an essential part of the results. Actually, without interpretation assertions, and examples would be meaningless. It is the interpretations that give a ‘soul’ to the results in this kind of research. (Compare the above to the interpretation derived from the same example in Study 3, chapter 5.1.3)

More examples and interpretations on the assertions can be found in Study 1 at the end of this thesis.

5.1.2 Study 2. Automation Technology in Elementary Technology Education

This study has been published in the *Journal of Industrial Teacher Education (2000 37(4))*. Compared to Study 1, this study goes further in the analysis concerning automation technology. I also wrote a conference paper with Jukka Hiltunen (Järvinen & Hiltunen 1999). In the paper we focused the analysis on just one class and only the fourth time block. However, in Study 2 the analysis focused on two classes and the time blocks three and four. Thus, the results differ in terms of empirical assertion and more detailed classifications, as well as in terms of differing data examples and interpretations. Moreover, the data analysis that was carried out also for the third time block yielded one more classification; “closed loop control systems and the concept of feedback“.

The results of the Study 2 are as follows:

Empirical Assertion:

Although pursuing relatively less structured design challenges, the children spontaneously dealt with essential contents of automation technology. The children also have been observed to have at least procedural, socially shared understanding of the substance in the focus.

During analysis process, the following contents of automation technology were classified to emerge from the data corpus:

– using sensors and switches in the context of automation technology,
– open loop control systems,
– closed loop control systems and the concept of feedback,
– block-based programming and system configuration especially in the context of automation technology, and
– logic(al) operations.

Open Loop Control Systems

Open loop control systems appeared to be the most common form of control systems observed in the works of the children (Time block three: 12 groups out of 13. Time block four: 7 groups out of 7). The idea of open loop control systems were attained and accomplished in relatively simple works. They did not need complicated programming either, adequate programming was done even by using only two or three basic commands.

The following example illustrates one such situation in which students were involved in making open loop control systems:

The group had build an automatic door for the dog. Lotta presents the system to the whole class.

01 Lotta: (“Leads" the dog [made out of Legos] by her hand) This dog is alone in the home while rest of the family has gone for a holiday and now it wants to go out and it passes light sensor on the way, which opens the door....the door is open

> for five seconds and then it closes....and when this dog wants to go in the house it have to push this touch sensor and the door opens again and the dog can go in. (Time block three; 5.A-class, 2nd group. Transcription from the video recording)

Interpretation

In this example Lotta explains her a priori process knowledge: the dog wants to go out and come back again and the functions of the door built for the dog. In addition to her understanding of the application process and the meaning of sensors when automating this application process, Lotta's explanations reveals the idea of an open loop control system. As a matter of fact, the idea is prevalent in both directions: when the dog goes out and when it comes back into the house. Although, in both cases the programmed system meets the requirements of an open loop control system, the solution presented by the group can not be found in teaching materials or curriculum guides. It is a unique piece of successful work based on children's own ideas, their own contribution to the learning activity (Biesta 1994) and moreover, contextually connected to the (pet care) culture prevalent among the children (see McCormick *et al*. 1996).

Closed Loop Control Systems and the Principle of Feedback

Closed loop control systems were not commonly understood at a conceptual level. In spite of this some of the children had a procedural ('device') knowledge of the idea of closed loop control system and they also applied it in their work (see McCormick 1998) (Time block three: 3 groups out of 13. Time block four: 0 groups out of 7). In spite of the ideas coming from the children themselves, the teacher's or researcher's contribution was usually needed in order to achieve a fully functioning system. Interestingly, all closed loop control systems done by the children were achieved only in the third time block, but not in the fourth time block. This phenomena can be interpreted to be due, at least to some extent, to the design challenge in the fourth time block; doing home security systems simply did not prompt the children to tackle closed loop control system and the idea of feedback (Järvinen & Hiltunen 1999).

The following example illustrates a situation in which students worked with the ideas of closed loop control systems and feedback.

The group presents to the whole class their system built for the dog staying alone at home while rest of the family is having a vacation.

01 Lauri: [Explains the system while Jennistiina operates the functions of it from the command center.] This is a doghouse and if temperature in there rises over 27 degrees [Celsius] this fan starts to rotate. [Takes a temperature sensor to his hand and begins to heat it up. Soon the fan turns on] So this fan turns on and it keeps rotating until the temperature is lower that 25 degrees. [Now he places the sensor into the doghouse just in the front of rotating fan.]

02 Researcher: Yes, leave it [fan system] to wait until it cools up....and what is this another automation system there?"
(Transcription from the video recording)

The students' programme was written as follows:

```
to tuuletin ("fan")
waituntil [temp1 > 27] talkto "motorb on
waituntil [temp1 < 25] talkto "motorb off
repeat 1 [tuuletin]
end
```

(Program copied from the group's project file)
(Time block three; 6.A-class, 2nd group)

Interpretation

This example illustrates those rare situations in which the children managed to do closed loop control systems in their work. The group had accomplished a system which controls a doghouse temperature to be in between 25 and 27 degrees elsius. Output (a rotating fan) gives feedback to the input (a temperature sensor) in order to keep the system in desired, appropriate condition. In explaining the principle of the system Lauri can be interpreted also to understand it (line 01). Actually, they have found out the very basic idea of the system known as a rule-based closed loop control. Importantly, procedural knowledge during the process and the final accomplishment is achieved through spontaneous action connected to the culture close to the children themselves (McCormick 1998, Suomala 1993).

Logic(al) Operations

Logic(al) operations, especially in the output-side of the system, appeared to be very common feature in children's outcomes (Time block three: 12 groups out of 13. Time block four: 7 groups out of 7). When the children designed different functions for the Output, they managed to do conjunctions of different operations.

The following example is about the process where the children dealt with logic(al) operations.

In this example the group has developed the home security system to the phase they want to test it. The test goes accordingly:

01 Sara: [Activates the system from the control panel] The thief thinks that it is just a piece of cake to go in to this house...and presses this [touchsensor] and then the thief is captured. [the door closes behind the thief]

02 Lydia: [playing the role of thief] Cripes!...I got caught...and now the siren began to blare.

(Time block four; 6.A-class, 4th group. Transcription from the video recording)

Interpretation

When the thief presses the touch sensor input is given to the system, resulting as a desired output and the thief is captured by the closing door (line 01). Moreover, the output consists of blaring siren, as indicated in the Lydia's comment (line 02), indicating a logic(al) operation; IF(touch sensor)- THEN(door)AND(siren). There were no requirements posed by the teacher or textbook to use logic(al) operations in the work, and importantly, they were achieved in the spontaneous process (Suomala 1993) where the pupils' pursue their own problem. Interestingly, in this case Lydia is prompted to play the role of the thief and thus she can be interpreted to be emotionally engaged in the situation (Lave 1988). This, although short, piece

> of process indicates context-dependent authenticity and enculturation took place in the process (McCormick *et al.* 1996).” (Järvinen & Hiltunen 2000, pp. 60-68)

The above example can also be interpreted from the general viewpoint of systems thinking. The children’s reasoning involves consideration of how every function relates to others (International Technology Education Association 2000).

Examples and interpretations of the other classifications of automation technology can be found in Study 2 at the end of this thesis.

5.1.3 Study 3. Meaningful Mathematics through Technology Education

This study has been submitted to *School Science and Mathematics*. Compared to Study 1, this study goes further in terms of more extensive, structured and detailed classifications and interpretations of the mathematical subject matter.

The results of this study illustrate how profoundly teaching automation technology is naturally saturated with a mathematical substance. Since this phenomenon is prevalent also in other activities related to technology teaching (Lindh 1996), it is quite surprising that there is not more collaboration between mathematics teachers and, for example “technical work“ teachers. This issue is tackled in more detail in the discussion of Study 3 (chapter 6.1).

The results of Study 3 are as follows:

> *Empirical Assertion*
>
> *Mathematical content appeared in children's work spontaneously and meaningfully when they applied it within the automation technology context in solving their own problems and they can also be interpreted to understand, mainly at procedural level, the mathematical subject matter they encountered.*
>
> During the analysis process, the following contents of mathematics were classified to emerge spontaneously from the data:
>
> – decimal system,
> – logical reasoning and thinking,
> – symmetry,
> – proportional reasoning, and
> – three-dimensional spatial thinking.*
>
> *Not supported by particular example, but rather interpreted to emerge throughout the process.
>
> *Decimal System*
>
> Example
>
> The children are making an environment that enables the pet to survive alone at home. The group is just programming an automatic door for the dog.
>
> 01 Pirkko: [looks at the command line Marko has just written] Ten...so you have programmed it [the motor attached to run the gate] to operate for one second.

Both Pirkko and Marko explores the movement of the gate by their hands.

02 Marko: [continues programming and thinks aloud] Onfor 10....wait a minute...yes...of course...talkto motorb onfor 10.

(Time block three; 5.B- class, 7th group. Transcription from the video recording)

Interpretation

The conversation between Pirkko and Marko seems to indicate their understanding of the principle of the decimal system (lines 01 and 02) [value 10 in programming language stands for one second]. They use this particular mathematical content as an indispensable problem-solving tool in technological problem solving situation (Adams 1991). Marko's speaking aloud while writing program (line 02) indicates that he is at a stage where learning is assisted more by his own self and not any longer so much by the more capable peers (Gallimore & Tharp 1990). Importantly, the programmed value "onfor 10" is neither a right answer to the textbook question, nor is it an answer to the question posed by the teacher. Rather, it is the most appropriate solution to the specific problem in which the children are engaged (see Lampert 1990, Franke & Carey 1997).

Symmetry

In making various constructions out of Legos the children seemed to have a natural tendency to symmetrical solutions. This phenomenon can be seen to be in accordance with all the symmetry that surrounds us, both in terms of human-made symmetry and also symmetry found in nature (Nagy & Darvas 1990).

Example

This example is from the group's presentation at the end of the second time block:

```
to auki ("open")
tto "motora setleft setpower 5
tto "motorb setright setpower 5
tto [motora motorb] onfor 10
end
to kiinni ("close")
tto "motora setright setpower 5
tto "motorb setleft setpower 5
tto [motora motorb] onfor 10
end
```

(Program copied from the group's project file)

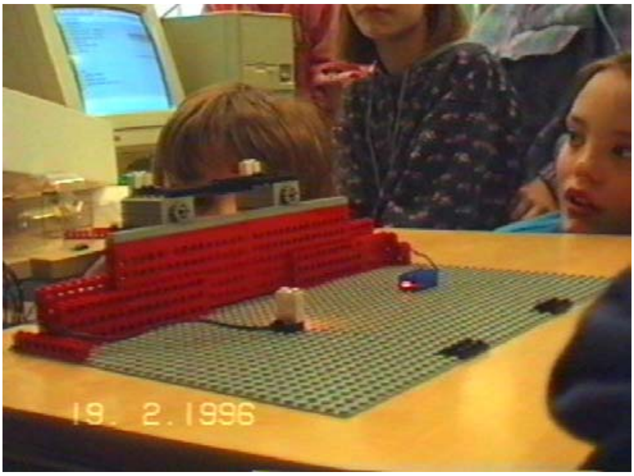

Fig. 5. Symmetrical gate made by the group of children. (Still picture taken from the video recording).

(Time block two; 5.B-class, 6th group)

> *Interpretation*
> In this example symmetry is prevalent at two "stages". Firstly, it emerges in the gate constructed by the children: the gate consists of two symmetrical halves and motors. Moreover, the lamps are symmetrically positioned as well. Secondly, the above program is written to be parallel to the construction. Provided the other half of the gate has been constructed differently, the program would also have to be asymmetrical." (Järvinen & Karjalainen submitted)

Examples and interpretations of the other classifications of mathematical content can be found in Study 3 at the end of this thesis.

5.2 Case Study II

5.2.1 Study 4. The Influences of Socio-cultural Interaction Upon Children's Thinking and Actions in Prescribed and Open-ended Problem Solving Situations (An Investigation Involving Design and Technology Lessons in English and Finnish Primary Schools)

This study was published in the *International Journal of Technology and Design Education, (10) 1, 2000*. The study was done in collaboration with Lecturer John Twyford from the University of Exeter, School of Education. It has many differing features compared with the three previous studies. The study is not based on the Haapavesi teaching project on automation, but it reports a different case. Moreover, this particular study shows that technology education can be carried out with relatively cheap and conventional materials in a typical school environment. The schools do not need to be equipped with the latest computer driven learning environments in order to introduce technology education to general education. The question is more about fostering appropriate pedagogical approaches, regardless of the materials, from the viewpoint of the nature of technology itself.

Moreover, as in Case Study I, the activities were arranged not only within the framework of "tekninen työ" or "tekstiilityö", but rather were implemented into school teaching practice through multidisciplinary approaches and importantly, regardless of gender.

The results of Study 4 are as follows:

Assertion one:

Children naturally made connections to their earlier experiences in applying their already culturally constructed knowledge to make a personal sound producing product.

The following example is taken from the Finnish data, and reveals the broad thrust of the assertion:

Pupils were asked where they found their design ideas from, one boy answered, that:

> 'There is corrugated panel placed in the walls of corridor. Once, I ran a wooden ice-cream stick on it and found out that I was able produce a kind of rattle sound. When the teacher introduced the project to us I decided to apply that 'panel-experience' and I cut a piece out of left over panel and placed a string in it. In this way one can carry it around ones neck. The sound is made by running a wooden stick on the surface of the 'panel plate'. The stick is attached to the panel and when not used, it doesn't get lost.' (Questionnaire)

Comment

This example is in accordance with the constructivist idea of how previous knowledge is applied in a new context (see von Glasersfeld 1995). The boy can be interpreted as acting like a technologist, because he applies his previous experiences, knowledge and skills to a new problem solving situation. Nobody told him to use his previous experiences with the panel in this project. The outcome was totally due to his own reasoning and can be claimed to be a result of innovative and original thinking (see Fritz 1998). The outcome met the requirements of the sound producing device project. Openness in teaching can positively contribute to to pupil's free thinking and inventiveness in designing and making. Interestingly this pupil was independently motivated to follow his own ideas, despite the fact that the class visited the museum and saw traditional rattles. (Järvinen & Twyford 2000, pp 25-27)

Although the interpretation ("comment" in this study) from the above example is justified and touches upon the constructivist idea of learning, as well as refers to the assertion one, it could have been written in a slightly more comprehensive way. "Innovative and original thinking" that the boy was able to carry out also represents divergent thinking and production. If he had been thinking strictly convergently (corrugated panel is meant to be used as wall covering), the idea to use the corrugated panel in order to make the noisemaker would not have come to his mind. This divergent kind of solution was essentially “boosted“ by his previous experience to run the ice-cream stick on the wall panel and also by open-ended instruction in problem solving.

The following example is taken from the UK data, and also reveals the broad thrust of the assertion:

> “Pupils were required to describe how they made a 'rattle' idea for a special purpose. One girl wrote about how her rattle was made to make a certain noise, as well as to look attractive. Her annotation to her design drawings state:‘In the designing and making of a rattle for a special purpose, I will use different shaped beads so that it looks attractive; the beads can slide up and down ...... ‘(Pupil’s design folder)

Comment
She clearly identified how to make a simple ‘rattle’ work and look attractive from her own thoughts and feelings about this work. She has related the decorative aspects of her sound maker to the processes of making it. She intuitively devised pleasing arrangements of an assortment of coloured beads, cotton reels and wooden wheels of different diameters to rattle together to form a noise maker. Her previous experiences of arrangements of objects in colourful patterns dominated this task. Also, she identified readily with an enthusiasm for making things which look attractive, as well as making something which simply made a loud noise.

Assertion two:

Pupils demonstrated their understanding of the original design problem and focused on producing effective products, as a result of their creative and open thinking.

The following example is taken from the Finnish data, and reveals the broad thrust of the assertion:

This description is taken from the videotape data and reveals these processes in action.

> At Vattukyla Primary School, Finland, the children took part in an enactment of a hare hunt in a local forest, using their rattles. Thus, as hunters they waited in a forest clearing. In the distance, there was heard a cacophony of different noises. First it was faint, then increased in volume. The pupils were driving through the forest to frighten hares towards the hunters. Many different noises were made - rattle, chink, clatter, banging and so on. (Videotape)

Comment
It is evident that many solutions were effective enough to make a loud noise to startle a hare. Different kinds of sounds exemplify the different solutions to the problem of driving animals in a hunt. Thus, the pupils learned the social meaning of the sound devices because they actually used in a real hare hunting experience (see Savery and Duffy 1995). They also learned the value of authenticity in designing and making.

The following example is taken from the UK data, and reveals the broad thrust of the assertion:

> Pupils were required to think about what a rattle is, and to understand what supporting a team, or event, means, including when to cheer and when to be quiet! (Researcher's notes)
> When invited to use their rattles to show that they worked pupils made a tremendous excited noise! Children had combined the available materials for the prototype rattle to make as much noise as possible using cotton reels and beads. Pupils knew only too well the purpose of making a loud noise - for the pleasure of doing it!
> Simply making a noise was the natural component of this work for these children. They used their previous experiences to demonstrate what it means to cheer a team on or to show approval of something through making a loud noise. The contemporary noises used in popular entertainment culture, to show approval of something entertaining or sporting were strikingly evident in the whole classes response, especially by rattling and banging things! (Teacher's lesson evaluation notes)

Comment

The UK children's purpose for a noise making artefact demonstrated how they could bring previous experience into a project of this kind through examples of what they have learned from 'popular' culture when cheering.

Before making the 'rattles' pupils were asked to describe where making a noise is acceptable and where not, as noted in the teacher's report. The children were drawn into a discussion about the different sounds and noises which people use. They identified that people cheer on their favourite team by using rattles, and that traditional football supporters used them to great effect. Children discussed why people need to make a loud noise to support a team. They were also told about the Jewish festival of Purim, involving the story of Esther, in the Old Testament. This Jewish custom uses rattles. Children make very loud rattle noises when they hear the name of a bad man and cheer when they hear the name of Esther, the heroine.

Pupils also demonstrated from their experiences that they understood that people support their favourite sports teams by cheering and making all manner of noises. They understood that rattles were used at football matches, although not so much today because they are classed as an offensive weapon by the police. They commented that people cheer on their teams to do well and to win the match or game.

Knowing a purpose for making a noise informed making a sound device, and thus enhanced pupils' understanding of the rattle product because they were excited to make something which would be noisy.

Assertion three:

Pupils interacted in the socio-cultural setting of their respective classrooms, formulating design ideas, both together and individually, but also with the support of the teacher.

The following examples are taken from the Finnish data and reveal the broad thrust of the assertion:

> "A little bit later some 6th grade boys began to make the biggest rattle in the world. It was their own idea and they began to do the work by themselves. When it was ready it was also tested in the woods. It's reeeally big!" (Teacher's report)

> “ ... and then we began to make it. The sound plate was not durable enough, but we made it thicker, then we made a kind of ‘ adjusting device’, which meant that when the sound plate wears out more of it can be fed onto the striker. The final product was quite good, although the striker could have been a little bit more durable..... .“ (Questionnaire)
>
> (Järvinen & Twyford 1999, pp. 28-32)

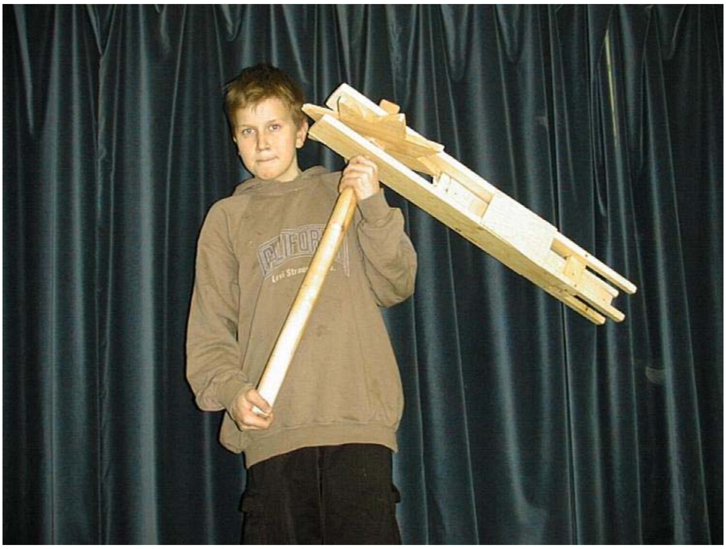

Fig. 6. ‘The biggest rattle in the world’ (Picture by Risto Klasila).

Comment

In this example the pupils were active agents in their own independent design work (see Savery and Duffy 1995). They were successful in making ‘the biggest rattle in the world’, from their point of view. One boy developed the idea in the first place, (see example three in Study 4) and involved three other boys in making it. During the process the boys faced a problem with the sound plate, but together they developed an appropriate solution to this problem. Thus, social interaction in problem solving was seen to take place. At the end of the quotation it is clear that the boy is able to think reflectively about the rattle product.

This individual pupil’s continued thinking about design problems led them to a personally motivated idea. This one boy’s opportunistic thinking prompted the social interaction with other pupils because he inspired others to join in making the biggest rattle in the world.

The following example is taken from the UK data and reveals the broad thrust of the assertion:

> The teacher’s notes identify that pupils worked collaboratively, as required in the UK National Curriculum, item 2b at Key Stage 2, where “ pupils should be given opportunities to work independently and in teams“ (Department for Education, 1995,p. 4) The 42 pupils were supplied with a range of materials and tools sufficient for them to work in small teams, as well as on their own. The

> teaching materials require each pupil to create their own rattle, but also to share resources and to discuss ideas. (Researcher's notes)
>
> *Comment*
> The practical making tasks followed out of a broad whole class discussion about the social factors involving using sound for distinct purposes. Pupils were also required to experience the use of sound in developing their designing and making skills, as outlined in the teaching materials.
>
> In one English school the teacher's evaluations of the lessons and reports indicate that pupils were challenged to interact with each other as members of an established class of peers. The children's concept of a making a 'rattle' was formed through active peer interaction and discussion concerning the manufacture of a 'rattle'. Pupils discussed the different forms of component and assembly techniques, especially the order in which parts were put together. In these ways children revealed examples of how they reconstructed their thoughts.
>
> They were directed in the necessity of sharing equipment, as part of acceptable social behaviour routines within whole class activities. Pupils clearly and enthusiastically worked together in making an effective personal rattle. The fact that all the children worked enthusiastically in this project reinforced the success of all concerned.
>
> Implicit, social interaction in children's designing and making occurred to enable them to make something which worked well. This was noted as the outcome of individualised and socially driven active learning, whereby each pupil produced their version of a rattle. (Järvinen & Twyford 2000, pp. 32-33)

More examples and comments on the assertions can be found in Study 4 at the end of this thesis.

6 Discussion

The purpose of this chapter is to reflect upon both both of the Case Studies, as well as the general issues overlapping through the research. These general issues range from suggestions of more appropriate pedagogical approaches to technology education to reflective discussion of the research process including some ideas of possible future research interests. The discussion also reflects on credibility issues.

6.1 Discussion of Case Study I

Study 1. The Lego/logo Learning Environment in Technology Education: An Experiment in a Finnish Context

The results of this study support the notion that social interaction can be interpreted to promote technological problem solving and learning. For the most part the children taught themselves in an interactive social setting. Knowledge transfer among the children sometimes appeared to be apprenticeship-like in which expert know-how was transferred to the novice. This was not, however, the predominant phenomena. At least equally apparent were the situations in which the children acted more like peers and learned from one another. The teachers were not always in the role of omniscient experts but often were learners themselves. This supports the idea of teacher's new role as a facilitator of learning and co-ordinator of learning environments where children can be active agents of their learning processes.

According to the socio-cultural interpretation of constructivism learning is understood to take place in the socially interactive context and is seen to be as a process of enculturation, whereby the learner participates increasingly in an authentic and context dependent activity (McCormick *et al.* 1996, Kooulaidis & Tsatsaroni 1996, Knuth & Cunningham 1992, Ernest 1991). Although the results show that the children were able to work in a collaborative and interactive way, the contributions by the group members were not equal. In spite of this, the final solutions could not have been achieved by just one member of the group. The final solutions consisted of a mixture of ideas, skills and knowledge which were brought together through constant discussions and negotiations in solving the emergent problems.

During Case Study I the Lego Dacta manuals were put aside in order to avoid having the children to copy and model ready-made solutions concerning construction and programming. This procedure derived from the notion that the children should be given opportunities to encounter authentic technological problems and to use their own creativity and spontaneous innovation in the process of solving those problems. Although many of the solutions accomplished by the children were rather simple in terms of mechanisms and programming, they were made by the children themselves and, importantly, raised from the needs significant for the children.

Programming the computer appeared to be the most difficult and frustrating to the children. This is partly due to syntax sensitivity of the Logo-language but also to the limited amount of time that the children had overall. In spite of the difficulties, programming was an essential part of the children's work. It gave possibilities to apply mathematics naturally in authentic, child-driven problem solving situations. The programming also enabled a feeling of control over constructed devices and thus emphasized the meaning of appropriate commands and procedures in order to make automated systems. Even though the teachers played a more active role in the programming portion of the activity, it did not seem to lessen the constructivist nature of the learning situation. The children were not always able to proceed independently and had to be supported. However, this is in accordance with the constructivist notion of learning in which an individual takes information from the environment and constructs personal interpretations based on prior knowledge and experience. The children used the knowledge they gained from the teacher by applying it in new situations. Moreover, the knowledge was negotiated and transferred among the children.

One possibility to overcome the problem of syntax sensitivity could be a more icon based programming software in which the children could use appropriate icons to achieve the desired functions. Actually, Lego has recently introduced the Mindstorms Robotics Invention System and RoboLab construction sets in which the programming can be done by using picture icons (see Lego Dacta 1998). It would be interesting to make comparisons between these two ways to program; to what extent does programming with the icons make it possible to avoid the frustrations caused by writing the commands and procedures with a syntax sensitive programming language? Do the children then have essentially more energy to orientate their enthusiasm, interest and thinking towards the general principles and logic of automation technology?

The issue mentioned above causes at least two dilemmas. Firstly, from the viewpoint of education about technology, if the aim of technology teaching is to open the 'black boxes' of technology, i.e. to make technology transparent and understandable to children, to what extent does the use of icons only reveal the logic of programming behind the icons themselves? Are children just users of an attractive graphical interface, but have no idea of the programming that is needed to create the picture icons? Consequently, there might be just more 'black boxes' around children. Moreover, is simplifying the learning environment always a reasonable thing to do? This question does not mean that the children should not learn in a pleasant and easy way, but it aims to ponder the issue of authenticity of school learning in relation to the reality outside the schools. If the learning environments are reduced to the easiest and simplest level, there might not be very much authenticity left for the children to experience and thus the learning is far away from the real-life situations (see Honebein *et al.* 1993).

Secondly, the question is if there will be a growing demand in the future for people capable of making use of and applying prefabricated graphical interfaces effectively and creatively in order to create useful systems and subsystems? If so, the value of sheer "typed" programming could be interpreted to have diminished as a relevant skill taught in the schools.

Considering technology education in a larger context, the Lego/Logo learning environment is handicapping in many ways. For example, it does not introduce a very wide range of materials and the constructions must be done within the limits of the Lego components. This restrictive element of Lego construction was obvious in terms of the solutions bearing striking similarities to the previous artifacts. For example, the children applied the ideas of gate and peat conveyors from the second time block to the third time block. Some of the solutions were almost identical to the previous ones, some slightly modified. For example, there were automatic doors (gates) and feeding devices (peat conveyor).

The above-mentioned phenomena can also be understood in a positive way. The children applied and made use of previously assimilated experiences and knowledge in new problem solving situations. The final solution does not always need to be totally new and original. A workable response to an emergent need should be the most important criterion. Moreover, in order to act like a technologist one does not need to be constantly innovative. For instance, the ancient Romans are known to have been capable of applying and modifying previous inventions to meet their practical purposes and needs (Lähteenmäki 1990).

On the other hand, an advantage of the system is that it consists of components with which most children are already familiar from early childhood. The study found that the children seemed to be somewhat amazed when the learning environment was introduced in the first place. Their reactions could be epitomized as follows: "Are we going to *play* with Legos in the school?" The 'Lego world' of a child's room at home appeared to be transferred to the school with the comfortable, relaxed atmosphere. This phenomenon was undoubtedly due to the absence of conventional tests and the anxiety that usually accompanies them. This is consistent also with the thoughts of Ausubel and Robinson (1973) regarding the creation of an appropriate atmosphere for solving problems that is low in stress and allows concentration on the task at hand.

Importantly, mathematics, but also science turned out to have an important role as a problem-solving tool in the technological processes. This is consistent with the reality where mathematics, science and technology are entwined together. However, it has to be admitted that the learning situations and experiences that the children went through did not develop children's understanding of physics very much in a scientific sense. The children did not use scientific language and concepts, nor did they act according to the processes typical of scientific inquiry. The children simply did technology and acted correspondingly. In this respect there are no possibilities to claim that the children were taught to understand the meanings and structures in physics according to definitions within the scientific community (Kurki Suonio & Kurki Suonio 1994). For example, the children did not deal with the issues of friction and mass in the way in which physicists tackle the concepts. In spite of the emphasis on children's procedural ('device') understanding in technology lessons (McCormick 1998), the connections between science and technology teaching are important, even inevitable.

Actually, well-established and properly designed collaboration could contribute positively to both fields of education. A scientific viewpoint could bring some deeper insights into the phenomena in the focus. For example, the science teacher could arrange a workshop where the children's experiences about the increased mass speeding up their Lego 'soapbox' cars would be questioned and challenged by experiments of falling objects in a vacuum. On the other hand, the children's practical and meaningful experiences, together with the feeling of usefulness in technology lessons could be transferred to a positive attitude towards science. Children with positive attitudes and cognitive drives to learn science, as well as mathematics, form a fertile ground to make science more interesting, acceptable, and even more understandable to the children.

Study 2. Automation Technology in Elementary Technology Education

The results of this study show that the children became familiar with some essential aspects of automation technology. The children found an idea based on their own needs and they were able to make use of automation technology. This observation was especially true considering the need to understand the meaning of sensors, the importance of programming in order to make useful systems and as well as the idea of open loop control system. However, children's skills were not always at the level of their ideas. Quite often the teacher and researcher in the role of a tutor in the need, were needed to achieve the final accomplishment.

One of the most remarkable results of this study was the motivation and task orientation of the children. When the work was based on the problems found in their own life, they seemed to have an ownership and emotional engagement over the task at hand. This phenomena is in accordance with the ideas presented by Savery & Duffy (1995) and Lave (1988). However, at the same time, their work consisted of the classified contents of automation technology and interestingly, without any use of textbooks, worksheets, manuals or the like. Although the children mainly worked on the basis of procedural knowledge, or device knowledge, their knowledge reflected "as much of the context of the device (e.g. its operation) as any abstract knowledge taught in science" (McCormick 1998, p. 7). Moreover and importantly, they participated in the process of the technological development in order to meet one's needs and wants (Hacker & Barden 1988). Although children's knowledge and skills were far from complete in this regard the children seemed to be successful.

The children can be interpreted to spontaneously acquire procedural 'device' knowledge, and to learn to act like a technologist in many ways:

- they created something which has not existed before,
- their knowledge and skills developed in the course of the experiment and were applied in forthcoming problem solving situations,
- they transferred knowledge and skills among themselves in expert-apprenticeship-like situations and
- they acted on the basis of social or individual needs thus carrying out the true nature of technology. (Järvinen & Hiltunen 2000, p. 69)

In technology lessons, the action itself, as well as its understanding, are most important. Teaching technology should not begin with the introduction of conceptual jargon, but with design challenges which enable children to come across the underlying technological principles spontaneously while engaged in the learning activity (Papert 1980, Suomala 1993). Technological principles encountered by the children at procedural level can be conceptualized later on.

From the viewpoint of automation technology in general, it is essential for children to understand the differences between the two systems (open and closed loop control system) as well as their most appropriate fields of use according to their differing principles. Children should also be capable of applying the knowledge and skills of automation technology that they acquire to problem situations that arise from their own needs. Based on their needs, they should be able to design and implement simple control systems and they should also be able to explain their usefulness, intended use and working mechanisms as fully as possible.

Study 3. Meaningful Mathematics through Technology Education:

The purpose in Case Study I was not to teach and do science and mathematics with the children. Rather, the main purpose of the technology teaching was to familiarize children with automation technology, and to apply automation in the problems that were identified from their own living environment and experiences of life. However, mathematics also emerged to be one of the key issues in the course of the children's work. As the results of this study indicate, the children encountered the classified contents of mathematics and 'had to' use them in order to accomplish their work. Essentially, the children could not have been able to work and succeed in the way they did without the use of mathematics.

Importantly, most of the mathematics appeared spontaneously and naturally and in a form that the children did not recognize. Much of the mathematics was disguised in the 'cloak' of other activities. This was obvious in spite of the fact that the children did not make workbook exercises on mathematics, nor did they work under the pressure of traditional school evaluation practices. This seems to indicate how profoundly saturated our world is with mathematics and gives it the importance it deserves in technological problem solving. The children never asked: "what is this math for...do we really need it?". Actually, natural and meaningful appearance of mathematics in the children's work is in accordance with Adams's (1991) thoughts of mathematics being one the most important tools for an engineer. Also, in modern technology education mathematics could naturally have an important role as a problem-solving tool. As a matter of fact, even in general (not vocational!) technology education mathematics is valued from the quite utilitarian problem solving point of view (Laridon 1996).

However, not everyone agrees with the use of real world problems in order to teach mathematics (see Fordham Foundation 1998). One might argue that this kind of 'utilitarian' perspective on mathematics does not help to teach the subject itself? It has to be emphasized here again that the purpose of this study was to teach automation, *not* mathematics. As indicated above, the children confronted, at least to some extent, similar concepts and problems of mathematics which are to be found in the actual mathematics lessons. Take the decimal system, for example. Although the decimal system did not appear as a complete system in the teaching, an essential feature of it was handled by the children: one second consists of ten tenths of a second.

Consequently, the results of this study suggest that increased collaboration between teaching in technology and mathematics could be mutually beneficial. This can be achieved through substantial parallelism between the ongoing contents of mathematics taught and the themes in technology lessons. If, for example, the decimal system is in the focus in mathematics lessons, the technology teacher should take this into account in terms of tasks that offer a considerable potential for children to apply it spontaneously in their work. On the other hand, when there are certain themes planned to be taught in the technology lessons, the mathematics teachers should be well informed about the plans in order to adjust teaching according to those themes.

Most importantly, acquired mathematical knowledge and skills should be given possibilities to 'come to life and flourish' 'in real world, authentic problem solving situations (see Laridon 1996, Ernest 1991). However, mathematical tools have to be mastered, at least to some extent, before they can be applied appropriately in technological problem solving. For example, in playing piano, some basic rules have to be learned before proper playing is possible, not to speak of being creative in combining different techniques.

In technology education, children themselves may be better at defining appropriate learning outcomes than are shown in textbooks or teaching manuals. This also fits to the idea of having meaningful mathematics through technology education, as the children tend to deal spontaneously with mathematical content in their work. Moreover, mathematics was not done by following the rule laid down by the teacher, nor were the answers [solutions] ratified by the teacher. (Lampert 1990, Franke & Carey 1997).

Owing to the important role of mathematics and science in the development of modern technology, they have to be taken into account in a technology education curriculum. Otherwise, the technology education would not reflect the real world around us. This is true in spite of the fact that there can be found various interpretations about the relationship between technology and mathematics and science.

6.2 Discussion of Case Study II

Study 4. The Influences of Socio-cultural Interaction Upon Children's Thinking and Actions in Prescribed and Open-ended Problem Solving Situations (An Investigation Involving Design and Technology Lessons in English and Finnish Primary Schools):

The constant interaction between the information provided, the thoughts and actions of different class mates, as well as the actions of the teachers reinforced and extended individual learning about how to make a 'sound maker'. Pupils' designing and making was seen to progress through these forms of interaction, not least through social interaction.

Pupils knew that there were practical problems to be solved because the work itself posed them. All pupils were required to use their experiences to:

> i) acquire the skills to fashion components with broadly the correct use of measurements, tools and equipment; prototype the assembly of the 'rattle' to ensure a correct fit and alignment of components; determine the logic of timing the most useful order of work in the making and final assembly of the sound maker;
>
> ii) importantly in Finland, pupils used the above skills to fashion a personally designed product which demonstrated that they understood the meaning of using sound for a purpose.

This study describes the influence of socio-cultural interaction in teaching and learning. It also accounts for the tensions between prescribed and open-ended teaching approaches present in the work. For example, comparisons between the groups can be made in how pupils were driven by similar peer dynamics within each group, despite the differences in character of the two Design and Technology projects.

The variety of curricula characteristics and constraints of both the UK and Finnish contexts demonstrated the different interpretations given for teaching and learning in D&T. In Finland the task given to the children enabled them to be more divergent, innovative and original in their thinking (Dugger & Yung 1995). Correspondingly in UK, the pupils' design thinking processes were more prescribed and convergent for this focused task. This is evident in the final outcomes of the pupils. The researchers agreed that if children are always guided too much by prescribed design work then they may find it more difficult to work creatively. (see for example Fritz 1998) Alternatively, children should be enabled to carry out their design ideas with knowledge and understanding.

Individual children used their knowledge and experiences to make a sound device, and as they grasped the direction of their work they focused on their personal concepts. Some of the children mimicked other pupils, some modified examples seen in wider use and some invented their own novel products. Copying and mimicking are facets of learning to design but should be used to support the creative excellence to be found in originality. The project required the children to produce either a similar product, as in the UK example, or a personally found product idea, with an identified use, as in the Finnish examples. Each product tended to be a personally modified version of a general idea already known or used by some human culture. However, it was clear, from examples developed in Finland, that some of the children had invented unique products.

It was demonstrated that children can, literally, be simultaneously constructors of both their physical world and also their mental structures when engaged technologically. The former is an example of how children use their spontaneous concepts in the socio-cultural context of the classroom, demonstrating: "...a distinctive and transforming impact on the school child's mental development. In Vygotsky's view, the structure of school learning provides the kind of cultural experience in which the higher psychological processes, such a voluntary attention and logical memory, are formed.“ (Panofsky *et al.* 1990, p. 251).

In the context of the 'rattle' assignment, spontaneous concepts are understood to be the child's perceptions of how to simply make a noise through cheering, clapping and banging things. The formal conceptualisation is seen in how individuals reason that making a noise can mean something purposeful in an authentic context. (see Honebein *et al.* 1993)

Vygotsky argues that one follows from the other. That formal concepts arise from spontaneous ones, which are derived from a more holistic development of concept formation. (Panofsky *et al.* 1990) Concept formation is not linear, but holistic, which is reinforced by the culture of all experiences. The two teaching contexts in this study took as their standard idea that of encouraging the children to make use of sound for a purpose. Thoughtful design and technological experiences involve pupils in using their own language to reflect, converse and form and test theories. The interaction between designing and making things is at the heart of these ways of thinking. Speaking generally, children may learn through design and technology by simply experiencing creating things or by being directed to do so. However, it is a vital task of teachers to provide children with effective experiences from which they can 'grow' technologically. Also, importantly, teachers should facilitate opportunities for children to extend their experiences into personal inquiries or experiments. This approach was much more evident in the Finnish context, and lacking in the UK context, for this study. This approach to learning engenders the spirit of technology, when children think like designers or technologists.

6.3 General issues to be discussed

This chapter aims to make some general statements and suggestions about teaching technology. Importantly, the discussion is intended to be useful also within other activities in technology education, i.e. not only concerning teaching automation technology, or to make noisemakers. My argument is that the discussion below can be applied regardless of the content in focus.

According to the results of both the Case Studies, the socio-cultural constructivist approach appears to be natural and effective in organizing learning, especially in technology education. One of the most important things in education is to adjust the pedagogical approaches according to the nature of the content. When the content is technology, it is essential that children can have a feeling that they are pursuing their own needs, wants and purposes and what is significant and meaningful to them. In this regard the design briefs and task allocations should be open enough to allow children to explore their own living environment in order to find problems that need to be solved (Schwarz 1996, Lehto 1998) and given changes to apply technological knowledge and skills they have previously acquired (Adams 1991, Lindh 1997).

Also, as described earlier in this thesis, technology can be regarded as an inherent part of human activity, which is driven by the very fundamental human nature, the will. In this regard, pedagogical approaches adjusted according to the nature of technology take naturally into account that children are treated as active, intentional and goal-directed humans whose activities are driven by the human volition or will. When participating in the activities, the children were actors in the process where they constructed the technological reality on the basis of their own needs and ideas. This phenomenon was especially prevalent in the third and fourth time blocks (Case Study I) where the problems given to the children were the most open-ended. Actually, it can even be said that the children participated in the process of technological development, the human endeavor that has existed since the dawn of the human race (Hacker & Barden 1988, Barnes 1988, Vohra 1988).

In all of the studies, the tasks presented to the children were designed by adults. In this regard the starting points were not entirely child-centered. Actually, an overly child-centered approach is one of the pitfalls for constructivism (Ernest 1995) and we did not want to fall in to that pit. Importantly, there has to be a certain direction in the learning activity. That direction could be set by curriculum, for example. However, the task allocation should be open enough for children to formulate their specific problems to work with and accomplish solutions unknown in advance (for example Järvinen & Twyford 2000). This does not mean that the requirements of curriculum are not intended to be attainable.

Regardless of the media used in technology education, it is essential that children are encouraged to work and learn in a way that fosters innovation with creativity and discovery (Futschek 1995). To promote effective learning, the emphasis has to be on appropriate pedagogical approaches and in relating the problems to the children themselves. On the other hand, the teacher has to be sensitive in his/her intervention and not assist too much or too early. Children's problem solving should be given time to develop and mature on its own. Here the teacher's role is reduced to the kind of educational 'detective', who is capable to uncover the situations where children really need help and assistance in order to progress further (Tudge 1990, Gallimore & Tharp 1990).

According to the most radical idea of constructivism (von Glasersfeld 1993, Schwandt 1994) there is no reality that exists outside the individual; he/she has to perceive and experience the outside world personally in order to formulate it as his/her individual reality. Moreover, since the reality is in the 'eyes' of the observer, there can be said to be as many realities as there are observers. Also, no one can claim that his/her way to perceive the outside world is the only correct one. The world consists of various and alternative ways to see and experience it.

Similarly, there is not just one right answer to be found in technology. No one, not even the teacher, can claim that 'my technology' is the only correct solution to a given purpose. There might be a wide variety of alternative, equally appropriate and useful solutions. Moreover, the actual needs and purposes vary even if the staring point is the same (see Case Study I; Time blocks 3 and 4). Thus, at least to some extent, the technological reality we create represents our understanding, mental construct, of the world and the needs we notice in that world.

Consequently, in technology lessons, there should not be any right answers, or constructs, to the posed questions. Rather, there should be appropriate solutions to the emerging problems. Thus, in technology, truth could not be found in the same sense it is pursued, for example, in science or mathematics. These perspectives have also been agreed on by the Committee for the Future/The parliament of Finland as follows: "In technological fields, teaching cannot be geared towards finding the correct answers. There simply are no correct answers to the questions asked" (Järvinen cited by Suurla 2001, p. 64, also Järvinen *et al*. 2001) In this way children can be real contributors in the learning activity (Biesta 1994) and the learning structure can be efficient in terms of procedural knowledge acquisition, but also meaningful.

The above notions lead to the essences of technology. There would not be a technological reality around us if we had not, literally, constructed it. Epistemologically, technology is a human construction. When we construct technology, say a technological artifact, we also form a mental representation of it. Also, technology created by the others is embedded in our minds as mental constructs. Importantly, in technology lessons there could be a huge potential for constructivist learning activities, and not only in the sense of concrete doing, but also in the terms of learning processes to develop higher thinking skills and innovative problem solving.

What could the above mean in practice? In addition to the reported outcomes of the children's work, I will take one more imaginary but realistic example from the context that is familiar especially in Finland. In traditional handicraft education one of the topics of working has been and still could be to make a 'sauna ladle' that is meant to be used for throwing water onto the stove. At the end of the lessons everybody has made a well-finished 'sauna ladle'. The children have assimilated a great amount of new skills and knowledge concerning the working techniques and modes on differing materials: wood for the handle, copper for the ladle, iron for the rod between the handle and ladle. Some qualitative changes in the cognitive structure may have taken place in relation to the handling and forming of the materials. For example, the child might have thought "I should not use the hammer in this powerful way when forming the copper ladle, but rather in a more sensitive way to avoid breaking the soft material.“ Thus, by comparing and manipulating the assimilated experience-based knowledge, the child has changed his/her hammer handling procedures accordingly.

However, one might say that "in our long and narrow sauna the stove and seating area are in the opposite ends of it. Thus the ladle, although nice in appearance, is just useless piece of work. With this ladle water will be thrown more to the floor and walls than to the right address, the faraway stove.“ (in this regard see Kankare 1998, p. 127) So, what to do? Here 'convergent' handicraft education could change to 'divergent' technology education. Instead of following meticulously the instructions of making a sauna-ladle, the problem could be posed as "how to get water to the stove in a very long and narrow sauna?" Now the answer is not necessarily the ladle anymore, but through the process which takes place in a meaningful and interactive context-specific situation, alternate solutions to the emerging problem could be found.

In the problem-solving situation posed above, previously acquired knowledge, skills and experiences alone do not guarantee that the solution is found. Nor does the constructed know-how about the properties of materials. What is needed here are new ways of (divergent) thinking, a kind of cognitive storm, which, firstly clears "the table“ of the burden of traditional (convergent) thinking and all prescribed solutions in relation to the problem in the question. Secondly, the mind is needed, from the perspective of this particular problem, to be structured again. In this re-construction, the open problem is now targeted with all that tremendous potential of previous knowledge, skills and experiences that one has accumulated during his/her personal history. Without the restrictions of a prescribed design brief, the cognitive structure goes through comparisons and modifications in the process of seeking the most appropriate and useful solution to the context-specific problem.

Personally constructed knowledge, skills and experiences which will be utilized in the solving of the ‘water to the stove’ problem could be drawn from a child’s past as follows: During the problem solving process one might connect for example the knowledge of water pipes and the experience of a small stream carrying his/her small boat downwards into a workable solution: attach a slightly descending water pipe to the wall of the sauna, the upper end of the pipe in the seating area and the lower end just above the stove. In order to make pouring the water to the pipe easier one might add the idea of a cone (possibly he/she has seen home-made juice to be poured through a cone to the bottle) and construct the upper end of the pipe accordingly. When actualizing the idea in a real functional solution, one needs to use several materials and various techniques and modes. In the problem-solving process described above, the mental construct of the idea precedes the physical solution. The final solution that is made is, in a way, located in two places: it is, in terms of a reconstructed mental construct in the child’s mind, as well as a functional physical solution located in the sauna. Moreover, everybody in the family could proudly enjoy the ingenious fruits of the child’s technological problem solving.

Interestingly, intellectual activity during the time of the Renaissance contributed positively to the development of technology (see Adams 1991). Actually, the lack of intellectual activity has been one of the dilemmas in Finnish handicraft education. For example, in many cases it “has been said to include more copying and reproducing processes....than modern design oriented processes“ (Alamäki 1999, p. 39). Traditionally, handicraft education focuses on mastering certain specific skills and techniques. Thus, in the concept of “technology“ only “techne“ (skills) seems to be prevailing.

I would like to encourage technology teachers to try open-ended, constructivist ideas of teaching in their classroom practice. This kind of teaching might require a little bit more work and preparation time. It might also require the teacher to take new perspectives and reject some of the old modes of thinking. But it is certainly rewarding in many ways. When the final outcome of children’s problem-solving processes is unknown in the design brief, it is not boredom, but rather a thrilling anticipation that lingers over the technology lessons. Moreover, it would be fruitful if the teachers could develop a kind of opportunistic attitude to look constantly around in order to find authentic and meaningful problems to be solved by the children. This kind of opportunism requires certain amount of sensitiveness to notice emerging possibilities for technological problem solving situations.

Knowledge and skills acquired at school should be useful, meaningful and applicable outside the school setting. From the perspective of technology the children should be educated to be aware of technological reality around them, to be sensitive in noticing possible problems to solve and capable of applying acquired technological knowledge and skills to those problems. Understanding the logic and functional mechanisms of everyday technology are also considered to be essential features of technological capability. (Morrison & Twyford 1994, Lindh 1997)

Since the schools are not acting in a ‘vacuum’ void of connections to the real outside world, the curriculum should ensure that children are systematically given skills and knowledge to cope with the socio-cultural environment in which they are already living and going to live in the future. This environment also consists of the outcomes of human intelligence and skills in terms of technology, mathematics and science. (see Stenhouse 1976, Benjamin 1975, Mc Cormick 1994). Thus the contents, but also the methods of teaching should be under a constant state of evaluation; how do they relate to the real world. Skills and knowledge taught in the schools should be meaningful and useful in everyday life, they should be applicable in a wide variety of different contexts and transferable to be used even in the future working life. Here the question is essentially about proper and up-to-date enculturation as well (McCormick *et al.* 1996).

In the above regard, the human made environment should not be forgotten. I am confident that this thesis has made a sufficient emphasis on this. However, recently, I have been thinking of *bionics* as an area to combine nature and technology in education. In retrospect, I think we did not explore the idea of bionics to the extent it deserves. There would be lots of fruitful opportunities for collaboration, even integration, between biological and technological education. If technology is taught through the multidisciplinary approach, bionics could give an enormous potential to introduce the children to the surrounding environment on a much broader level.

6.3.1 Open vs. prescribed problem solving

If children are working according to prescribed instructions, the working methods and the final outcomes are already known at the beginning of the process. This has been, and to an unfortunately great extent still is, the case in traditional handicraft education. This kind of repetitive process is like moving along a very narrow platform which leads to a certain product or solution. Moreover, children have rather few opportunities to apply previous knowledge, skills and experiences while working in the narrow problem-solving platform. Even if some personal and unique, more appropriate and useful ideas come across their minds concerning the task in hand, they are still restricted to follow instructions.

Thus, in addition to the need to do something and possessing appropriate skills and knowledge to progress in task accomplishment it is also important to enable children to proceed in an open problem-solving platform. Although open-endedness is quite naturally achieved when children’s work is based on problems arising from their own meaningful needs, it might be useful to explore this idea a little bit further. Open-endedness in task allocation should mean that nobody knows exactly what the actual outcomes will be at the end of the process. The solutions are not found in the teacher’s manuals, answer books or the like, and thus every situation is new and unique even for the teacher. Consequently, the problem solving process is really an interactive, mutual endeavor between the children and the teacher.

When the problems presented to children are open-ended in nature, there are more opportunities for applying previous knowledge, skills and experiences in the process, which finally leads to unique, personal outcomes and solutions. Moreover, there might be even more possibilities for discovery learning and re-construction of cognitive structure, not to speak about social interaction between children and also between children and teacher. Due to the traditional prescribed pedagogical approaches, as in traditional handicraft education, children can feel truly open ended tasks a bit confusing, especially so because not even the teacher can tell where the process lead and what would be exactly the right answer. Thus, also children need to be educated to encounter learning situations where they have to consider various possible ideas, test them and select the most appropriate one as the final solution. In this way they would act according to the technological processes (Layton 1993). In this respect, the process can be seen to progress in an open platform, not restricted by the narrowing limits of prescribed instructions (see Fig. 7.). However, it is essential that the process in which children are engaged has a certain broadly defined direction. Significance and meaningfulness to the task comes with motivation, volition or will, arising from the need to do technology.

Thus, open ended, though clearly focused, teaching approaches are recommended in design and technology education. They give children wider possibilities to make connections to their previous experiences and knowledge, especially in order to create original and innovative designs and products.

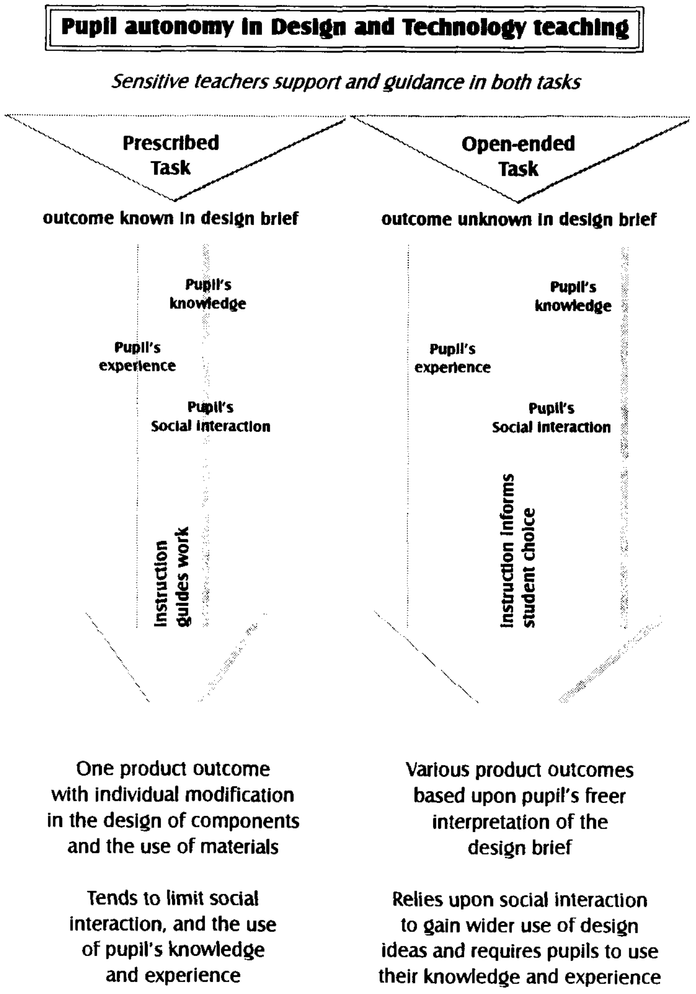

Fig. 7. Pupil autonomy in Design &Technology teaching (Järvinen & Twyford 2000, p. 38).

The teaching model based upon inquiry and discovery is offered as a means of structuring children's acquisition of design knowledge and understanding so that their different views can be addressed, accounted for or let be. Within a given project useful interaction and acknowledgment of children's experiences can be established when teachers and children:

- find out which ideas children already have about a problem, issue or situation being dealt with respect to designing;
- know what children think should happen, for which reasons and with which words they can use to explain or describe design issues;
- take children's ideas seriously;
- give them the opportunities to try out their ideas by investigating the issues, objects or situations for themselves;
- challenge children in discussion to find evidence for their own ideas, especially by ensuring that children talk through their ideas;
- organise discussions so that different ideas about the same things can be brought together;
- enable children to become aware of ideas which are different from their own and to try them out;
- offer a designer's view of a problem or brief allowing children to explore its value for themselves.
- provide challenges for children to use or modify ideas in trying to solve different problems, as well as to make sense of new experience.

Moreover, it is vital that children are encouraged to become interested in the explanations which their classmates or others may give for certain events or tasks in design. Knowing how to respect the views of others is part of learning in technology. (Järvinen & Twyford 2000, pp. 37-39)

6.3.2 Credible or not?

While considering the credibility and quality of qualitative analysis at least the following issues, according to Patton (1990), have to be taken in to the consideration:

> 1) rigorous techniques and methods for gathering and analyzing qualitative data, including attention to validity, reliability and triangulation;
>
> 2) the credibility, competence and perceived trustworthiness of the qualitative researcher; and
>
> 3) the philosophical beliefs of evaluation users about such paradigm-based preferences as objectivity versus subjectivity, truth versus perspective, generalization versus extrapolations and theory versus action. (p. 491)

Since the data gathering methods focused on authentic situations where the children were engaged in real technological problem solving, the data appeared to be rich in terms of such detailed information that would be impossible to acquire by using quantitative methods. Literally, the children’s social interaction ‘spoke’on its behalf. When the child expresses himself/herself verbally in intentional authentic activity he/she reveals attitudes, knowledge, skills in the form that might be difficult to find out by traditional examinations or tests.

In qualitative inquiry it is essential that the whole report is written in such a way that the reader can understand what happened in the scene and why. According to Miles & Huberman (1994, p. 279) it is important that "the account "rings true", makes sense, seems convincing or plausible, and enables a "vicarious presence" for the reader". This requirement is hopefully satisfied through a detailed account of both of the Case Studies.

The credibility of qualitative research is also dependent on the external reviewers; can they agree with the presented results and interpretations, do they accept the methodological perspective and methods of inquiry used in the studies? In a way, the journal reviewers have been taking part in the interpretative analysis process when giving suggestions, feedback and proposals for corrections. In short, this research process was done openly within the scientific community and was constantly revised along the way. The above-mentioned notion of reliability is correspondent with the thoughts of Patton (1990, p. 462): "The qualitative researcher has an obligation to be methodological in reporting sufficient details of data collection and the processes of analysis to permit others to judge the quality of the resulting product"

The credibility of the research was also enhanced by two kinds of triangulation. Firstly, multiple data collecting sources and strategies were employed. Data were collected by means of group observations documented in a field diary and video recordings. The field diary were written on all of the groups and were done partly by the help of dictating machine recordings. Moreover, the groups project files, including the written programs, were saved and copied to a floppy disc to be used in the analysis. As reported in chapter 4.3.1, I encountered some unexpected difficulties to collect some of the data in a completely consistent way. In this regard multiple data collection methods were very important indeed. (see Miles & Huberman 1994, Wiersma 1986). Secondly, the concept of triangulation was also achieved through investigator triangulation (Cohen & Manion 1986, Ritchie & Hampson 1996, Denzin 1988). This was true not only in terms of multiple observers, as in Case Study II, but also through other investigators who participated in the interpretative analysis process.

The concern of external validity is generalization. Because the analysis process was qualitative in nature and based on examples of activities taken from a relatively small number of people, there are not very much possibilities to make generalizations in the traditional sense. Actually, the research did not aim to generalize the findings, but rather to understand the learning processes of the participating children. However, there are some features within the Cases that might offer possibilities for increased external validity. Wiersma (1986, p. 256) states that "the external validity can be enhanced by including variations of the research context in the same study. For example, if writing instruction in the elementary school is being studied, including two or more elementary classrooms in the same study would increase external validity." There were two classes participating in two of the three studies conducted within the Case Study I (Studies 2 and 3), and consequently, the results are of those classes. In this way, it is a well-justified claim that the external validity was better in the Studies 2 and 3 than in Study 1 where just one class was in the focus of analysis.

In Case Study II there were also, on the Finnish side of the study, two classes participating in the making of “noisemakers“. However, in the UK context there was only one class taking part in the activities. Because the teaching approach differed considerably between Finland and the UK, it cannot be claimed that the external validity was enhanced by three participating classes. Rather, I would say that external validity was more substantial on the Finnish side of the study, because there were two classes taught with similar instruction.

However, enhanced external validity does not mean that the results of the Case Studies can be ‘taken out’ of their context and generalized in other classes or schools in Finland. Rather, the results are about the participating classes. I do not see this as a problem for the thesis does not aim to make any generalizations, but to gain in-depth information about the participating classes. (Patton 1990, Radnor 1999)

Wiersma (1986, p. 255) notes that researchers conducting naturalistic, qualitative research “are not very much concerned about whether or not others could replicate their studies.“ The results of this thesis are only about singular cases carried out in the unique context of particular field schools. Both of the Case Studies belong now to the past and it will never be possible to generate identical case, but only cases which might have some similarities with the ‘original’ one (Golby 1999). However, what is seen to be important are the possibilities to replicate the data gathering and analyzing methods. In order to make this possible for others the researcher is obliged to a complete account about the research process. In addition to the rather detailed account, I have described the research process also in terms of “the structure of the research process“ (see Figure 4.). Importantly, the figure did not precede the research, but was formulated during the course of the process. It can be used to structure similar kinds of research activities regardless of the phenomena in the focus, and this is where, at least to my mind, its value and contribution lies.

Because the researcher himself/herself is the instrument in qualitative research, the report must include some information about him/her (Patton 1990). I have explained my background, position and interests at the beginning of the research. However, it is quite difficult for me to evaluate whether the information that I have given is sufficient or not. Thus, it is the reader who shall make the final judgment about this issue.

Have I been subjective during the course of research? I was closely involved in the activities in both of the Cases. Especially in the case of teaching automation I was truly immersed in the scene. Actually, I rejected purposefully the traditional notion that keeping at a distance from those in the focus of the research increases its objectivity. In this regard, I agree with Patton (1990, p. 480) “distance does not guarantee objectivity; it merely guarantees distance“.

But how did my role and relation to the children develop during the course of the research? When the data collection started, I was not any longer in the role of the class teacher, as I had been prior to the project, but in the role of a participant observer and tutor in the need. I was an outsider in the class and I did not share everyday school life with the children in the same way as the class teacher did. Did I lose something essential because of my role? Would it have been better to have a class of my own and be more like an ‘insider’ during the activities? The dilemma is twofold. Firstly, if I had been collecting and analyzing data in the role of a class teacher, I could have had possibilities to be a little bit more sensitive in data collection knowing each child in a more comprehensive way.

But, on the other hand, I could have been too sensitive by targeting data collection procedures to those children that I might have thought would be good informants from the viewpoint of the research problems. Then, data collection would have been biased and the validity of the research decreased. Thus, I think in the role of an ‘outsider’, I was better able to aim the data collection evenly among a larger number of children. Here I mean especially situations where I, equipped with pen, paper and dictating machine, visited the working groups.

I am confident that my role was suitable from the viewpoint of carrying out in-depth qualitative research. Importantly, at the beginning of the data collection, I told the children that I was collecting data for my own research purposes and I would not be showing any of it to the teacher, nor to their parents. I also told the children that they were not going to be evaluated in any way, nor could their teacher use any of the data for evaluation purposes. Moreover, I mentioned that in order to secure anonymity all the names of the children were to be treated as pseudonyms. I think the children trusted me, and during the course of the time blocks began to consider me as a ‘natural’ part of their school environment. This is evident, for example, in the video recordings; the children discussed issues that were apparently not intended to be heard by their teacher.

6.3.3 Closing remarks

It is quite amazing how little influence the nature of the subject matter seems to have had on technology teaching in general education. In many countries teaching materials are still rather descriptive and the outcomes of the children are well known beforehand with only marginal variations. Thus, the question is; do the children then really have any motivation to work with a feeling that they are pursuing their own needs, wants and purposes? If not, then something very essential is missing about technology itself.

According to the major research task, more appropriate pedagogical approaches to technology education were under consideration and development. During the course of the research process many interesting theoretical insights emerged, and these were subsequently tested on practice. Even though this thesis is not an ultimate and complete answer to the questions raised during the research process, I am confident that it has been on the ‘right tracks’. My hope is that the recommendations and proposals presented earlier would offer food for thought for the future development of this field of education.

One of the purposes of this thesis was to produce evidence about the impact of technology education on children’s learning processes. Although there is still a need for a lot more research to be done, the results in this thesis can be regarded as a starting point to explore further the children’s problem solving processes in technology. There seems to be some initial evidence concerning what it means for children to be educated about and through technology. Educating about technology, i.e. taking the human-made environment into focus, was evident, for example, in terms of meaningful connections to the automation around us. While the children in Case Study I worked on the basis of their needs, they were educated about technology in terms of increased procedural understanding or device knowledge (McCormick 1998) concerning the basic principles of automation. In the proceedings of the PATT-9- conference de Vries (1999 p. 150) writes accordingly: “In the study by Esa-Matti Järvinen and Jukka Hiltunen we find evidence of an impact on the pupils’ understanding of underlying principles for the case of automation as part of Technology Education.” Moreover, the children were educated through technology by giving them possibilities to act like technologists, i.e. to create something useful on the basis of their needs, wants and purposes.

In spite of the fact that the Finnish handicraft education, at least “tekninen työ”, appears to be in the phase of re-evaluating contents and methods (see Alamäki 1999) it still seems to provide a rather narrow framework for comprehensive technology education. In this regard, a useful way to introduce technology education to the Finnish schools, at least on the primary level, could be through a multidisciplinary approach. Due to the loose guidelines of the curriculum framework, there are possibilities, in spite of the preferences in handicraft education, to profile both the contents and methods through cross-domain activities. Actually, I would claim that technology can be an umbrella concept for almost all school activities. For example, in Case Study I automation technology was not taught solely within the framework of handicraft education, but rather through cross- domain activities for both boys and girls. Similarly, in Case Study II, all the activities in making “noisemakers“ took place through a multidisciplinary approach. Here, the question is about the profile chosen for the school curriculum. However, if the multidisciplinary approach is taken, serious consideration should be given to the true nature of technology and its processes. Otherwise the essence would be obscured.

A further problem in the Finnish educational handicraft is that in practice it effectively separates boys and girls. Although “tekstiilityö“ might be oriented too much artistically, there is also a potential for real technological activities, in which the students’ thinking skills and technological problem solving processes are fostered as efficiently as in “tekninen työ“ lessons. Importantly, all the aforementioned issues could be appropriate approaches to ‘textile’ education as well. In fact, technological processes overlap through different materials. They are commonly encountered and accomplished in a wide spectrum of technological activities regardless of the materials used (Open University 1987). The main focus of handicraft education should not be anymore solely in producing artifacts or workpieces but, rather, move towards offering general all-round awareness and capabilities about technology.

Actually, one way to implement technology education in Finnish schools could be by introducing a new school subject called “technology“. Further, even though this may be a radical idea, it could be worth of revising the contents and methods in both of the current handicraft subjects, “tekninen työ“ and “tekstiilityö“, and merge them together in order to create one broad, comprehensive technology education which would be equal for both boys and girls. This new subject should actively seek opportunities for collaboration with other related subject areas such as mathematics, science, and environmental studies (Kantola 1998), or even history.

During the course of the research process I started to ask myself why technology education should be developed and taught only in the framework of handicraft education. This is still an acute dilemma for me, in spite of the fact that various differing approaches in technology education have their origins in a craft-oriented approach (de Vries 1994). However, from the viewpoint of this thesis, the dilemma is by no means the most essential thing. The thesis has focused, true to its title, on developing more appropriate pedagogical approaches to technology education.

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8. Appendix

Appendix 1. The handout sheet delivered to the children (in Case Study I)

Appendix 1. The handout sheet delivered to the children (in Case Study I)

LEGOLOGO

OHJELMOINTIPAKKI

MOOTTORIT JA VALOT

talkto ”motora tai tto ”a	käskee moottoria
talkto “lampc	käskee lamppua
talkto “sounde	käskee ääntä
tto [motora motorb]	käskee yhtäaikaa moottoria a ja b
on	käynnistää moottorin tai sytyttää lampun
off	sammuttaa
alloff eli ao	pysäyttää kaikki toiminnot
onfor 30	esim. moottori käynnissä 3 sek (30/10 sek)
setpower 5	virran/moottorinvoima 5 (arvot 1-8)
setright/setleft	moottorin pyörimissuunta

SENSORIT

waituntil [angle5 = 10]	kun kulmasensori on 10 astetta, niin
waituntil [temp6 < 60]	kun lämpösensori mittaa kylmempää kuin
waituntil ”touch1	kun kosketussensoriin kosketaan

TOISTO

repeat 2[ ]	toistaa toiminnon 2 kertaa

PROSEDUURI

```
to kone
tto ”a setright setpower 5 onfor 30
end
```

Kirjoittamalla kone- komentokeskukseen moottori käynnistyy 2 sekunniksi 5 teholla ja pyörii oikealle

```
to tunto
waituntil ”touch5
kone
end
```

Kirjoittamalla tunto- komentokeskukseen ohjelma käynnistyy. Kun kosketussensoria painetaan, niin moottori käynnistyy 2 sekunniksi 5 teholla ja pyörii oikealle.

ERIKOIS

ask ”lampb [on]	ohivalinta
cc	tyhjentää komentokeskuksen
flash 20 10	vilkutustoiminto
rd eli reverse direction	kääntää moottorin pyörimissuunnan
tone 60 10	soittaa äänen 60 1 sek ajan

Ali - ja pääohjelman tekeminen Procedures - sivulle:

Esimerkki toimivasta ohjelmasta, jossa kaksi aliohjelmaa on sisällytetty pääohjelmaan:

```
to valo
talkto “lampa flash 2 1 on
end
                                   --->   Aliohjelmia
to ääni
talkto “soundb on
end


to vahti
waituntil [light5 > 450]
valo
ääni                               --->    Pääohjelma
waituntil  “touch1
ao
vahti
end
```

Käskyjen ja ohjelmien toimivuutta voidaan testata komentotilassa (command center) ja/ tai projektisivulle valmistettavalla ohjauspaneelilla. Kun komentotilaan kirjoitetaan em. pääohjelman nimi: vahti, ohjelma aktivoituu toimintaan. Pääohjelman nimi “Vahti“ on kirjoitettu toisen kerran ennen end- komentoa siksi, että ohjelmaan muodostuu ns. looppi. Loopin tarkoituksena on saada ohjelma toimimaan jatkuvana, kertautuvana prosessina.