Pupils Identify Key Aspects and Outcomes of a Technological Learning Environment

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This article is based on a presentation at the ITEA Conference - PATT 9 Session, Indianapolis, 1999.

Over the past two decades, the contribution that a rich learning environment makes toward attaining educational goals such as improvement in learning achievements and attitudes towards studies and school has been considered in educational research (Fraser, Giddings, & McRobbie, 1995; Fraser & Tobin, 1991; Perkins, 1992). The term *rich learning environment* not only includes physical devices, such as experiment kits or computers, but also the teaching technique, the type of activity pupils engage in, and the method of assessment. Associating science and technology studies with a rich, flexible, computer-embedded learning environment may enable pupils to attain higher academic achievements and overcome their cognitive and affective difficulties (Barak, Waks, & Doppelt, 2000).

The Creative Thinking and Technology (CTT) program (Barak & Doppelt, 1998) was developed for that purpose. The CTT program's main goal is to cultivate creative thinking via project-based learning. The program integrates creative thinking tools from the CoRT 1 series of thinking tools (De Bono, 1986) within the technology curriculum (Barak & Doppelt, 1999). The pupils create authentic technological projects and prepare portfolios that are used for assessing the learning process. LEGO/Logo is attractive to technology education, as previous works have shown (Jarvela, 1995; Jarvinen, 1998; Kromholtz, 1998; Papert, 1991; Resnick & Ocko, 1991). The current research shows an application of LEGO/Logo by using pupils' authentic projects for learning technology as a major subject in high school. This article concentrates on the pupils' perspective on the preferred learning environment.

Background

One of the proclaimed goals of science and technology education is to enhance pupils' higher-order intellectual skills, such as mathematical-logical thinking and creativity (Gardner, 1993; Perkins, Jay, & Tishman, 1993; Sternberg, 1998). De Bono (1986) suggested a series of creative thinking tools that can be used as a general approach to teach thinking. Perkins and Swartz (1992) suggested that the fostering of thinking should be integrated in the learning of a specific context, such as science and technology.

Waks (1997) observed that lateral thinking initiates the learning process when working on a technological project, as pupils seek for alternatives and examine different solutions. Vertical thinking is essential in the stage of choosing a solution and developing it. Vertical thinking and lateral thinking complement each other, and both are the essential elements of creative thinking (De Bono, 1986).

Imparting creative thinking within science and technology education requires not only changing the teaching methods and learning environment, but also adopting new assessment methods such as portfolio assessment, which is based on records of pupils' activities. The portfolio can consist of written material, computer files, audio and video items, sketches, drawings, models, or pictures. The portfolio reflects what pupils have learned and how they question, analyze, synthesize, solve problems, and create new ideas or design and build useful products or systems. The portfolio also shows how pupils interact intellectually, emotionally, and socially with others (Collins, 1991; Wolf, 1989).

Perkins (1992) identified several features of learning environments: information database, symbol platforms, construction systems, phenomenarium (microworlds), and assignment organizers. A learning environment should be sufficiently flexible, allow different learning styles (Kolb, 1985), and develop different skills (Gardner, 1993; Sternberg, 1998). It should include a portfolio assessment of pupils' original projects, rather than pen and paper examinations.

A rich, flexible learning environment is necessary for accelerating the learning of at-risk pupils (Levin, 1992). How to advance low-achieving pupils is an on-going challenge for educational systems. Routing low-achievers to lower-level learning tracks creates a vicious circle. The school system has low expectations from the pupils, the pupils accumulate a history of failure, and the teachers emerge as having a low self-esteem and professional image (Barak, Yehiav, & Mendelson, 1994).

The LEGO/Logo learning environment was selected as the basis for implementation of these guidelines. LEGO/Logo is a widely used learning environment for technology education in elementary and secondary schools. It combines LEGO bricks and Logo commands for creating procedures that control the prototype. In addition to the ordinary LEGO bricks, the LEGO systems contain motors, sensors, and gears that allow pupils to create complicated projects and to learn principles in technology and science. According to Resnick and Ocko (1991), the LEGO/Logo learning environment creates a community of learners, changes the teacher's role in class, and fosters the development of pupils' authentic projects as the basis for the learning process. Learning environments such as LEGO/Logo enable the learner to construct concepts (Papert, 1991). When pupils create an authentic project in the LEGO/Logo environment, they experience meaningful study that enables the exercise of sophisticated ideas that originate from their own projects.

The CTT program embraces the following: learning through completing authentic projects, integrating creative thinking activities into the technology curriculum, and allowing freedom to learn and encouraging learning from mistakes. Because the pupils study technology as a major, it is pertinent to create authentic technology projects as a way to advance pupils' competencies and knowledge. This article focuses on the influence of the CTT program upon affective and cognitive domains from the pupils' point of view.

Intervention

The CTT program (Barak & Doppelt, 1999) encompasses two hours of study each week during an entire school year. During the first semester (about 15 weeks), the class learns thinking tools from the CoRT 1 thinking program (De Bono, 1986). This program consists of a series of thinking tools, such as PMI (plus, minus, interesting), CAF (consider all factors), and APC (alternatives, possibilities, choices). In the first stages, the pupils learn and exercise these thinking tools by drawing examples from their daily lives. Later, learning focuses on design, construction, and improvement of small devices such as cars or robots using LEGO building blocks and mechanical components. For example, all pupils construct identical cars according to a given LEGO design, compare their features, and suggest improvements while using the CAF and APC thinking tools. In the course of this process, the pupils also become familiar with the LEGO/Logo system, the computer interface, and simple programming in *Multi-Techno-Logo*. This is a Hebrew version of LEGO/Logo that combines the advantages of Logo-Writer and LEGO/Logo using the mother tongue for programming (Doppelt & Armon, 1999).

During the second semester (about 15 weeks), the pupils choose and create original technological projects. As Barlex (1994) stated, "It is difficult to capture the breath of spring that successful technology project work brings to a wintry curriculum. Perhaps it's the risk of failure and the uncertainty with no right answers, only one possible solution" (p. 143). Barak and Doppelt (2000) reported that the pupils coped with complex problems and found solutions that were dependent on the synthesis of lateral and vertical thinking into creative thinking.

The pupils create portfolios in which they collect their documentation of creative thinking and other outcomes of the learning process. Over a period of several years, each class developed criteria for assessing the portfolios. A scale for assessing pupils' creative thinking through their portfolios was created on the basis of these experiences (Barak & Doppelt, 2000).

This scale comprises four levels: awareness of thinking, observation of thinking, thinking strategy, and reflection upon thinking. The proposed scale is applied to two portfolio domains: (a) learning outcomes, such as a piece of research, or a technological product, and (b) processes of learning, thinking, and teamwork in the class. Several examples of the scale's application to pupils' portfolios demonstrate how this methodological assessment can help educators to develop and evaluate learning assignments aimed at fostering creative thinking. Through designing, and systematically reflecting upon the portfolio, pupils can develop an awareness of their internal thinking processes and learn to direct their own thinking.

Research Goals

The main goal of this research was to learn

Pupil X assesses the influence of input A

INPUTS (15)

Learning styles
- Self learning
- Group discussions
- Team projects
- Individual progress rate

Pupils activities
- Thinking
- Designing
- Programming
- Construction

Class atmosphere
- Open mindedness
- Acceptance of mistakes
- Tolerance of different opinions
- Freedom to chose subjects
- Rich environment

Learning materials
- Instruction sheets
- Work sheets

Other

on desirable pupil's outcome B

OUTCOMES (25)

Social integration
Department pride
Technical skills
Mutual help
Independence
Self-confidence
Personal initiative
Team work
Perseverance
Self-responsibility
Curiosity
Imagination
Challenge
Desire to learn
Critical thinking skills
Success in technology subjects
Interest in technology studies
Success in other subjects
Interest in other subjects
Desire to come to school gladly
Improvement in relationship with the teacher
Motivation to work at home
Increase in other pupils' appreciation of the department

is

Very much
To
Very little

Figure 1. A mapping sentence for assessing "inputs" and "outcomes" of a technology project-based curriculum.
The pupils rate the contribution of each one of the inputs (for example, self-learning) to all the 25 outcomes. A sentence can have a structure such as, pupil 1 assesses that the influence of [self-learning] upon [curiosity] is [little].

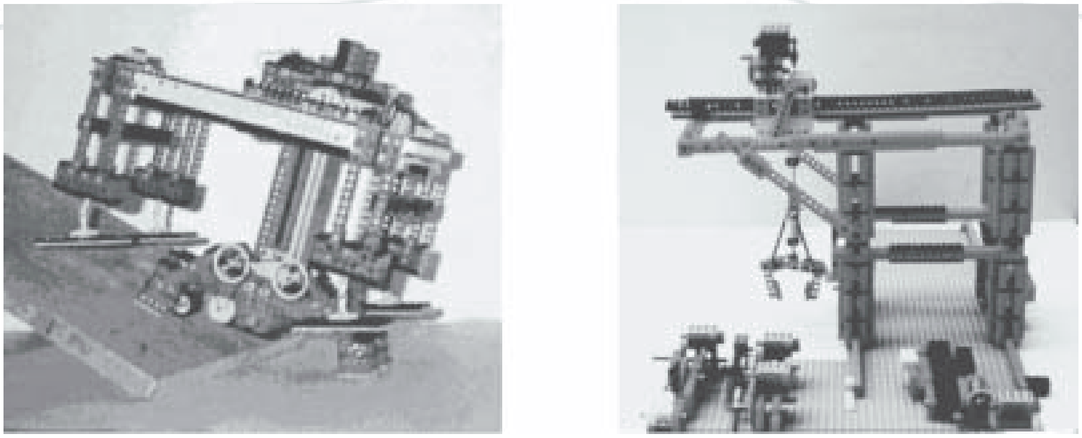
about pupils' perception of the influence the learning environment has on their outcomes. Several characteristics of learning environments have been expounded in the theory. This article focuses on the contribution of these characteristics to learning outcomes from the pupils' point of view.

Method

Subjects

The participants in this study were 10th grade pupils in a high school in northern Israel. These were low-achieving pupils who had chosen to major in the Machine Control Department. Some of the pupils chose this route on their own; others had been thus directed by school advisors, in whose opinion this route is the only solution for low achievers.

In Israel, at the end of junior high school, pupils have to choose one or more areas in which to major, such as sciences, humanities, art, or technology. The high school technology curriculum includes several major subjects that are related to physics and mathematics, such as computers and electronics, mechanics, and control systems. Typically, the "high achievers" are directed to computers and electronics and the "low achievers" are directed to mechanics.



a. An obstacle climbing robot

b. An object identifying crane

Figure 2. Examples of pupils' projects.

Barak, Yehiav, and Mendelson (1994) have previously raised the issue of integrating low achievers into technology studies in Israel. Some of the pupils considered here may fit Levin's (1992) definition of at-risk pupils.

The CTT program ran for five years between 1994 and 1998. A total of 56 pupils participated in this program (9 to 24 pupils each year). This article examines the program's influence on the first participating group of pupils, who were in 10th grade in 1994, through 12th grade in 1996.

Data Collection

This research combines qualitative and quantitative tools: observations of class activities, interviews with pupils and parents, and follow-up of the pupils' academic achievements. Such a combination has been found to be effective and contributes to the understanding of the research field (Fraser & Tobin, 1991). In quantitative research, it is common to validate conclusions from the findings of one instrument by the findings of another instrument (Denzen & Lincoln, 1994).

As a result of content analysis of the interviews, a questionnaire was developed for assessing pupils' progress in an open learning environment, in terms of the input-output relationship from the pupils' viewpoint. The mapping sentence presented in Figure 1 provides a flexible structure for researchers to construct and use similar questionnaires in classes (Waks, 1995). The terms for both the input and the output category were extracted from interviews with the pupils. This questionnaire is based on an assessment of the influence of a learning environment's inputs on pupils' outcomes. Pupils completed this questionnaire by rating each pair on a scale from 1 (*having a very high influence*) to 5 (*having a very low influence*).

Findings

Examples of Pupils' Projects

Over the five-year period during which the CTT program was implemented, 56 pupils built approximately 50 different team projects. All the ideas were suggested by the pupils themselves. Two examples are presented in Figure 2. Figure 2a illustrates a robot that moves forward or in circular motions and traverses obstacles, and Figure 2b depicts a crane that scans an area, collects randomly distributed objects, and then delivers them onto a train.

Other examples include an automatic conveyor belt that receives, identifies, and counts items loaded off a truck, and a chocolate drink machine that fills powder into a glass, mixes it with milk, and delivers the glass onto a conveyor. These examples demonstrate how the project-based learning approach enabled the pupils to create various authentic projects. These projects won nationwide attention from educational curriculum councils and other research groups.

Community of Learners

Observations in class revealed a variety of interactions between younger and older members of the Machine Control Department, between parents and children, and between pupils and teacher. An external spectator could observe pupils, who were working individually or in pairs, and the teacher, who circulated among the groups in turn. The laboratory became a second home to the pupils. They came to work on their projects during breaks and free hours, and even after school. They could familiarize themselves with projects made by former pupils who still visit the Machine Control Department from time to time.

Pupils' and Parents' Viewpoints

The following quotations, taken from interviews with pupils and their parents, demonstrate the impact of the CTT program and its influence on the learning atmosphere at school.

Adam: "It is very important to continue the LEGO/Logo lessons...it is a way for me to achieve my goal, in my way...there is freedom to choose, and nobody tells me what to do...the teacher only guides me...this is like independent learning...I like the creativity through the lessons. It gives the opportunity to understand the theoretical issues of mechanics."

David: "I was an average pupil in junior high school...since I came to the Machine Control Department I have changed...my achievements in the technology subjects are high...even in humanities subjects I have improved...the way we learn through LEGO/Logo, the team work, and the independence the teacher gives us all encourage us to help one another."

Benny: "We do not build robots only for fun, we learn how to design prototypes...we learn automation, center of gravity, it demands thinking, develops us, and we can apply what we learn...it is interesting and adds spice and motivation to learn more."

Mother of twins, speaking of her children who achieved well in the matriculation examinations and finished high school, despite both having a history of difficulties during junior high school:

> "There is a dramatic change in their self-confidence. They are alive and they have started to smile again; they were very sad in their past experiences in school. Learning LEGO/Logo has developed my son's thinking about how technology systems work. There was a drastic change in his self-confidence during learning in school."

A mother who decided to send her son to major in the same department as well as his sister:

> "I am proud that my daughter studies technology as a major. She started to learn from her own motivation...the LEGO/Logo strengthens her and it caused her to invest efforts in other subjects at school. It was a challenge for her...we are going to send her brother to the same department as well."

Questionnaire Results

A closed questionnaire was constructed in order to probe further the influence of the learning environment from the pupils' viewpoint, based upon the interviews with the pupils. The questionnaire included 15 "inputs" of the learning environment, such as freedom to choose subjects, team projects, individual progress, and construction activities. These aspects are considered as inputs of the learning environment because they are concerned with the organization of the learning in the class, such as various activities that have been introduced to the pupils, flexibility, and degree of freedom to choose activities. Pupils pointed to 25 outcomes that were influenced by the CTT program, for example, personal initiative, self-confidence, interest in technology studies, and challenge.

As mentioned above, the pupils rated the contribution of each input to each of the 25 outcomes on a scale of 1 (*very high*) to 5 (*very low*). An average score for each of the inputs and outcomes was calculated, representing the weight attributed by the pupils to the inputs and the outcomes. Figure 3 presents the final results, where the most significant inputs and outcomes are shown in rank order.

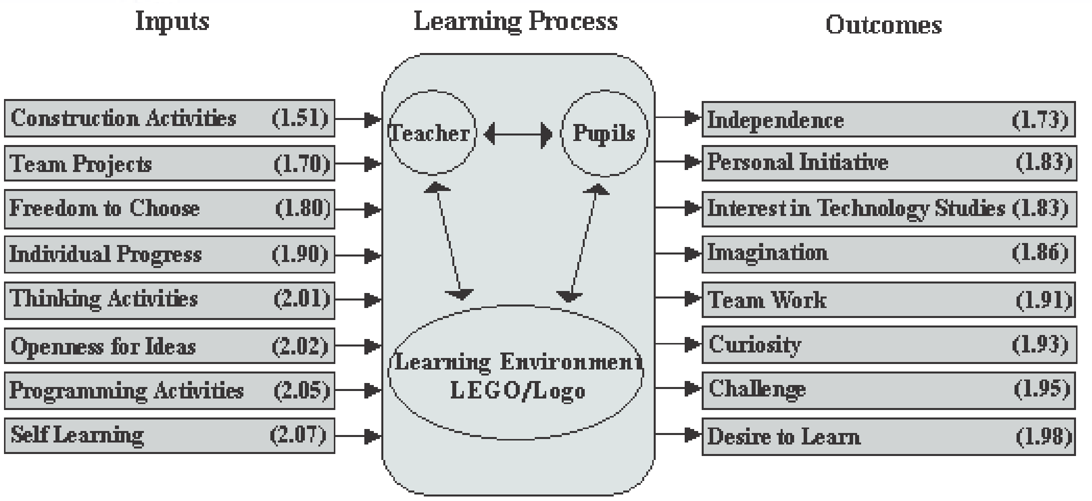


Figure 3. The most influential inputs upon the major outcomes of a rich technological learning environment from the pupils' point of view.

Discussion and Conclusions

The current research addresses the issues of how to promote low achievers by providing them with a rich, modern, and flexible technological learning environment. The pupils created authentic technological projects using their own imagination and documented their work in rich portfolios (Barak & Doppelt, 1999, 2000). Observations of pupils' activities in class, interviews with pupils and their parents, and questionnaire findings all indicated improved pupil self-esteem and self-confidence. Pupils changed their attitudes towards their everyday learning and their future intentions to continue studying.

The findings from this research suggest that educators invest resources in the development of learning environments that combine hands-on activities with what Papert (1980) has called "heads-in" activities. Computerized simulations and programming are important components in the learning environment, but they do not stand alone. Educators can use LEGO/Logo to advance learning and thinking. LEGO/Logo is attractive to technology education, as demonstrated in previous studies (Jarvela, 1995; Jarvinen, 1998; Kromholtz, 1998; Papert, 1991; Resnick & Ocko, 1991). Moreover, the current research shows an application of LEGO/Logo for studying technology, mainly mechanics and machine control, as a high school major.

The present study directs attention towards the kind of learning environments that pupils opt for: construction activities, team projects, and freedom to learn. The most important outcomes, in the pupils' eyes, are independence, personal initiative, and interest in technology. In many cases, the school ignores these outcomes because education systems concentrate mainly on academic achievements. A rich learning environment is especially important for low-achieving pupils. Sophisticated school science and technology labs are frequently reserved for the high achievers, while other pupils study craft in lieu of technology in outdated workshops, which are often located at the far end of the school.

Finally, the present findings regarding the most influential characteristics of the learning environment, from the pupils' perspective, agree with the principles that have guided the Accelerated Schools Project (Levin, 1992), aimed at advancing at-risk pupils. Schools should seek alternative ways to develop pupils' learning skills, instead of trying to offer them slow learning programs.

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