The Lego/Logo Learning Environment in Technology Education: An Experiment in a Finnish Context

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Introduction

According to constructivist theory, learning is an active, continuous process whereby the learner takes information from the environment and constructs personal interpretations and meaning based on prior knowledge and experience (von Glasersfeld, 1995). Personal interests and needs that arise from the learner have a great influence on the learning process. Learning is also seen as a social phenomenon in which learning is mediated through the social interactions among the members of the learning community as they engage 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 by means of context dependent language (Gergen, 1995; Björkvist, 1994).

According to Rogoff (1990, p. 141) social interaction in cognitive development quite often resembles the apprenticeship situation, where novice and the expert are engaged in the same problem solving (Järvelä, 1996). Although 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).

In the culture of schools, teachers often feel obliged to ensure that pupils learn socially accepted knowledge and skills (textbook knowledge assessed through tests) in the learning activity (Edwards & Mercer, 1987). This is epitomized in authoritative teaching methods (Wertsch, 1991), whereby the teacher controls the social interaction and other classroom actions. This mitigates against children's collaborative construction of understanding and individual pupils may feel that they are outsiders in the learning activity. Thus, the actions of many children are in response to what they perceive to be the teacher's expectations (Edwards & Mercer, 1987). In this kind of school setting the pupils do not necessarily feel the teaching and its content to be personally important or useful.

Effective teaching requires the creation of optimal learning opportunities through pedagogical means and also the encouragement and maintenance of a

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positive willingness to learn. Thus, a teacher's role changes to the role of a facilitator of learning and coordinator of learning environments. Since learning is social interaction to a great extent, the relationship between people and the interaction between a learner and a target of learning are emphasized in the planning of learning environments. Thus, teaching methods have a significant role in what and how pupils learn. Moreover, the present idea of learning emphasizes pupils' active role as constructors of their own information structure. Pupils' perceptions and expectations guide what they observe, what kind of information they accept, and what kind of interpretation they give to it.

Society poses demands for what is expected from schools. Instructional technology and its applications are considered to be essential to the teaching-learning process, starting as early as the primary school level. This priority is especially true in the teaching of mathematical and scientific subjects. The Finnish Ministry of Education has at least *planned* to equip all the schools with appropriate computer systems in the near future. This initiative is largely based on the felt need to get students interested in studying these mathematics and science and to assure that they master them well. At the same time, the development of teaching methods and approaches that are more meaningful and interesting for the pupils is far more important than the use of instructional technology alone. Technology education can provide a concrete method and context for the mathematical and scientific content.

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 and have basic skills in key areas of modern technology. Some contend that the ability to compete globally is a matter of national survival. Throughout history technology has enabled humans to survive (Hacker & Barden, 1988). What Finland faces is "modern survival" through technology.

Technology education in Finland developed in part in response to the demands just mentioned (Kananaoja & Tiusanen, 1991). Lindh (1997, p.133) defined the aim of Technology Education accordingly:

> The aim of Technology Education is that pupils could be more able to understand the logic and functional mechanism of 'everyday' technology and can solve technological problems applying technological knowledge and skills they have got.

The relationship between modern technology and mathematics and science is very close (Dugger & Yung, 1995, p. 10; Traebert, 1988). Thus, the three subjects must be considered together when developing technology education curriculum.

Purpose

The purpose of the project and resultant study reported herein was to support and further develop technology education curriculum. The study is based on the assumption that constructivistic-driven, open-ended problem solving and pupil-centered approaches are especially suitable for technology education. The objective of this study was to investigate the meaning and suitability of a teaching method that embodies these approaches in technology education. Learning as a social process has already been studied extensively; therefore this study does not provide great insights about the learning process at a general level; rather, it focuses specifically on technology education.

The study was directed by the following main problems: 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 problems 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 Experiment

The goal of the experiment was to help pupils become familiar with some areas of modern technology, specifically control technology and programming skills. A secondary intention was to emphasize the importance and meaning of technology in their everyday lives. Teaching approaches were correspondingly developed to support both these goals as well as to provide pupil-centered, open-ended problem solving based upon the personal needs of the pupils and their past experiences (Hacker & Barden, 1988, p. 1).

The Lego/Logo Control Lab learning system was selected for the project with the costs underwritten by a local electrical power supply company, IVO Ltd. The materials were part of the Technic series of the Lego product line. They included sensors for light, touch, angle, and temperature; a control interface that connected to the computer; and the Lego/Logo language software which allowed the pupils to write control programs. The Lego/Logo programming language is based on the Logo language developed by Seymour Papert for the purpose of enhancing learning in mathematics. Papert (1980) believed pupils can solve problems and complete tasks that they thought were beyond their capabilities as long as they work in a learning environment that provides suitable emotional and intellectual support.

A series of activities were developed within the Lego/Logo learning environment. Six classes at the fifth and sixth grade level worked with the activities in groups of three to four members. Students 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 pupils were free to decide the assignment of roles (programmers, constructors, and so forth).

From the six classes, one class of 22 pupils at the fifth grade level was randomly selected for the study. There was no reason to believe, either before or after the study, that this class differed from the other five. All six classes were treated in the same way and were given similar instructions and arrangements, and followed a similar class schedule.

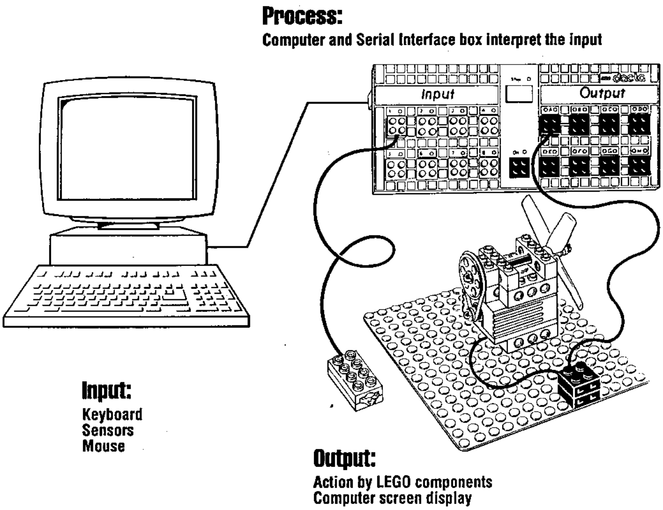

Figure 1. Principle of Lego/Logo Control Lab-learning environment. (LEGO DACTA , 1993, p. 5)

The experiment utilized three, six hour instructional time blocks. This time was taken from mathematics, science, technical/textile work, and English courses in which the pupils were enrolled. The project was arranged to fit into normal school routines by means of a workshop-like environment. The computer lab was reserved for the construction and testing of projects. A work station was provided to each group and consisted of a computer (Intel 486-66 MHz), the Lego/Logo materials, and adequate space in which to work.

Time Block One. The first two lessons of the experiment took place in the classroom. The pupils were told about the experimental project and its aims. After the introduction the pupils were divided into their working groups. The Lego components of the learning environment were introduced. The groups were given the challenge of constructing a Lego “soap-box” car as quickly as possible. The groups’ creations were also tested in competition. Once this was complete, the pupils moved to the computer lab where the Lego/Logo materials were shown as an intact system. Handout sheets that included some of the principles of programming and the main commands in the Logo computer language were distributed. The pupils were then allowed to freely investigate the possibilities of the learning environment.

Time Block Two. During the second time block the whole class visited a local peat-fired electrical generation plant. At the beginning of the visit a plant representative explained the operation of the power plant at an understandable level. Then half of the pupils (still organized in the working groups) went to investigate the functions of the main gate of the plant where the peat is feed into the fire box of the boilers while the other half observed the conveyors that transported the peat. The pupils were told to take notes to help them understand and remember what they had seen.

The remainder of the time was spent in the computer laboratory. The visit to the peat plant provided a theme for working. The students were told not to simply build a model of the plant. Instead they were encouraged to use their creativity and imagination to improve what they saw and implement it in a Lego/Logo model. For example, the students were encouraged to improve the peat delivery gate since this device did not function well in Finland's snowy winters.

Time Block 3. In the third time block the students were given the most open-ended problem to solve. 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 didn't know beforehand what the groups might accomplish. Consistent with contemporary technology education, there were no single correct solutions. Rather, the viability of the solution was relative to what the students knew about the needs of their pets.

Method

The sociocultural constructivist perspective relative to learning requires a theoretical background that draws on both constructivism and interpretivism. Constructivism and interpretivism aim to understand the meanings constructed by pupils 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 social interaction between the group members as well as the context and substance of social interaction .

The methodological perspective of the study was qualitative in nature and based on interpretivist, inductive analysis. The study was guided by the a stated research problems. It involved direct group observations and employed a search for patterns within the data. (Patton, 1990)

This study focused mainly upon the small-group social interaction and its effect at the individual level. Therefore data collection procedures were aimed at capturing pupils' social interaction and actions in small-group settings. Data were collected by means of group observations recorded in a field diary and videotaped recordings of group social interaction. The field diary and video tapes represent the primary data sources. Videotaping was aimed at a single group throughout the study and this group was separated from the rest of the class. The field notes were written on all of the groups.

The researcher assumed the role of participant observer. During the study the researcher also acted as a tutor. This procedure enabled the researcher to be "inside" the study, true to the nature of qualitative research (Erickson, 1986).

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 without all of the expectations usually connected with a research study or traditional school evaluation practices. (Patton, 1990: p. 132; Honebein et al , 1992: p. 89).

Verbatim transcriptions were derived from the initial viewing of the videotapes and were combined with the observation field notes. During the transcription process, irrelevant data were excluded such as discussions of boy friends and girl friends. This is consistent with the recommendations of Miles and Hubermann (1994, p. 11). The main focus of the data collection was on the technological content of the social interaction and its understanding at the individual level. Situations in which the pupils spontaneously generated technological problems to solve were included in the transcription, as well as situations in which mathematics or science were used as tools in technological problem solving. Secondary data sources also provided valuable information. They were used to supplement information in the search for emergent patterns on the data. To ensure validity and credibility of the research, multiple data collecting sources and strategies were employed, applying the concept of triangulation (Miles & Hubermann, 1994: p. 266).

During the first viewing of the videotapes, the researcher began to form an idea of the emergent categories relative to the theme of the study. The resultant categories are reported in Table 1. Before the second viewing of the videotapes and reading the field notes, these emergent categories were used to develop a matrix into which the number of action situations in social interaction could be placed during the second round of data analysis. These numerical data were collected mainly to determine the amount of pupil-centered work. Data analysis was, however, in accordance with qualitative methodology and therefore the numerical data in the matrices were not intended to be quantitatively analyzed further. The main emphasis was on the interpretations drawn out of primary data sources.

Results and Discussion

The inductive interpretative analysis process used in this study enabled the results to be framed as empirical assertions, with data as evidentiary warrants (Erickson, 1986: p. 145). Thus results are presented through three assertions supported by evidentiary examples taken from primary and secondary data sources. Examples presented to support assertions two and three were also “microanalysed” in order to clarify the interpretative analysis process, which consequently led to more general assertions.

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.

The teacher’s tutoring was needed but it was much less frequent than the learning that was facilitated by students working and solving problems by themselves. Nevertheless the teacher’s advice was often indispensable. In many cases the teacher was truly a member of the group. In other cases the teacher or the researcher was in the role of a learner. The Group Action Occurences taken into account are represented in the form of exemplars supporting assertions 2 and 3.

Table 1
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 occurences	Discourse, mainly verbal, but also includes other noticeable action, which focuses on technological, mathematical, or scientific content. Also includes the pupil's independent action on behalf of the group and the final accomplishments (see Vygotsky in Wertsch and Toma, 1995, p. 163).

Table 2
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	5	1	1	0	1	1

The data in Table 2 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.

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 examples illustrate situations where the pupils handled the content in accordance with the above assertion.

> Ulla is sitting in front of the computer and says: “Now we have to write those commands...motorb..” Kati advices Ulla and says, “Talkto matorb!” 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 2)

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.

> Lupu points to the gate and says, “Look!..touchsensor...when it’s touched.. the gate opens…we have to place a touch sensor somehow here and when somebody touches it...” Now Hupu interrupts Lupu’s reasoning and says: “It doesn’t need a touch sensor...we can use lightsensor in order to open the gate.”
>
> (Time block 2)

Lupu understands the meaning of touch sensor (input) in order to trigger the appropriate function (output). Hupu also understands the meaning of the sensors and, moreover, seems to be more aware of the possibilities of different sensors in this particular context. It was apparent that both Lupu and Hupu understand the principle of control technology and they were able to create a complete system (input-process-output).

The following example illustrates the situations when the teacher or researcher himself was participating in the group work.

> Kati says: “We have to write procedures for the other (motor) setright and for another (motor) setleft.” I say: “Yes, that is pretty much it. Very good. …In which gate (output) is this motor (left)?” Kati answers: “It’s in gate

> b." I continue, "Okay, then write the procedures there (on the gate b procedures page). Now you have to take into account how much time the motor has to rotate in order to open the gate. You know it doesn't has to rotate much, only a short time and then it stops."
>
> (Time block 2)

In this example the researcher was engaged in the problem solving with Kati. She already knew the meaning of the setright and setleft commands and also shows ability to apply them in this particular case. In this example the researcher seems to be more like a peer, not like an omniscient teacher who only dispenses knowledge. This particular example raises the question of whether the group has found out the short rotation time for the motor without the intervention of the tutor. If the information had not come from the tutor, it may have taken more time for trial and error to solve the problem. As Dugger and Young noted, however, trial and error is sometimes quite typical in the technological process (Dugger & Young, 1995 p.10).

During the afternoon of the third time block, the programming needed to be done for the devices that the students had constructed. The level of the challenge and the exhaustion that the students felt after lunch caused them to become frustrated more quickly and some almost gave up on the task. An interesting phenomenon appeared in these difficult situations. Almost without exception somebody in the group had enough energy and motivation to exhort and support the other pupils to continue working. At this time the teacher's advice was needed quite a lot, but significantly the idea to continue further despite the difficulties came from the pupils themselves! They apparently wanted to accomplish the assignment they had formulated.

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. Though 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 students. 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 classes, the students 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." (though oil was not used because of it's messy nature.)
>
> (Time Block 1)

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 it seemed evident that knowledge transfer took place. The pupil's deeper understanding of the phenomena behind the increased mass or lubrication is difficult to substantiate, 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 3)

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.

Conclusion

The results of this study support the notion that social interaction can be interpreted to promote technological problem solving and learning. The pupils taught themselves in an interactive social setting. Knowledge transfer among the pupils 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 pupils 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.

Programming the computer appeared to be the most difficult and frustrating to the students. This is partly due to syntax sensitivity of the Logo-language but also to the limited amount of time that the students had overall. Despite the difficulties, programming was an essential part of the project. It gave possibilities to apply mathematics naturally in actual, pupil-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. This fits with the constructivistic notion in which an individual takes information from the environment and constructs personal interpretations based on prior knowledge and experience. The pupils used the knowledge they gained from the teacher by applying it in new situations. Moreover, the knowledge was transferred among the pupils.

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. In sociocultural interpretation this takes place in interaction with the social environment and the knowledge is commonly shared. This notion leads to the essence of technology. There would not be technological reality around us if we have not, literally, constructed it. Technological development has usually been driven by individual or social needs to sustain living and to make it easier or safer (Hacker & Barden, 1988; Suplee, 1997) or for other purposes that seem important. According to results of this study the sociocultural constructivist approach appears to be natural and effective in organizing learning, especially in technology education.

When participating in the project, the pupils were actors in the process where they constructed technological reality on the basis of their own needs and ideas. This behavior was especially prevalent in the third time block in which the problem was the most open-ended. The researcher felt confident that the pupils in the project were participating in the process of technology, a human endeavour which has existed since the dawn of the human race (Hacker & Barden, 1998).

Considering technology education in a larger context, the Lego/Logo-learning environment is in many ways handicapping. It does not introduce a very wide range of materials and the construction must be done within the limits of the Lego components. On the other hand, an advantage of the system is that it consists of components of which most students are already familiar from early childhood. The “Lego-world” of a child’s room at home appeared to transfer to the school, along with the comfortable, relaxed atmosphere that they had enjoyed with their family.

This phenomena was also undoubtedly due to the absence of conventional tests and the anxiety that accompanies them. This is consistent with the thoughts of Ausubel and Robinson (1973, p. 530) regarding the creation of an appropriate atmosphere for solving problems that is low in stress and allows concentration on the task at hand.

One of the most important things in education is to adjust the teaching methods to the nature of the content. When the content is technology, it is quite natural that the pupils solve open-ended problems on the basis of the their own needs and what is significant and meaningful to them. Regardless of the media used in technology education, it is essential that the pupils are encouraged to work and learn in a way that fosters creativity and discovery (Futschek, 1995, p. 724). To promote effective learning, the emphasis has to be on appropriate teaching methods and in relating the problems to the pupils themselves. The action itself and it’s understanding are most important. In technology education, pupils may be better at defining appropriate learning outcomes than are textbooks or teaching manuals. At least based on the limited scope experiment reported herein, traditional school evaluation methods may not be the most appropriate way to evaluate the pupil's outcome nor, perhaps, the process which led to it.

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