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LEARNING SCIENCE THROUGH A HISTORICAL APPROACH: DOES IT AFFECT THE ATTITUDES OF NON-SCIENCE-ORIENTED STUDENTS TOWARDS SCIENCE?

KEY WORDS: A historical approach to learning science, a variety of teaching methods, science for all, students' attitudes towards science

Nowadays, at the outset of the twenty-first century, the idea that each person should have some familiarity with the nature of science is becoming more and more accepted. For example, notions such as 'scientific literacy for all' are beginning to play an important role in considerations pertaining to educational goals. However, these ideas pose many problems, both regarding the actual meaning of the term 'scientific literacy for all', as well as the ability to provide all students with some background in science. Contrary to the situation at the beginning of the 19th century when science was viewed as important, interesting and exciting, the image of science today is rather negative. It is therefore reasonable to assume that this lack of interest can hinder students' motivation in getting involved in science studies. Here we attempted to use a historical approach to science teaching in order to improve the attitudes of non-science-oriented students (those who did not choose to major in any of the scientific disciplines) towards science and science studies. More specifically, the objective of the present study was to test whether using the module: "*Science: An Ever-Developing Entity*" (Mamlok, 1995), which uses a historical approach to teaching science, would affect the attitudes of non-science-oriented students towards science.

THEORETICAL FRAMEWORK

A wide gap currently exists between two communities, or rather two cultures – the scientists and the literary intellectuals (Snow, 1988), a gap that seems to have widened considerably since 1955, when Snow first coined the term. The need for super specialization in the sciences has resulted in a

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situation where even scientists from different research areas find it difficult to communicate with each other. Consequently, this has had a formidable effect on high-school science education. In many countries the decision as to what, and how, students should be taught is in the hands of members of the scientific community, i.e. scientists or science teachers who were educated or influenced by the scientific culture. As a result, high-school science classes present, in many instances, a reduced revision of science education at the university level. However, the target population for science education at the high school level is rather different from science graduates at the universities. In fact, the majority of high-school students are non-science-oriented, and therefore, we are faced with the need to decide: (1) is it necessary (advisable) to teach science to all students? (2) if the answer is affirmative, should we teach all students similarly? and (3) whatever our answer to the former question is, we should rethink very thoroughly about how we can contribute to close the gap between science- and non-science-oriented citizens.

Many researchers have answered the first question affirmatively. The American Association for the Advancement of Science (1989), for example, was concerned with the problem of how to "teach science for all Americans". Similarly, Sjøberg (1996), presents four arguments regarding the importance of the public to understand science: (1) the economic argument: Science for preparation for work, (2) the utilitarian or practical argument: Science for mastery of daily life, (3) science for citizenship and democratic participation, and (4) science for cultural literacy, science as a major human product.

In recent years we have become increasingly aware of the need for people to understand the nature of science in order to make decisions posed by new developments in both science and in technology. However, many students, even those who intend to become scientists, are unaware of the true nature of science (Irwin, 1996). Nevertheless, students both in high school and at the college level generally have positive views regarding the nature of physical reality and scientific inquiries. Although they may regard science as a systematic gathering of facts and laws, very often they are not aware of the roles of science and scientists in building models and theories as tools to understand nature (Jungwirth, 1987; Hayes & Perez, 1997). Arons (1984) claimed that many science teachers do not devote time to discuss the nature of the scientific process and, as a result, miss opportunities to instill critical and investigative thinking.

If this is true for science-oriented students at various stages of their education, it is even more so for non-science-oriented students, who chose not to specialize in any of the natural sciences. However, as part of a community of concerned citizens, who live in a society highly influenced by developments in science and technology, they will have to make their own decisions in this area. Apparently these students were neglected in the past, either because they did not study science at all, or they were forced to take courses especially designed for students not majoring in science, students with different interests, motivation, needs, and learning abilities. The problem of how to provide these students with an insight into those factors that will dominate their lives in the future as citizens has been a cause for concern for many science educators all over the world. The suggested solutions are numerous and differ according to the philosophy and beliefs of those involved in the decision-making process and are subject to the local pedagogical conditions.

If we accept the notion that science should become an integral part of every citizen's vocabulary, then the question of how we can achieve this goal becomes prominent. The Science/Technology/Society (STS) currently has four common aims (Aikenhead, 1994)): (1) to increase citizen's scientific literacy, (2) to generate student interest in science and technology, (3) to encourage interest in the interactions among science, technology, and society, and (4) to help students become better at critical thinking, logical reasoning, creative problem solving, and especially decision making.

If we look at this list, two of the items mentioned belong to the affective domain, i.e. raising interest in science and technology and their interaction with societal issues. In the last twenty years "Science for All" emerged as a slogan that embodied a new challenge for science educators, both at the developmental level as well as in the implementation stages of the curriculum (Fensham, 1992; Yager, 1992; Bybee & Ben-Zvi, 1998; Hofstein & Mamlok, 2001; Bodzin & Mamlok, 2000; Mamlok, Ben-Zvi, Menis & Penick, 2000). Harms & Yager (1981) stated that science and technology should be part of the education of those who will eventually be what they fondly termed "future citizens." In their report *Project Synthesis*, they considered four interrelated "goal clusters" for teaching science: (1) science for personal needs, (2) societal issues, (3) career awareness, and (4) academic preparation. These multiple approaches have served to develop science teaching in its authentic context (Yager, 1992). The function of STS is to attempt to present science, together with its technological and social manifestations. Yager (1992) claimed that this approach has great potential to enhance the attainment of these goal clusters. Thus, it will help in shaping the character of science-literate citizens, who will be able to make important decisions about current problems and issues of a scientific origin, and better understand how science, technology, and society mutually interact. Moreover, they will be able to use their knowledge in handling the problems and issues that they confront (Bybee, 1997; Hofstein, Aikenhead & Riquarts, 1988). These multiple approaches of the social, economic, and environmental aspects of science are often absent in those curricula that are exclusively based only on the acquisition of scientific knowledge. In conclusion, by learning through the STS instructional approach students are taught about natural phenomena in a way that links science with the technological and the social world of the student (Hofstein et al., 1988; Bodzin & Mamlok, 2000; Hofstein & Mamlok, 2001).

If we want to achieve, even partially, the objectives mentioned above, we are immediately faced with the difficult question of how to do it. There are many problems with the way science is taught in schools, especially if we consider non-science-oriented students as our target population. The tendency, in many countries, was to give students a taste of an assortment of facts considered as important by the scientific community. Apparently, the idea behind this philosophy was the feeling that if students will have access to knowledge, their ability to cope with the modern world as well as their attitude towards science will improve. Now, it seems that this hope was not realized and the feeling nowadays favors the idea that 'less is actually more.' O'Neill & Polman (2004) suggest that on a societal scale, schools would function more effectively if they covered less content, in ways that would allow students to build a deeper understanding of how scientific knowledge claims and theories are constructed. This would be of use to all students in their decision making outside of school, and beneficial to those pursuing postsecondary studies in science as well. Indeed, international studies such as the Third International Mathematics and Science Study (Stigler & Hiebert, 1999), and the Organization for Economic Co-operation and Development (OECD/PISA/SFEG, 2004) showed that in many highly developed countries, the minimal requirement, that of acquisition of factual knowledge, is rather low.

Two main reasons (or a combination of them) can be pointed out for this lack of success. One relates to the affective domain, and the other one – to the cognitive one. If students are not interested in science, they tend not to make an effort to learn and understand the meaning of concepts that are being taught to them. It was shown that the most effective factor contributing to students' decisions to study science is their interest in the subject (Milner, Ben-Zvi & Hofstein, 1987; Lindahl, 2003).

Students who are interested in science and understand the scientific concepts will have better attitudes towards science and science studies than those who have learning difficulties in the science disciplines. According to Koballa, Crawley & Shrigley (1990), attitudes are feelings of "like or dislike." Simpson & Troost (1982) referred to attitudes towards science and science learning and concluded that people are committed to science when they better understand science and desire to take more science courses, and to continue reading about science. Pintrich, Marx and Boyle (1993) and Barila & Beeth (1999) argue that students' motivation is an important factor that can lead to raising or lowering the status of a conception. Similarly, Fairbrother (2000) claims that pupils learn only if they want to learn.

Regarding the cognitive domain, some researchers claim, that students' initial scientific knowledge is analogous to the knowledge of scientists in the ancient world, and it is made up of observations and conclusions that were often intuitive (Thagard, 1992; Irwin, 1997; Erduran, 2001). Just as these scientists tended to personify objects, or describe processes and natural phenomena in emotional terms, so do children build a conceptual world that is adjusted to their own world of knowledge and emotions. Children believe in what they sense and tend not to believe in what is out of the scope of their senses.

However, the process of cognitive change is not simple, in particular for those who encounter difficulties in grasping basic scientific concepts (Nussbaum, 1989). Scientists themselves encountered difficulties in modifying their perceptions. Teaching the development of the understanding of a concept, together with scientists' perceptions of this concept, may help to achieve a more basic and profound understanding of it and cope with any misconceptions (Matthews, 1994).

The obvious conclusion of various studies is that the science curriculum must develop a historical approach to the teaching of science (Abd-El-Khalick, 2002). As a case in point, the National Science Education Standards (NRC, 1996) emphasize the fact that

> In learning science, students need to understand that science reflects its history and is an ongoing, changing enterprise. The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures (p. 107).

BACKGROUND

In Israel, the history of the reforms in science education followed a pattern similar to that in many parts of the western world. During the early 1960s, Israeli science educators were mainly concerned with the science-oriented students, who were seen as younger versions of a scientist. Only in the early 90s was a committee set up by the Ministry of Education in Israel that considered the need to make science an integral part of the education of all citizens (Tomorrow 98: Superior Committee on Science, Mathematics and Technology Education in Israel, 1992). In 1992 the recommendations of the committee were accepted and the government committed itself to the decision that science will be taught to all high-school students in the country. It was also decided that different programs will be taught to science and non-science-oriented students, namely high school students (grades 10–12), who did not choose to major in any of the science disciplines (biology, chemistry, or physics), the reasons for which are numerous and diverse. The programs consist of a series of interdisciplinary-type modules. Each of these modules presents a certain scientific topic with its technological, social, and personal applications and ramifications (Cohen, Ben-Zvi, Hofstein & Rahamimoff, 2004).

On the basis of the recommendations of this committee, a new program, "Science and Technology for All," consisting of a series of modules, was developed. Three of the main guidelines of this program are as follows: (1) the modules should be independent of each other, each tackling a specific problem in the interface between science, society, and technology, (2) the program is aimed at non-science-oriented students and should be taught in the 10th and 11th grades (age group 15+), and (3) the science presented should deal more with the "why" and "how" than with the "how much." In this paper we will focus on the module "*Science: An Ever-Developing Entity*" (Mamlok, 1995).

Science: An Ever-Developing Entity

"*Science: An Ever-Developing Entity*" (Mamlok, 1995) is a module (a teaching unit) aimed at non-science-oriented high-school students. It interweaves aspects of science, technology, and society, related to the development of the concept "structure of matter." It was designed in order to encourage a change in students' views regarding science in general and the structure of matter in particular by studying the evolution of man's thinking and investigations.

The module surveys the development of our understanding of the structure of matter. It attempts to develop models that can explain the accumulated observations regarding matter and chemical reactions, which is a process that is as old as science itself (another parallel subject is, for example, astronomy). Ideas concerning the structure of matter and the way models are used to explain it, which changed throughout history, constitute a good example of the representation of the history of science to students. Thus, the module was developed with the following objectives in mind: (1) to enable students who did not choose to major in any of the scientific disciplines to familiarize themselves with the nature of science, (2) to enable students to understand the interplay between science and technology, and (3) to change students' attitudes towards science in general and more specifically towards science taught in school.

The description of the module will be presented in relation to these objectives.

1. *To enable students to familiarize themselves with the nature of the scientific enterprise.*

We feel strongly that it is very important for students to understand that science is not a given body of knowledge that was somehow given from heaven but rather is an ever-developing structure. We therefore follow the development of the changes of our understanding of matter from ancient times up to the present (almost).

The main theme of the module is in understanding the interplay between theories, new data that refute these theories and the previous conclusions that have to be modified. The following is a question that haunted generations of alchemists: "Can simple metals be transmuted into gold?" Dealing with this question enables us to illustrate the changes in our understanding of the structure of matter. In the ancient Greece, matter was conceived of just four entities or elements – earth, water, air, and fire. Each of these elements could be changed into another by performing different operations, such as heating, cooling, mixing, and crystallization. The natural conclusion, based on this theory, was that gold could be made from other materials provided one was clever enough to know the right transforming operations and sequence.

Interestingly, scientists' attempt to fathom the structure of matter has always been performed through models. These models, constructed or invented, were in part contradictory, and in part a development and an improvement of a specific basic model. The module emphasizes the model's main role in providing a framework and serving as a guideline for scientific research. The relationship between the various models of the structure of matter and the periods in which they were developed is emphasized (Cramer, 1979) in order to provide the student with an understanding of the interaction between science and society (Elkana, 2000).

The Greek model survived for many centuries until evidence and knowledge from experimentation led to contradictory conclusions. The module describes how the introduction of quantitative considerations into the chemistry laboratory brought about the revival of the atomic theory originally postulated by the Greeks. Matter, according to Dalton's 18th century views, consisted of small, indestructible particles. Dalton's atoms were the basic units of this matter; hence, they could not be interchangeable. Since Dalton's theory was generally accepted, scientists concluded that one element could not be transformed into another. At this point the period of the ancient alchemists ended.

More recent experimental data, from sources such as natural and artificial nuclear reactions, provide a deeper understanding of the structure of matter. For example, atoms are no longer considered the ultimate basic particles of matter and hence, elements can be changed into other elements. In some respects it is therefore possible to refer to these modern physicists as "modern alchemists." After all, we now know how to produce gold by using this method! But, though possible, calculations evaluating the economic feasibility show that it is far cheaper to produce gold from natural ores than by using this transmutation method. Although the "modern alchemists" may have fulfilled the vision of the ancient alchemists, it required many years of experimentation, generation of knowledge, and revolutionary change in the fields of science and technology.

If indeed, one can claim that children's understanding of scientific concepts develops in a way analogous to that of the knowledge of scientists during the known history, then presenting students with the steps of this development may help them to "grow up" with science. In this way, they are not confronted with "our" way of thinking but instead can start with their own picture of the world and can gradually reconcile it with what is acceptable nowadays. It is hoped that if this happens, students will feel less estranged and this will also be manifested in their attitude towards science in general and also towards their science studies.

2. *To enable students to understand the interplay between science and technology.*

One of the problems that we face today is the confusion that exists between the roles played by science and technology. People tend to blame science for all the disasters (real or imagined) of the modern world, when really what is to be blamed is the manner in which science, i.e. technology, is used. Another thing that should be understood is that since the beginning of time science and technology are linked together. Developments in our understanding of the world in turn enable the development of new technologies, and the introduction of new equipment opens the door to new ways of thinking.

For example, the development of more accurate balances enabled quantitative considerations that led to the revival of the atomic theory. However, theoretical developments of the atomic model enabled the development of batteries and the wide use of electricity from conventional power plants, and later, from nuclear ones. We hope that this presentation will enable students to better understand how technology influenced scientific developments and vice versa.

3. *To change students' attitudes towards science in general and more specifically towards science taught in school.*

It was our hope that using a historical approach might help students perceive science as an activity that is related to them and to their future lives and thus would help create for them a more positive attitude towards science. Those students who studied this unit in the framework of the program "Science and Technology for All" had some experience in studying science in junior high school. For many of them, however, it was not an enjoyable experience. In fact, many of them used to avoid science classes because they were afraid of the formulas and did not understand what the teachers wanted from them.

Pedagogical Approach

STS programs are by definition interdisciplinary in their approach (Bybee & Trowbridge, 1996). In this way, this approach provides the teacher with a wide range of teaching techniques, enabling diversifying the classroom-learning environment. Consequently, the student's motivation to learn science increases and creativity is enhanced (Tobin, Tippins & Gallard, 1994; Hofstein & Walberg, 1995). Another aspect of the STS program is that the science presented should not deal with the "how much" but rather with the "why" and the "how." Thus, we avoided calculations and the excessive use of formulas and used instead a combination of the analysis of historical events and developments in the theories pertaining to the structure of matter (Roach & Wandersee, 1995). These two activities included analyses of original writings, performance of experiments similar or identical to experiments that had been conducted throughout various periods, debates, and discussions.

The description of the topic 'combustion' serves as an example. Very often the introduction of this topic is used as an excuse for teaching how to write and balance chemical equations. In the module "*Science: An Ever-Developing Entity*," it is used to explain the confrontation between the Phlogiston and the Oxygen theories. Research shows that many students have erroneous perceptions regarding the combustion of matter (Watson, Prieto & Dillon, 1997); thus, it was considered important to try to clarify this issue. Therefore, a brief program, planned for three lessons, was developed around the Phlogiston Theory. Its objective was to present the students with the ancient theory of combustion and to compare it with their perceptions. In this program, experiments are proposed, the purpose of which was to monitor the work of scientists such as Priestley and Lavoisier. This is followed by a discussion of theories prevalent in various periods in contrast to theories accepted today.

METHOD

Participants

The participants were 10th grade students from high schools located in the central part of Israel. The group of students consisted of 90 non-science-oriented students (students who chose not to major in science) in three classes – one in each school. All students were between 15 and 16 years old and came from middle to upper socioeconomic levels. They studied about the structure of matter using the module "*Science: An Ever-Developing Entity*" (Mamlok, 1995), for 40 periods (50 minutes each) during the school year. The three teachers were experienced teachers (having more than 15 years of experience in teaching chemistry, physics, or biology for high-school students).

Data Sources

As mentioned before, the objective of the study was to test whether using the module "*Science: An Ever-Developing Entity*" (Mamlok, 1995), which uses a historical approach to teaching science, would affect the attitudes of non-science-oriented students towards science. Three kinds of data sources were used: (1) interviews with students, (2) observations of classroom activities, and (3) informal conversations. All these data sources, which were originally in Hebrew, were translated into English. The translation was done by professional translators, and was critically read for validation by the first and the second authors of this paper.

Interviews – The interviews were conducted by the first author of this paper at the beginning of the study and after the study was completed. The researchers asked each teacher from the three classes to choose four students for the interviews. Two students were low achievers and the other two were high achievers. The teachers categorized their students according to their achievements in a mathematics test which was conducted at the beginning of the school year. David, Sarah, Nadav, Orit, Gila, and Aric were categorized as low achievers, and Alon, Elana, Danny, Nora, Leora, and Ron (pseudonyms) were categorized as high achievers.

The interviews were semi-structured and the discussions were carried out around questions such as the following:

1. What do you do when a program that deals with a scientific issue appears on television?
2. When you read newspapers, are you interested in articles about science?
3. In your opinion, is science related to everyday life?

4. How, in your opinion, do the scientific inventions influence society?
5. What do you think is a scientists' daily routine?
6. How do you feel about studying science using a historical approach?

We are aware of the fact that questions 3 and 4 might look a little leading. However, the way in which non-science-oriented students perceive these issues was very central to this study, and unfortunately, we could not find a better way to phrase these questions.

Observations – The first author of this paper observed and videotaped three specific lessons that were given in each class, which centered around three events: (1) presenting mini-projects to all the students in the class, (2) participating in a scientific conference in school, and (3) debating on the subject: "For and against basic research" (for more details, see Appendix).

Informal conversations – The informal conversations were held by the first author of this paper with students during the breaks, and were summed up later. These discussions added insights and understanding about the students' feelings and attitudes toward learning the module "*Science: An Ever-Developing Entity*" (Mamlok, 1995), and served as another tool for validating the data collected from the semi-structured interviews.

Data Analysis

The data analysis is based on basic methods of qualitative data analysis (Tobin, 1995; Glaser & Strauss, 1967). We constantly compared the data from the interview with the data from the observations, and refined them. When clarification was needed, we collected more data by informal conversations.

Prior to studying the module, during informal discussions with the twelve students, statements such as the followings were heard:

- "The science studies in junior high school bored me."
- "I am not good at it."
- "Science programs on television don't interest me. Science studies scare me because I have to learn so many formulas."
- "I don't understand anything about science because I am not good in mathematics."

Some also expressed negative attitudes towards science in general, for example:

- "It might cause disasters, like Chernobyl and Hiroshima, or may cause damage, like the hole in the ozone layer, pollution, and disease."
- "Why does the man in the street have to invest in order to satisfy the curiosity of scientists or research institutions?"

- "Why don't scientists concentrate on what is really needed: development of medicine to fight severe illnesses, materials to fight pollution or developing better safety mechanisms for cars to decrease the number of accidents?"

The quotations were from both low and high achievers. Interestingly, in these two diverse groups of students, we could not point out any meaningful differences regarding their attitudes towards science. Based on their statements, we concluded that the decision of many of the twelve students from the non-science-oriented classes not to continue in their science studies was influenced by their past experiences.

After the study was completed, the interviews were audio-recorded, transcribed, and analyzed according to four main categories that emerged from the teachers' answers:

a. Students' attitudes towards science and science studies.
b. Students' perceptions of the world of the scientists.
c. Students' understanding of the nature of science and of technology.
d. Students' attitudes towards studying science using a historical approach.

Table I summarizes examples of students' quotations during the interviews conducted after the completion of the study.

From Table I we can conclude that after studying the module, students' statements regarding their attitudes towards science changed. However, we could not find differences between the attitudes of the low achievers and the high achievers. We will elaborate on each of the categories that emerged after analyzing the data from the three sources of data.

a. Students' attitudes towards science and science studies

The students' initial negative attitude towards science and science studies seemed to have undergone a gradual change during the period of study. Some of them began to show interest in the phenomena around them, exemplified by their reading science sections in the daily newspapers and watching science programs on television. In addition, they brought interesting articles from the newspapers and shared them with their colleagues. During one of the interviews, Aric remarked: "I don't turn off the television anymore when I happen to see a program devoted to a scientific subject."

Most students claimed that they had a negative attitude towards science studies because they were afraid that they would be unable to cope with formulas or with mathematical computation. Therefore, studying the module changed their attitude toward science studies and reduced their anxiety. They also claimed that the method used which provided them with a good

TABLE I

Examples of students' quotations during the interviews conducted after the completion of the study

Characteristics of students' responses	Quotations from low achievers	Quotations from high achievers
Students' attitudes towards science and science studies.	**David**: Perhaps, in the end, I'll become a scientist, who knows? **Sarah**: My enthusiasm to do work in science proves that I became "closer" to this sphere and actually it interests me!	**Nora**: The projects I prepared gave me an understanding and an overall comprehension of the subject and thus my approach to science studies has changed. I began to like science and became interested in it.
Students' perceptions of the world of the scientists.	**Orit**: Galileo was an exceptional man but there are many others like him and we don't know much about them but they are responsible for all innovations. **Alon:** Scientists' curiosity and desire to know are beyond boundaries. It appears that their way of thinking leads them to discoveries and inventions that ultimately help to improve life.	**Elana**: Scientists' greatest achievement nowadays is their ability to cooperate with each other and to publish their work, so that other scientists all over the world will benefit from that knowledge.
Students' understanding of the nature of science and technology.	**Gila**: Every accident or fault that we read about in the newspapers often causes the public to develop negative attitudes towards various developments in science or technology. **Sarah**: The public makes almost no differentiation between developments in science or technology, and between science, values and technological applications, which may be discussed in terms of good or bad. **Aric**: We don't know enough about the positive things for which science and technology are responsible. Whenever anything happens, science and technology are immediately blamed.	**Danny**: All in all I'm in favor of science and technology. Human life has been much improved. Even serious illness is better treated. All these are actually based on human curiosity, and the desire to know what the atom is made of and what matter is made of. Basic research drives applied research and applied research provides basic research with additional questions and problems. **Ron**: How can one believe that once there was no electricity? It's a wonderful invention that everyone takes for granted.

TABLE I

Continued

Characteristics of students' responses	Quotations from low achievers	Quotations from high achievers
Students' attitudes towards studying a science curriculum using a historical approach.	**Orit**: I liked very much the chapters about the alchemists. I liked the magic in the work of the alchemists who worked according to the theory of Aristotle. I pitied them because they followed a theory that was a dead end and they did not understand it.	**Alon**: I loved the idea of moving back and forth, sometimes toward the alchemists and at other times toward contemporary scientists. I liked the idea that nowadays we can change base elements into gold, only it is expensive. I thought to myself that even we or some of us can become scientists. Everyone can make mistakes and the scientists are only human beings.

understanding and an overall perspective of the subject, made them like it and in fact enhanced their interest. This can be exemplified by the words of Nadav:

I used to hate science studies because I was afraid of the formulas and didn't understand what they wanted from me. In this year's program very few formulas were included and we learned to understand phenomena without becoming entangled in calculations. Personally, I stopped being afraid of science and even enjoyed myself.

Almost all the students expressed their satisfaction with the variety of teaching strategies. After preparing mini-projects and presenting them to their peers, both in class and at a scientific conference in school, the students were extremely proud of their work and of the fact that their projects were presented together with other students – students who chose to major in science. Students' quotations regarding their attitudes towards science and science studies are presented in Table I.

b. Students' perceptions of the world of the scientists

Before they studied the module, most of the students did not have a realistic picture of science and of scientists. For example, Gila said:

I always thought that names like Aristotle or Galileo or Newton are names of weird and strange people who lived in a strange world. Now I know that they are people just like us, only very curious and persistent.

As mentioned, one of the activities accompanying the unit was a group activity where each student had to prepare a mini-project and present it to his peers. The topics were, among others, simulations of an argument between: (a) Lavoisier, Priestley, and Cavendish about the oxygen vs. the phlogiston theories, (b) Galileo and Aristotle concerning the nature of a scientific theory, (c) the alchemists and (d) the work of Newton. Exposure to these activities seem to have broadened students' horizons. Students' quotations regarding their perception of the world of scientists are presented in Table I.

c. Students' understanding of the nature of science and of technology
The data collected can be grouped under the following headings:

* *Pure vs. applied science*

Before studying the module, students claimed that scientists should only deal with the immediate needs of people ("Why don't scientists concentrate on what is really needed: developing medicine to fight severe illnesses . . . "), while during their studies, they came to appreciate the importance of constructing a theoretical basis:

Leora: "If we were satisfied only with applied research, we would still be living in the days of the alchemists. They studied and worked, but they were interested only in one task: seeking a way to produce gold from basic metals! They did not examine the theory according to which they worked and did not allow themselves to sit and think because that would be considered then "a waste of time." Progress took place when researchers came forth those who were curious about many phenomena that could not be explained by theories existing at the time. Their curiosity led them to new hypotheses, questioning existing theories, and building a new theory. This way of thinking developed until they arrived at modern theories pertaining to the structure of matter. Thus, while building new theories and models, many processes become possible, among them also transmuting basic metals into gold! And so basic research assists applied research . . . "

Other student's quotations regarding students' understanding of the nature of science and technology are presented in Table I.

* *Science vs. technology*

During the discussions and debates in class, students started to wonder about the relationship between science and technology. Students' quotations regarding this issue can be found in Table I.

d. Students' attitudes towards studying science using a historical approach
Our target population was students who opted not to continue to study science; therefore, they were reluctant to start the module "*Science: An Ever-Developing Entity*" (Mamlok, 1995). However, questions such as "What

are we studying? History or science?" were repeatedly asked during the course of the module. However, studying the module seemed to change their attitude towards science studies and reduced their anxiety regarding science. Students' quotations concerning their attitudes towards studying science using a historical approach are presented in Table I.

It seems appropriate to end with two quotations, both in the affective and the cognitive domains.

Danny: "It is terrific to study science. It broadens your horizons. It is nice and not too difficult. The program is fine, it opened our eyes."

Gila: "I did not like to study science, since I could not understand the meaning of many concepts. For example: the concept of energy and its scientific explanations did not mean anything to me. However, when we started to learn about the Phlogiston theory, it interested me. According to the Phlogiston theory, if something burns, it means that it consists of a material that enables the burning. This material was called Phlogiston, meaning: creator of flames. Today we know about the existence of Oxygen, which is "responsible" for a burning reaction, but then, people did not know about it. In my opinion, the Phlogiston theory made sense and was not ridiculous. Today we use the "energy" concept, but do people really know how to explain it?"

We may conclude that the historical approach helped high achieving students such as Danny, as well as low achieving student, such as Gila. The students' better understanding of the scientific concepts also influenced their attitudes towards science.

DISCUSSION

The main objective of the study was to examine the effect of learning the module "*Science: An Ever-Developing Entity*" on 10th graders who did not choose to study science (non-science-oriented students). The research question was examined through observations in class, interviews with twelve students, and informal conversations.

Based on the data analysis, we may conclude that for students who did not choose to major in any of the science disciplines, the combination of scientific subjects, the analysis of historical events, and issues taken from the spheres of the social sciences and humanities were more interesting and aroused more curiosity. Studying the concepts and their significance in various periods helped them to achieve a better understanding of the scientific endeavor. Many also remarked, regarding the variety of teaching methods, that the experiments that simulated ancient experiments, as well as films, articles, and projects that they prepared and presented to their peers and teachers greatly contributed to the learning and comprehension of the material. The students evaluated the instruction strategies as enjoyable, increasing their interest in science in general, and in the area of historical aspects in particular.

Before studying the module, the students expressed negative attitudes towards science studies. They could not see the importance of learning science, and the fact that science arouses curiosity and enthusiasm, and encourages thinking. After studying the module, however, their attitudes changed towards science and science studies. Moreover, they became interested in the scientific world, in the interaction between science and technology, and they expressed positive attitudes towards studying science using a historical approach. There was almost no difference between the attitudes of the low achievers and the high achievers before studying the module "*Science: An Ever-Developing Entity*." Both groups claimed that they did not choose to major in any of the scientific disciplines, since either they were bored by science studies in junior high school, or that they were scared of the formulas and calculations. Some mentioned the negative results of scientific discoveries, such as Chernobyl or Hiroshima, and wondered about the benefit of basic scientific research. "Why don't scientists concentrate on what is really needed: developing medicine to fight severe illnesses, materials to fight pollution or developing better safety mechanisms for cars to decrease the number of accidents?" was a popular claim.

Based on these findings, we suggest that the historical approach may help to achieve a better understanding of the essence of scientific phenomena, scientific methodology, and overall scientific thinking (American Association for the Advancement of Science, 1989; Sparberg, 1996; Monk & Osborne, 1997). In addition, this approach, which integrates scientific developments and historical analyses of scientific events, may help to achieve a better understanding of the essence of science and the work of scientists (Klopfer & Cooley, 1961; Hall, Lowe, McKavanagh, McKenzie & Martin, 1983; Matthews, 1994; Duschl, 1993; Meyling, 1997; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Finally, the students should become familiar with various projects of scientists on a specific subject (Ihde, 1984), and the effect of various cultures on scientific developments (Hayes & Perez, 1997).

Moreover, science should be presented in a way that will be understood by the students, and provide an atmosphere of learning environment in which students will learn to understand phenomena and link between them without the complications of formulas (Ben-Zvi, 1999). We believe, that if students study a challenging curriculum, situated and encored within a certain context (a historical one in this case), their perceptions, beliefs, and attitudes towards science and science learning will be positive (Blumenfield, Fishman, Krajcik, Marx & Solloway, 2000). Thus, we suggest integrating historical aspects into the science curricula. It should consist of scientific developments and historical analyses of scientific events, which will be taught by introducing the students to events in development of science and the work of scientists, more specifically by (1) discussions consisting of the deliberations that arose during their work pertaining to phenomena, (2) conducting classroom debates, emphasizing how controversial some theories in science were at the time of their proposal (Niaz & Rodriguez, 2002), (3) conducting experiments that simulate experiments carried out by scientists in various periods, or (4) learning about the spirit of the times (Conant, 1957; Brush, 1974; Irwin, 1997).

APPENDIX. THREE EVENTS OBSERVED AND VIDEOTAPED

1. Preparation and Presentation of Mini-Projects to the Students in Class

The students presented their mini-projects to their peers as posters, after an ongoing dialogue with their teachers who checked each stage of the progress. During the presentation the students also described the process involved in their work and in its composition. For example, the group that was involved in glass blowing visited a museum and interviewed a glass blower. They were amazed at the simple material used by the glass blower and the extraordinary results. Their poster included photographs that they took during the interview.

We will elaborate on one example: *A debate referring to the construction of atomic reactors.* The teacher divided the class into three groups:

1. Supporters the construction of a nuclear-plant.
2. Opposers of the construction of the power station who support a coal-powered station.
3. A committee of decision makers.

The students received work-sheets that contained relevant information and had to relate to various perspectives. This activity took one lesson, and in the following lesson, representatives of both groups (for and against) presented their arguments before the committee (each representative spoke for 10 minutes). At the end of the representatives' report, committee members left the class in order to reach a decision. When they returned, their representative delivered their decision: in favor of the construction of a nuclear-powered power station. This decision was reached by a majority of 4 of the 6 committee members.

The representative listed the main consideration for the construction of a power station driven by nuclear fuel:

It is more difficult to control toxic emissions resulting from coal combustion, than to take security precautions with a nuclear power station ... The number of people in the world who suffer as a result of toxic emissions from a coal-powered power station is greater than those who have been hurt as a result of accidents in nuclear power stations ... Activation of coal-powered power stations is one of the causes of the greenhouse effect and "acid rain," which are destroying the face of the planet. When a nuclear reactor works well, the amount of environmental radiation is negligible ... In developed countries (Japan, for example) the majority of power stations are nuclear-powered ...

2. Participating in a Scientific Conference in School (a Science Day)

In view of the students' excitement regarding the preparation of mini-projects, the teacher proposed to them to participate, together with the students from the science class, in a scientific conference organized by the school. The students agreed and selected various subjects that the teacher had proposed. They conducted their mini-projects, using the skills they had acquired while executing previous mini-projects, e.g., defining the objectives of the project, preparing sub-chapters, a synopsis, collection and classification of material, processing material, and preparing a poster.

3. A debate on the Subject "For or Against Basic Research"

The teacher's objective was to examine the students' attitude to the module and the ways in which she had taught them. "What are we studying: history or science?" This question was repeatedly asked during the course of the unit. There were students who argued that they did not like the sciences or history in junior high school and they definitely did not like their combination. During discussions that the teachers conducted with the students, the teachers spoke about the contribution of this approach to better understanding of (a) the development of scientific knowledge as part of the development of various spheres in each period, (b) scientists' methods of work in various periods, and (c) reciprocal relations between scientific and technological development.

The activity was conducted in two consecutive lessons. The teacher opened the discussion by emphasizing the fact that the Alchemists worked hard in order to find the "philosophers' stone" which would solve all problems – eternal life and transmuting basic metals into gold. They contributed a great deal to technology, but did not make any progress in their search because they adhered to a theory that did not allow this. They focused, according to the teacher, on what we would today call "applied research" and did not give any thought to basic research or to examine a theory in whose framework they worked. In order to clarify this point, the teacher asked the students if the relationship between basic and applied research was clear to them.

In contrast, there were students who supported basic research, driven by human curiosity and spirit, to discover new worlds and understanding mysterious phenomena that have not yet been explained. These students argued that had they not studied the module, and they would not have thought about this subject at all, and would not have been disturbed by this type of problem.

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