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IMPACT OF SCIENCE-TECHNOLOGY LEARNING ENVIRONMENT CHARACTERISTICS ON LEARNING OUTCOMES: PUPILS' PERCEPTIONS AND GENDER DIFFERENCES

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ABSTRACT. Science and technology are connected to each other and are mutually inspiring. The science-technology curriculum for junior-high school in Israel suggests that teachers integrate these subjects. In addition, this curriculum calls for infusing thinking competencies into the learning subjects and for implementing alternatives in assessment methods in the classes. The current research included three stages: field research, pilot research and expanded research. In the field research, an intervention program was planned and implemented. The intervention program included a three-year inservice training workshop consisting of 224 hours each year. Quantitative and qualitative tools were used to assess teachers' implementation of the intervention program. The findings revealed the characteristics of the science-technology learning environment and various learning outcomes. The pilot research enabled the development and validation of a questionnaire called the Science-Technology Learning Environment Questionnaire (STLEQ). The STLEQ was aimed at assessing teachers' and pupils' perceptions of learning environment. The conclusions from the pilot research showed differences between teachers' and pupils' perceptions towards the impact of learning environment characteristics on learning outcomes.

In the expanded research, two cohorts of pupils participated, namely, the 2002 cohort ($N = 207$) and the 2003 cohort ($N = 159$). These cohorts had studied science-technology in junior-high school. The findings of the expanded research partly match the findings from the pilot research, leading to insight into the pupils' perspective of the science-technology learning environment. No gender differences were found in pupils' scoring of learning outcomes. On the other hand, boys scored higher than girls on Computer Usage. This research enables researchers and teachers to use the questionnaire in order to investigate pupils' perceptions of their learning environment.

KEY WORDS: assessment, computer usage, laboratory experiments, learning environments research, science-technology, team projects

1. INTRODUCTION

Scientific-technological knowledge is a necessary component in the education of pupils towards the future of the third millennium. Science and technology are connected to each other and are mutually inspiring. Education must emphasize the interactions between science, technology, society and the environment. Studying science based on technological activities creates a rich learning environment by focusing on the design process (Roth, 2001). During the last 20 years, this approach has been implemented across the

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TABLE I
Comparison of Science and Technology

Technology	Science
Humankind's problems adapting to the environment	Questions about the nature world
Solutions to human problems	Explanations of natural phenomena
Design processes: strategy of problem solving	Inquiry processes: questions, experiments, observations and explanations
New problems	New questions
Environmental and social applications of solutions and explanations	

world and is known as Science-Technology-Society (STS) (Yager, 1996). In most applications of the STS approach, technology, as is defined in Table I, is neglected. De Vries (1997) claims that we should help pupils to integrate knowledge (scientific and other bodies of knowledge) into their design processes. It is evident that there is a role for science education that remains a crucial part of general education, even where technology education has gone beyond the 'technology is applied science' paradigm (De Vries, 1996). Technology education is a subject equally as valuable as science education, and both subjects should be taught (Gradner, 1997).

Waks (1994) suggests a model to discriminate between the emphasis of science and technology studies in a variety of dimensions. For instance, science emphasizes the analysis of existing phenomena, while technology concentrates on the synthesis of a new whole. The emphasis of science is on research, while technology deals mainly with design. Previous experience in Israel showed that such curriculum has a complex implementation and that one teacher cannot teach this integrated curriculum alone (Barak & Waks, 1997). Implementing an integrated curriculum, as described in Table II, demands the development of learning materials and inservice teacher training (Barlex & Pitt, 2001).

Project-based learning (PBL) could be used as a tool to develop pupils' competencies by working on integrated projects (Barlex, 2002). PBL through authentic issues, which are taken from the pupils' world, enables the teaching of science-technology to pupils from various backgrounds (Seiler, Tobin & Sokolic, 2001). An authentic project deals with real-life situations and, by definition, has an integrated nature. Past research showed that PBL affects pupils' motivation, thinking and achievement and teachers' development (Barak & Doppelt, 1999, 2000; Barak, Eisenberg & Harel, 1995; Barlex, 1994; Doppelt, 2003; Doppelt & Barak, 2002; Resnick & Ocko, 1991). Learning science and technology, in an integrated curriculum, needs a rich learning environment.

TABLE II
Number of Hours Devoted to the Main Content Topics in Science and Technology in the New Curriculum

Main Topics	Hours during grades 7–9	
	Basic	Expanded
Materials: structure, characters and processes	75	105
Energy and interaction	60	90
Technological systems and products	60	90
Information and communication	20	30
Earth sciences and the cosmos	30	45
Phenomenon, structures and processes in living creatures	120	150
Ecological systems	20	30
Total	385	540

Science-technology curriculum for junior-high school in Israel requires that teachers integrate these subjects into the design of their lesson plans. In addition, this curriculum calls for infusing thinking competencies into the learning subjects and for implementing alternatives in assessment methods in classes. Table II describes the syllabus that has been part of the national curriculum since 1996 for the teaching of science-technology in junior-high schools in Israel (Harari, 1992). This syllabus requires teaching of these content issues for four hours (basic level) to six hours (expanded level) per week over three years (Grades 7–9).

The integrative subjects that are shown in Table II should be taught while keeping society aspects in mind. This science-technology curriculum requires that educators create rich learning environments.

The assessment processes in a science-technology learning environment have an influence on learning. Involving pupils in the assessment process causes them to be partners in the learning process, to acquire reflection skills and to improve their documentation (Doppelt & Barak, 2002). Implementing portfolio assessment causes teachers to change their role in classes from lecturers to mentors (Doppelt, 2003).

Based upon 25 years of experience, learning environments research has called for the need to assess not only academic achievement, but also the influence of learning environment characteristics upon learning outcomes in the cognitive and affective domains (Fraser, 1998a). There is a need for investigating differences between teachers' and pupils' perceptions of the learning environment (Fraser, 1998b; Fraser, Giddings & McRobbie, 1995). Various characteristics of the learning environment impact the learning outcomes (Henderson, Fisher & Fraser, 2000). Wong and Fraser (1996) recommended investigating the impact of learning environment characteristics on learning outcomes by using a combination of quantitative and qualitative tools in the same research. This article concentrates on pupils' perceptions of the impact of learning environment characteristics on learning outcomes in the cognitive and affective domains. In addition, gender differences are discussed.

2. METHODS

The research that is presented in this article is the third stage in a longitudinal study that included three stages: field research (Stage 1); pilot research (Stage 2); and expanded research (Stage 3). In the field research, an intervention program was planned and implemented. The intervention program included three years of inservice training workshops involving 224 hours each year. Quantitative and qualitative tools were used to assess teachers' implementation of the intervention program. The findings revealed the characteristics of the science-technology learning environment and various learning outcomes. The conclusions from the field research (Waks & Doppelt, 2002) showed that most of the teachers implemented the workshop instructional methods and content. In addition, the teachers created similar learning environments in their actual classes. These conclusions enabled the development and validation of the questionnaire that is presented in Figure 1.

Learning Environment Characteristics	**Learning Outcomes**									
	Interest in the Learned Discipline	Understanding the Learning Subjects	Self Confidence	Desire to Learn	Curiosity	Critical Thinking	Independent Learning	Individual Initiative	Mutual Assistance	Relations with the Teacher
Team Projects										
Laboratory Experiments										
Concept Maps										
Assessment Activities										
Computer Usage										
Class Discussions										

Figure 1. Cells for rating the influence of learning environment characteristics on learning outcomes.

Each participant rated the influence of each learning environment characteristic on each of the learning outcomes. The rating was done directly in the figure's cells on a 1–5 scale, with 5 being of Very High Influence and 1 being of Very Low Influence. The Science-Technology Learning Environment Questionnaire (henceforth referred to as STLEQ) is aimed at investigating the participants' perceptions of the learning environment.

The STLEQ that is presented in Figure 1 was developed during the pilot research (Stage 2) with two groups of teachers and one group of pupils. The 21 science teachers from the first group participated in the intervention program. The 19 science teachers from the second group did not participate in the intervention program but taught the same science-technology new curriculum, as did the teachers from the first group. The third group includes 98 pupils who learnt science-technology in Grade 9 (15 years old) with the teachers from the first group. The findings from the pilot research (Doppelt, 2004) showed differences between teachers' and pupils' perceptions of the impact of learning environment characteristics on learning outcomes. The conclusions called for an expansion of the pilot research.

The expanded research (Stage 3) is discussed in this article. The first section of this article discusses the significance of differences between pupils in their perceptions of the impact of learning environment characteristics on learning outcomes. The second section of this article deals with the differences between the perceptions of boys and girls.

2.1. *Participants*

The expanded research that this article describes is divided into two sections. Two different cohorts of pupils participated in 2002 and 2003. In the first section of this research (Stage 3.1), 207 pupils participated by completing the STLEQ in March 2002. In the second section of this research (Stage 3.2), 81 girls and 78 boys from the same school as Stage 3.1 participated and completed the STLEQ in March 2003.

All the pupils had studied science-technology according to the new curriculum during Grades 7–9. All the pupils completed the STLEQ while they were in their second semester of Grade 9 (15 years old).

2.2. *Data Collection*

In Stage 3.1, the STLEQ, which was presented earlier in Figure 1, was expanded. The new STLEQ included 72 items instead of 60 items. The expansion of the STLEQ was aimed at splitting it into two parts. Each part of the split-half STLEQ included the same six characteristics of science-technology learning environments and six different learning outcomes. In

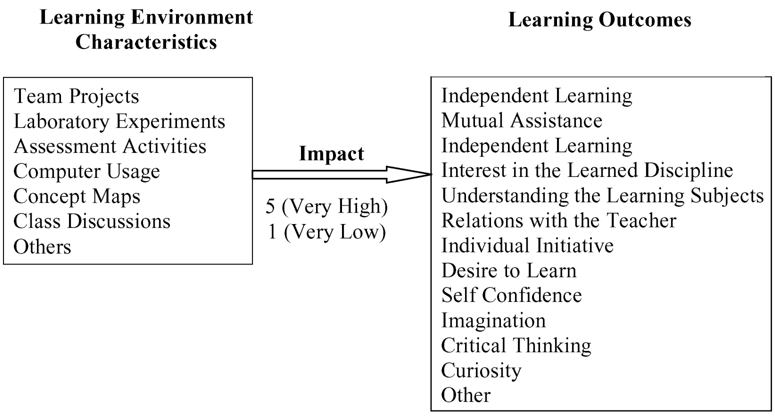

Figure 2. A mapping sentence for the questionnaire in the expanded research.

addition the participants were asked to justify their scoring. In order to make this process convenient, the participants justified only the high scores and low scores. Figure 2 presents a mapping sentence for the design of the expanded STLEQ.

The mapping sentence that is presented in Figure 2 provides a flexible structure for researchers to construct and use similar questionnaires in classes (Waks, 1995). Participants filled in this questionnaire by scoring each peer on a scale from 5 (Very High Influence) to 1 (Very Low Influence).

The STLEQ was validated during the three stages of the research. In Stage 1, a similar STLEQ, which had been developed in another research program (Doppelt & Barak, 2002) for PBL in high schools, was introduced to the teachers. This questionnaire included 15 characteristics of PBL and 22 learning outcomes. These teachers, who participated in the field research (Stage 1), were the judges of the STLEQ that was developed in the pilot research (Stage 2). The teachers mutually agreed upon the six characteristics and the ten learning outcomes, which were chosen for the STLEQ. The teachers scored the impact of the six learning environment characteristics on the ten learning outcomes. Analyses from the pilot research (Stage 2) showed that the STLEQ revealed the perceptions of the teachers and their pupils of the science-technology learning environment. In addition, the STLEQ was completed by a second group of science teachers who did not participate in the field research and were not involved in the design of the STLEQ. Analyses of these data, in Stage 2, showed again that the STLEQ revealed the perceptions of the second group.

The pilot research showed that the STLEQ might have low content validity because it does not cover all possible characteristics of science-technology learning environments. On the other hand, these characteristics were found to be relevant to science-technology learning environments by cross-examining it through analyses of various data that had been collected during the field research (Stage 1).

The STLEQ does not need to predict future perceptions of other cohorts or the same cohorts in future time. One might expect teachers to continue to develop professionally and to adapt their perceptions of the learning environment. In addition, one might expect different cohorts to have varying perceptions of learning environment characteristics. This STLEQ enables teachers and researchers to explore the impact of learning environment characteristics on learning outcomes. The expanded research (Stage 3), on which this article focuses, could widen researchers' perspectives on the science-technology learning environment.

2.3. *Analyses*

The analyses which were used in Stage 3.1 can be divided to three components: impact of the learning environment characteristics on learning outcomes; variance between the learning environment characteristics; and variance between the learning outcomes.

In the first component, a multivariate analysis of variance (MANOVA) with repeated measures was used. The hypothesis was that learning environment characteristics (independent variables) have a significant impact on the learning outcomes (dependent variables). In order to test the source of variance, pairwise comparisons were used.

In the second component, a univariate analysis of variance within subjects was used. The hypothesis was that learning environment characteristics (independent variables) have different impacts (dependent variables) on the learning outcomes according to participants' perceptions. Once again, to test the source of variance, pairwise comparisons were used.

In the third component, a univariate analysis of variance within subjects was used. The hypothesis was that the learning outcomes (independent variables) have been impacted (dependent variables) differently by the learning environment characteristics according to participants' perceptions. Here too, to test the source of variance, pairwise comparisons were used.

The second section of this research (Stage 3.2) is aimed at investigating differences in the perceptions of boys and girls. The original questionnaire from the pilot research was used. This time, the participants were asked to write the subject in which they chose to major at high school. Every pupil needs to choose at least one subject for a major in high school.

3. Findings

First, the findings from the first cohort (2002) are compared with those for the second cohort (2003). Second, significance of the findings from the first

TABLE III

Learning Environment Characteristics – Comparison of Mean and Standard Deviations for the Two Cohorts

Learning environment characteristic	$N = 207$ (2002)		$N = 158$ (2003)	
	Mean	*SD*	Mean	*SD*
Team projects	**3.32**	1.24	**2.87**	1.30
Class discussions	**3.27**	1.29	**3.07**	1.41
Laboratory experiments	**3.10**	1.35	**2.95**	1.39
Computer usage	**3.07**	1.35	**2.97**	1.44
Assessment activities	2.98	1.38	2.82	1.37
Concept maps	2.74	1.50	2.44	1.29

Means in bold type represent the higher scores given by pupils.

cohort are discussed. Third, pupils' justification for high and low scores is considered. Finally, the findings from the second cohort (2003) reveal gender differences in the pupils' perceptions of the impact of learning environment characteristics on learning outcomes.

3.1. *Comparison of the Two Cohorts*

Table III presents a comparison between the two cohorts' perceptions of the impact of the learning environment characteristics. These findings show that Team Projects, Class Discussions, Laboratory Experiments and Computer Usage are the most influential characteristics. The means in bold type in Table III represent the higher scores given by pupils. However, there are differences between the two cohorts. For example, in the first cohort, Team Project was found to be the most influential characteristic. In the second cohort, Class Discussions gained the highest score, and Team Projects was scored only in the fourth position. In both cohorts, Concept Maps was the least influential characteristic. Table IV presents a comparison between the learning outcomes.

The findings that are presented in Table IV show that three learning outcomes were most influenced by the learning environment characteristics according to the two cohorts' perceptions: Understanding the Learning Subjects, Independent Learning and Self Initiative. In both cohorts, Relationship with the Teachers was found to be the least affected outcome. In addition, Self Confidence and Critical Thinking also gained low scores in both cohorts.

It is interesting to investigate the significance of these findings and the source of variance between learning environment characteristics and between learning outcomes. For that purpose, the first cohort findings were analyzed.

TABLE IV
Learning Outcomes – Comparison of Mean and Standard Deviation for the Two Cohorts

Learning outcome	2002		2003	
	Mean	*SD*	Mean	*SD*
Understanding the learning subjects	**3.74**	1.10	**3.67**	1.14
Interest in the learned discipline	**3.33**	1.28	3.11	1.30
Independent learning	**3.31**	1.25	**3.19**	1.32
Desire to learn	**3.28**	1.30	3.03	1.29
Individual initiative	**3.23**	1.26	**3.36**	1.26
Curiosity	3.11	1.30	**3.15**	1.28
Mutual assistance	3.07	1.38	**3.39**	1.23
Critical thinking	2.82	1.20	2.73	1.29
Self confidence	2.80	1.39	2.69	1.25
Relations with my teacher	2.76	1.83	2.52	1.25

Means in bold type represent the higher scores given by pupils.

3.2. *Significance and Source of Variance*

As was mentioned earlier, the first cohort (2002) of participants ($N = 207$) was divided randomly into two sub-cohorts of pupils who responded to different halves of the STLEQ. The first sub-cohort ($N = 115$) scored the impact of the learning environment characteristics on the six learning outcomes of Self Confidence, Understanding the Learning Subjects, Individual Initiative, Imagination, Mutual Assistance and Desire to Learn. The second sub-cohort ($N = 92$) scored the six outcomes of Independent Learning, Interest in the Learned Discipline, Challenge, Curiosity, Relationship with the Teacher and Critical Thinking.

The three hypotheses that were investigated involved, firstly, the significance of the impact of learning environment characteristics on learning outcomes, secondly, the source of variance between the learning environment characteristics, and thirdly, the source of variance between the learning outcomes.

3.2.1. *The Significance of the Impact of Learning Environment Characteristics on Learning Outcomes*

In the first component, a multivariate analysis of variance (MANOVA) with repeated measures was used. The hypothesis was that learning environment characteristics (independent variables) have significant impact on the learning outcomes (dependent variables). In order to test the source of variance, pairwise comparisons were used. For the first half of the STLEQ items,

TABLE V

Significant Effects of Learning Environment Variables on Learning Outcomes (2002 Cohort – First Half of Questionnaire Items)

Learning outcome	Univariate $F(4, 456)$	p
Mutual assistance	30.45	<0.0001
Self confidence	27.47	<0.0001
Desire to learn	16.77	<0.0001
Understanding	6.38	<0.0001
Individual initiative	4.30	<0.001
Imagination	4.21	<0.001

TABLE VI

Significant Effects of Learning Environment Variables on Learning Outcomes (2002 Cohort – Second Half of Questionnaire Items)

Learning outcome	Univariate $F(3, 364)$	p
Curiosity	16.80	<0.0001
Challenge	12.78	<0.0001
Interest in the learned discipline	12.78	<0.0001
Independent learning	11.28	<0.0001
Relations with the teacher	9.13	<0.001
Critical thinking	8.15	<0.001

learning environment characteristics were found to have significant impact on the learning outcomes ($F[24, 91] = 14.43$, $p < 0.0001$). Table V shows the effects of the impact.

Further pairwise comparisons revealed that Team Projects was the most influential characteristic on Mutual Assistance ($M = 4.10$, $SD = 0.09$), Understanding the Learning Subjects ($M = 3.96$, $SD = 0.08$), Individual Initiative ($M = 3.91$, $SD = 0.09$) and Imagination ($M = 2.52$, $SD = 0.12$). In addition, Class Discussions was found to be the most influential characteristic on Desire to Learn ($M = 3.61$, $SD = 0.11$) and Self Confidence ($M = 3.53$, $SD = 0.12$).

For the second half of the STLEQ items, learning environment characteristics were found to have significant impact on the learning outcomes ($F[24, 68] = 8.60$, $p < 0.0001$). Table VI shows the effects of the impact.

Pairwise comparisons revealed that Laboratory Experiments was the most influential characteristic on Curiosity ($M = 3.74$, $SD = 1.11$) and Challenge ($M = 3.07$, $SD = 1.25$). Computer Usage was the most influential characteristics on Independent Learning ($M = 3.67$, $SD = 1.20$).

In addition, Class Discussions was found to be the most influential characteristic on Relationship with the Teacher ($M = 3.32$, $SD = 1.22$) and Critical Thinking ($M = 3.21$, $SD = 1.25$). Team Projects was found to be the most influential characteristic on Critical Thinking ($M = 3.14$, $SD = 1.12$) and Challenge ($M = 3.09$, $SD = 1.18$). Concept Maps was found to be the least influential characteristic on Interest in the Learned Discipline. There were no other significant pairwise comparisons.

3.2.2. *Different Impacts of Learning Environment Characteristics on Learning Outcomes*

In the second component a univariate analysis of variance, within subjects was used. The hypothesis was that learning environment characteristics (independent variables) have different impacts (dependent variables) on the learning outcomes according to participants' perceptions. In order to test the source of variance, pairwise comparisons were used.

For the first half of the STLEQ items, learning environment characteristics were found to have significant impact on the learning outcomes ($F[4, 456] = 22.87$, $p < 0.0001$). Peer comparison analyses were used to investigate the source of variance between the learning environment characteristics. The peer comparisons showed that, according to the perceptions of the first sub-cohort, Team Projects was the most influential characteristic ($M = 3.51$, $SD = 0.60$) and its score was higher than for all other characteristics. Class Discussions was found to be the next most influential characteristic ($M = 3.51$, $SD = 0.60$), next was Computer Usage ($M = 3.14$, $SD = 0.83$), then Laboratory Experiments ($M = 3.08$, $SD = 0.77$) and last was Concept Maps ($M = 2.37$, $SD = 0.85$). There were no other significant pairwise comparisons.

For the second half of the STLEQ items, learning environment characteristics were also found to have significant impact on the learning outcomes ($F[4, 364] = 8.94$, $p < 0.0001$). Peer comparisons showed that, according to the second sub-cohort perceptions, Team Projects was the most influential characteristic ($M = 3.18$, $SD = 0.67$) and its score was higher than all other characteristics. Laboratory Experiments was found to be the next most influential characteristic ($M = 3.17$, $SD = 0.71$), Class Discussions was found to be the next most influential characteristic ($M = 3.16$, $SD = 0.86$), and the last was Computer Usage ($M = 2.96$, $SD = 0.74$). There were no other significant pairwise comparisons.

3.2.3. *Differences in Learning Outcomes*

In the third component a univariate analysis of variance, within subjects was used. The hypothesis was that the learning outcomes (independent variables) had been influenced (dependent variables) differently by the learning environment characteristics according to participants' perceptions. In order to test the source of variance, pairwise comparisons were used.

In the first half of the STLEQ items, the learning outcomes were found to be influenced significantly by the learning environment characteristics ($F[5, 570] = 52.75$, $p < 0.0001$). Peer comparisons showed that, according to the perceptions of the first sub-cohort, Understanding the Learning Subjects was influenced by the learning environment characteristic ($M = 3.77$, $SD = 0.51$) and its score was higher than all other learning outcomes. Individual Initiative was found to be the next learning outcome ($M = 3.24$, $SD = 0.63$), next was Desire to Learn ($M = 3.31$, $SD = 0.41$), next was Self Confidence ($M = 2.80$, $SD = 1.00$), then was Mutual Assistance ($M = 3.07$, $SD = 0.66$), and last was Imagination ($M = 2.77$, $SD = 0.67$). There were no other significant pairwise comparisons.

For the second half of the STLEQ items, learning outcomes were also found to be influenced significantly by the learning environment characteristics ($F[5, 455] = 26.30$, $p < 0.0001$). Peer comparisons analyses showed that, according to the second sub-cohort perceptions, Interest in the Learned Discipline was influenced by the learning environment characteristic ($M = 3.38$, $SD = 0.60$) and its score was higher than for all other learning outcomes. Independent Learning was found to be the next learning outcome ($M = 3.27$, $SD = 0.78$), next was Curiosity ($M = 3.17$, $SD = 0.58$), next was Challenge ($M = 2.84$, $SD = 0.60$), then was Critical Thinking ($M = 2.71$, $SD = 0.69$), and last was Relationship with the Teacher ($M = 2.71$, $SD = 0.69$). There were no other significant pairwise comparisons.

3.3. *Pupils' Justifications for High and Low Scores*

First, Table VII presents the first sub-cohort's repeated justifications for high scores. Second, Table VIII shows the second sub-cohort's repeated justifications for high scores. At the end of this section, Table IX introduces pupils' justifications for low scores.

These pupils' quotations represent repeated reasons or justifications for their high scores. These justifications support the findings that were presented earlier. Educational research dealt with the contributions of Laboratory Experiments, Team Projects and Computer Usage to learning outcomes in the cognitive and affective domains. Different teachers from different schools developed similar learning environments in the field research (Waks & Doppelt, 2002) and in the pilot research (Doppelt, 2004). The intervention program in the field research (Stage 1) might have caused a new

TABLE VII

Pupils' Justifications for Scoring 5 (Very High Influence) – First Half of Questionnaire Items

Learning outcome	Learning environment characteristic			
	Class discussion	Computers usage	Laboratory experiments	Team projects
Self confidence	You get an opportunity to say your piece, and to convince and influence others.		Experiments are fun. They are enjoyable and improve my self confidence.	I think teamwork contributes to and raises my self confidence.
Mutual assistance	You learn that, if you do not listen to your friends, they will not listen to you.	We worked on the computer with peers and we shared tasks equally.		When you work as a team, it is usually important to every member that the work is successful. That's why everybody helps each other.
Understanding the learning subjects	It is the best way to learn. This way, I understand best.		Experiments make it concrete. They contribute to a deeper understanding.	In small groups, children can explain things to each other.
Individual initiative		There is more freedom to search and create your work alone with the computer.	When you do experiments alone, you need to push yourself to do things and to invest a lot of effort.	The teamwork helped me to take initiative.
Desire to learn	You are exposed to materials and discussions on exact sciences. It gave me a lot of motivation to learn and know more.	It is more interesting.	Experiments are fun. They are more practical than writing and listening.	I like team projects. It is important and fun to work in a team and it motivates me.
Imagination			Experiments contribute to imagination. Watching things happening in front of my eyes causes me to imagine how it really works.	Team projects enrich my imagination in all directions. You need a lot of imagination to create an interesting project. Friends' ideas enrich your imagination.

TABLE VIII

Pupils' Justifications for Scoring 5 (Very High Influence) – Second Half of Questionnaire Items

Learning outcome	Learning environment characteristic			
	Class discussion	Computer usage	Laboratory experiments	Team projects
Independent learning		I work alone better with the computer.	It pushed me towards better self thinking and learning.	I receive ideas from others and learn how my friends learn.
Interest in the learned discipline	It is more interesting to know what your friends think.	It is interesting to me to work with the computer.	Doing an experiment makes the learning more enjoyable. The laboratory report organized my knowledge.	It improves my thinking because the teacher does not 'feed' me the subjects.
Relations with my teacher	The teacher gave grades according to pupils' participation in class discussion. So, you had to develop good relations with the teacher.			The teacher tutors me and it improves our relations.
Challenge		It challenges me because I need to think creatively.	It made me prepare the experiment and perform it myself.	It is a challenge to work on your project.
Curiosity		I am very curious with things related to computers.	It is more interesting to perform an experiment and to watch it happen than to write down what the teacher knows.	The projects are very interesting. They go beyond the subjects which we learnt in class.
Critical thinking			You must use your critical thinking because you need to be objective and stick to the facts.	In the project, you need to criticize yourself and others.

TABLE IX
Pupils' Justifications for Scoring 1 (Very Low Influence)

Learning outcome	Learning environment characteristic	
	Concept maps	Computer usage
Self confidence	It made me understand that I do not know how to organize my knowledge. I simply do not know how to do concept maps.	It only made me see that I am really weak in it.
Mutual assistance	You do concept maps alone.	We usually work alone with computers and so it could not develop mutual assistance.
Understanding the learning subjects	I do not know how to do concept maps in spite of understanding the subject matter well.	I think we need to return to old learning methods.
Individual initiative		The teacher tells us what to do with the computer. So, it does not develop individual initiative.
Desire to learn		When we knew we are going to use computers, we came to class willingly.
Imagination	Concept maps do not contribute to imagination.	There is no imagination in using the computers.
Interest in the learned discipline		I don't like to work with computers. It bores me.
Relations with my teacher	We did concept maps mostly as homework and we did not interact with the teacher.	You learn less from the teacher and more from the computer. So, it can not improve your relations with the teacher.
Challenge		The work with the computer was easy and did not challenge me.
Curiosity	It bores me.	Learning with computers did not develop my curiosity.
Critical thinking		Working with computers is not associated with critical thinking.

learning environment to form in the teachers' actual classes. Furthermore, the other teachers who taught their pupils in the pilot research (Stage 2) created a similar learning environment. However, the learning environment characteristics influenced the learning outcomes differently according to the pupils' perceptions. Table IX presents pupils' justifications for their low scores.

The 2002 cohort scored Computer Usage in the fourth position. From the justifications, we can see differences between pupils' attitudes towards the computer usage in science-technology learning environments. The computer laboratories, in this school, are well configured. The teachers had participated previously in workshops that dealt with the use of computers in classes. On the other hand, the 2003 cohort scored this characteristic in the second position. It can be assumed that Computer Usage is related to learning style of each pupil. Making Concept Maps is a well-known teaching and learning method to improve understanding of science topics (Novak, Gowin & Johansen, 1983). Concept Maps was scored the least by the pupils, their justifications show negative attitudes towards Concept Maps.

On the other hand, these teachers had not participated in inservice training as described earlier. It is a possibility that, in order to infuse thinking skills into the curriculum and to implement computers for meaningful learning, there is a need for comprehensive professional change in attitude and approach (Doppelt & Barak, 2002; Waks & Doppelt, 2002).

3.4. *Gender Differences*

Gender differences in pupils' perceptions of the influence of learning environment characteristics on learning outcomes are presented in Table X. The learning environment means that are in bold type in Table X emphasize the higher scores given by the pupils. The findings show agreement between boys and girls concerning the impact of Team Projects, Class Discussions and Laboratory Experiments on learning outcomes. Table X shows no gender differences between boys' and girls' scoring towards the impact of the learning environment characteristics on learning outcomes. In the field research and in the pilot research, Team Projects and Laboratory Experiments were also found to be the most influential characteristic.

Girls and boys scored the influence of Computer Usage significantly differently. These findings were a surprise to the researcher who did not assume that girls would consider the Computer Usage to be less influential than boys.

Table XI shows no gender differences between the scoring of the learning outcomes. The learning outcomes means that are in bold type in Table XI

TABLE X
Gender Differences in Learning Environment Characteristics

Learning environment characteristic	Boys ($N = 78$)		Girls ($N = 81$)		Difference
	Mean	*SD*	Mean	*SD*	*p*
Team projects	**3.05**	1.31	**3.16**	1.28	0.593
Class discussions	**3.01**	1.39	**3.13**	1.42	0.591
Laboratory experiments	2.91	1.36	**2.99**	1.41	0.716
Assessment activities	2.76	1.41	2.86	1.34	0.647
Computer usage	**3.22**	1.44	2.75	1.40	0.039
Concept maps	2.51	1.30	2.38	1.27	0.241

Means in bold type represent the higher scores given by pupils.

TABLE XI
Gender Differences in Learning Outcomes

Learning outcome	Boys ($N = 78$)		Girls ($N = 81$)	
	Mean	*SD*	Mean	*SD*
Understanding the learning subjects	**3.44**	1.30	**3.50**	1.28
Independent learning	**3.05**	1.40	**3.12**	1.37
Individual initiative	**3.09**	1.35	**3.03**	1.38
Desire to learn	2.86	1.40	**2.98**	1.36
Interest in the learned discipline	**3.02**	1.34	**2.94**	1.37
Curiosity	**2.98**	1.35	2.84	1.37
Mutual assistance	2.78	1.35	2.70	1.33
Critical thinking	2.67	1.39	2.64	1.37
Self confidence	2.71	1.41	2.54	1.35
Relations with my teacher	2.59	1.36	2.53	1.35

Means in bold type represent the higher scores given by pupils.

emphasize the higher scores given by the pupils. There is a slight difference between the scores for Curiosity and Desire to Learn between boys and girls. Most of the girls' scores are slightly higher than boys' scores.

Figure 3 shows differences between boys and girls who intend to major in the humanities and those who intend to major in the sciences (Physics, Chemistry or Biology) or technology (Computer Science, Electronics Systems or Mechanical Engineering). Each pupil needs to choose one or more subjects as a major, in addition to mandatory subjects such as English, Mathematics, Literature, and History. These findings show differences between pupils who chose science or technology as their major and pupils

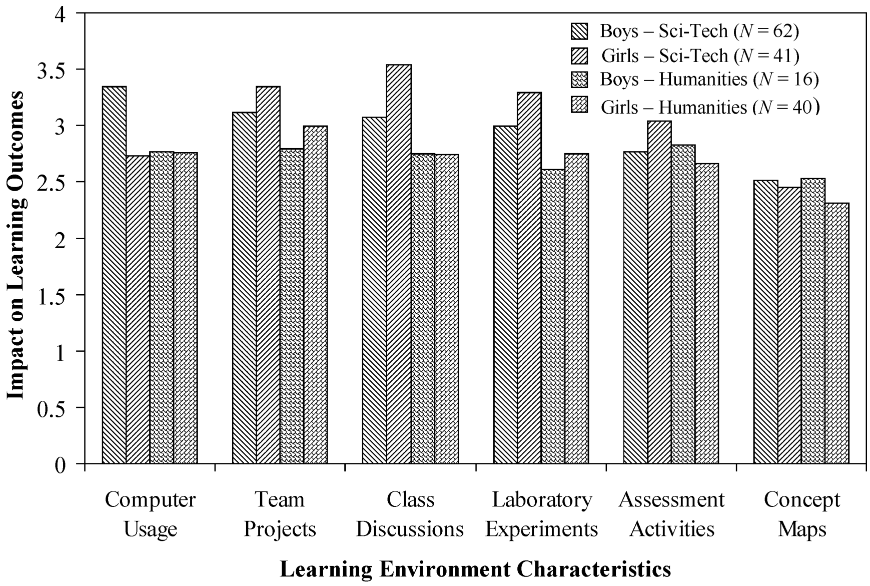

Figure 3. Differences between Majors and between boys and girls in perceptions of learning environment characteristics on learning outcomes.

who did not choose science or technology as their major subject in high school.

4. DISCUSSION

The field research (Stage 1) contributed to the identification of the characteristics of science-technology learning environments and learning outcomes. The teachers created learning environments that were similar to the learning environments of the workshops. These characteristics were revealed from analyses of the data collection from the quantitative and qualitative research tools. The pilot research (Stage 2) enabled the development and validation of the STLEQ. The STLEQ aims at assessing the impact of the characteristics of science-technology learning environments on learning outcomes in the affective and cognitive domains. This assessment reflected teachers' perceptions of science-technology learning environments as is shown in Figure 4.

The expanded research (Stage 3) involved two cohorts of pupils who had been learning science-technology during junior-high school. The findings led to a realization of the pupils' diverse perspectives of science-technology learning environments. These findings partly match the findings from the pilot research. There was agreement that Team Projects and Laboratory Experiments are the most influential learning environment characteristics

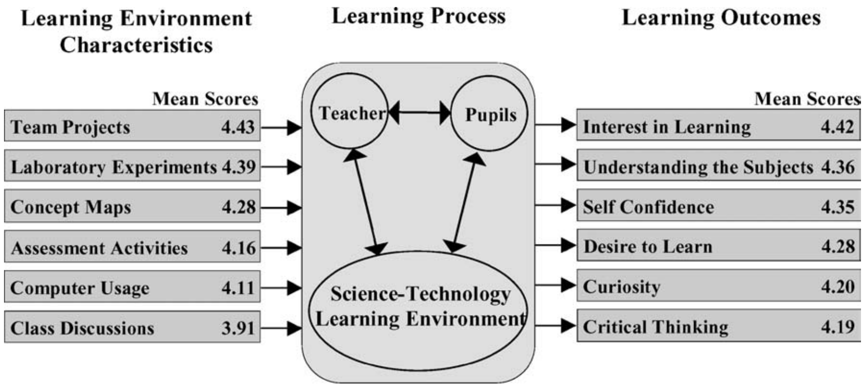

Figure 4. Impact of learning environment characteristics on major outcomes: teachers' perceptions.

on learning outcomes. However Class Discussions gained high scores in both cohorts (2002 and 2003).

These findings strengthen other research results regarding the importance of PBL as an instrument to foster learning (Barlex, 1994; Doppelt, in press; Doppelt & Barak, 2002; Resnick & Ocko, 1991). The use of PBL in science education at the middle school level is uncommon. In each of the stages of this research, pupils and teachers have a shared perspective regarding the importance of Team Projects. In previous research, this was found to be the most influential characteristic in a technology-based learning environment in high school (Barak, Waks & Doppelt, 2000). The importance of Laboratory Experiments to science learning is also familiar from past research (Linn & Eylon, 2000). The high scores that the two cohorts gave to Class Discussions are in accordance with the importance of discussion to the quality of study (Welch, Barlex & Lim, 2000). In addition, teacher control of the class was found to influence positively pupils' attitudes towards science learning (Wong & Fraser, 1996). On the contrary, these findings are consistent with past research regarding the contribution of open tasks in flexible learning environments (Resnick & Ocko, 1991). Pupils value and appreciate the higher levels of freedom, responsibility and independence which the curriculum gave them during their study (Pedretti, Mayer-Smith & Woodrow, 1998). My experience showed that the teacher should use discussion mainly in small groups. Short class discussion, in the end of the lesson, could assist in summarizing the learned issues.

There was high agreement between the participants regarding the most influential learning outcomes. This conclusion allows presentation of the pupils' perceptions of science-technology learning environments as is shown in Figure 5.

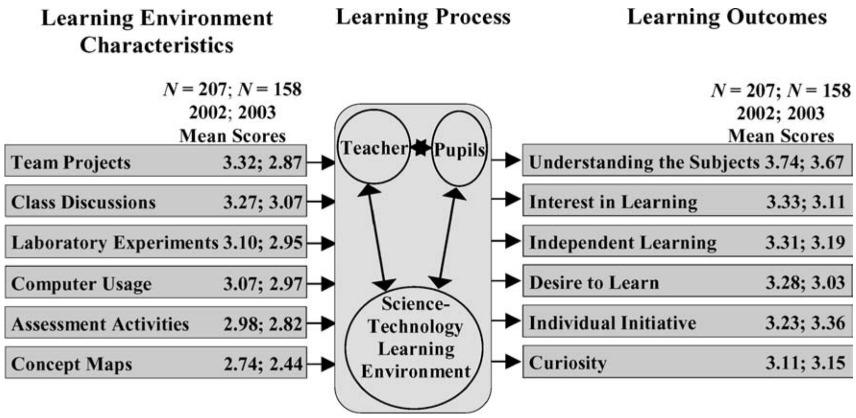

Figure 5. Impact of learning environment characteristics on major outcomes: pupils' perceptions.

The perceptions reflected in Figure 5 are similar to Figure 4. This article enables a wide perspective towards teachers' and pupils' perceptions of the impact of the characteristics of science-technology learning environments on learning outcomes in the cognitive and affective domains.

This study strengthens the importance of combining quantitative and qualitative tools in one study (Aldridge, Fraser & Huang, 1999). It showed no gender differences in pupils' scoring to learning outcomes. On the other hand, it revealed gender differences in pupils' perceptions regarding the impact of Computer Usage. Boys scored this characteristic more highly than girls.

Pupils who chose science or technology subjects for their major in high school gave higher scores to the impact of learning environment characteristics on learning outcomes than pupils who chose not to major in science or technology. These findings could lead to a careful conclusion that, in early stages of junior high school, the learning environment could influence pupils in choosing what they will learn in high school.

5. Final Remarks

Researchers and teachers can use the STLEQ to investigate pupils' perceptions of their learning environment. When teachers perform an inquiry process on their actual learning environment, they could improve the learning environment and contribute to their own professional development and to educational changes in their schools (Roth & Surry, 1999). To summarize this article, let us look at this quotation:

If the results of the actual form of SLEI in this study are indeed outcomes of the instructions and procedures used by the teachers in their laboratory work, one may hypothesize that the preferred changes in the existing didactic procedures are alerted. (Hofstein, Cohen & Lazarowitz, 1996)

We might assume that the intervention program (Stage 1) caused the formation of a similar learning environment in the teachers' actual classes. Furthermore, the other teachers who taught the participants in this research created a similar learning environment. However, the learning environment characteristics influenced the learning outcomes differently. The general conclusion of this article is that the characteristics of science-technology learning environments have an important impact on learning outcomes in the cognitive and affective domains.

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