Educ. quím., **22**(2), 90-102, 2011. © Universidad Nacional Autónoma de México, ISSN 0187-893-X
Publicado en línea el 19 de enero de 2011, ISSNE 1870-8404

High-School Students' Attitudes toward and Interest in Learning Chemistry

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ABSTRACT
Developing positive attitudes toward and interest in science in general and learning science in particular is one of the key goals for teaching and learning the sciences. Thus, over the years, this area fuelled many research studies, these being focused on: content, pedagogical, and curricular issues. In this paper we focused on the issue of enhancing attitude and interests in the context of chemistry learning mainly at the upper secondary level of schooling. The authors of this manuscript suggest that the three key factors that should be considered for enhancing attitudes and interests are the methods used to present the content (e.g. relevance, and historical approach), instructional techniques that are implanted, and gender issues. Although throughout the years we have learned a lot regarding teaching and learning of chemistry we are unable to provide conclusive recommendations regarding how in the context of chemistry education affective constrains could be enhanced. However, based on scholarly developments and research we suggest areas (see above) that should be considered by science (chemistry) educators, curriculum developers, and chemistry teachers who believe that developing positive attitudes one of the central goals.

KEYWORDS: attitude, interest, affective domain, learning science

General introduction and bibliographical background

For nearly 40 years, hundreds of journal papers as well as reviews (Gardner, 1975; Schibeci, 1984; Simpson, Koballa, Oliver, & Crawley, 1994; Osborne, Simon, & Collins, 2003; Koballa & Glynn, 2007) and dissertations were published all over the world with the goal in mind of investigating the sources, reasons, and theoretical constraints for developing students' attitudes towards and interests in science in general and learning the sciences in particular. Throughout the years, very often, scientists, science educators (curriculum developers), and teachers emphasized the importance of the affective domain in general and attitudes in particular, as central components of the goals for teaching and learning the sciences.

Here are a few examples of quotes regarding the importance of developing positive attitudes in the context of learning the sciences.

Sears and Kessen (1964), in the context of the AAAS Commission on Science Education, wrote that:

> The first task and central purpose of science education is to awaken in the child, whether or not [he] will become a professional scientist, a sense of the joy, the excitement, and intellectual power of science. (p. 4)

In their comprehensive review of science education, Shulman and Tamir (1973) wrote:

> We are entering an era where we will be asked to acknowledge the importance of affect, imagination, intuition, and attitude as outcomes of science instruction as at least as important as their cognitive counterparts. (p. 1139)

Although research on students' attitudes towards learning science fueled many research projects for a long time, in the late 1980s there was a significant decline in science education researchers' interest in science-related attitudes (Koballa & Glynn, 2007; Hofstein & Lunetta, 2004). However, toward the turn of the century, the issue of attitudes towards and interest in science became an international concern. Recent publications (Osborne et al., 2003) presented a gloomy picture regarding students' ignorance in science, the decline in their attitudes toward science in general and science learning in particular, and the decline in enrollment in science-based careers.

In addition, in many western countries, the gloomy results of the recent international comparative assessments in science education (TIMSS, since 1995 and PISA, since 2000) also sparked a tidal wave of documents, all of which called for rethinking the goals, content, and pedagogy of science education (Bybee, Fensham, & Laurie, 2009). This rethinking has led to a diverse set of reports on the practices and future of science education, for example, in the US report by John Glenn's committee entitled *Before it is too late* (2000); in the European context, we can find *Beyond 2000* (Millar & Osborne, 1998), the *Relevance of Science Education* study

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(Schreiner & Sjöberg, 2004), and *Science Education in Europe: Critical Reflections* (Osborne & Dillon, 2008). All these initiatives and reports include one common feature: that the content of school science and its related pedagogical approaches are not aligned with the needs, motivational patterns, and interests of most of the students (Gräber, 1998; 2002; Jenkins, 2005; Sjöberg, 1997; Sjöberg & Schreiner, 2006). Even in countries in which the results of TIMSS and PISA were above average, students do not view science learning as either motivating or relevant (Black & Atkin, 1996; Morell & Lederman, 1998; Osborne, 2003). This is specifically true for chemistry and physics education, and especially for those students who probably will never embark on science or science-related careers, but will nevertheless need science — personally and functionally — for their future as literate citizens (Roth & Lee, 2004; Holbrook & Rannikmae, 2007).

Attitudes towards science and understanding science

According to the literature, the way students perceive and evaluate their acquaintance with any kind of knowledge is very important in their learning process (e.g. Bloom, 1976). 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). It is suggested that when students feel that they are familiar with concepts or issues from their previous studies, and feel confident enough to explain them, it affects their motivation and achievements. Such data are very important for developing learning materials and for planning teaching strategies (Arzi, Ben-Zvi, & Ganiel, 1986). It is assumed that students who are interested in science and understand the scientific concepts, will have more positive attitudes towards science and science studies compared to those who have learning difficulties in the science disciplines. Munby (1988) claimed that an attitude consists mainly of three characteristics: feeling, cognition, and behavior. 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 it and want to take more science courses and to continue reading about science. Fairbrother (2000) claimed that pupils learn only if they want to learn. There are many problems regarding the way science is taught in school, especially if we consider non-science-oriented students as an important target population. Many countries tended to give students a taste of an assortment of facts considered as important by the scientific community. Apparently, the idea underlying 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. Unfortunately, it appears that in general these hopes were not realized and the feeling nowadays favors the idea that 'less is actually more'.

O'Neill and Polman (2004) wrote:

> We 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. (p. 237).

What is the meaning of attitudes towards science and how are they measured?

The meaning of attitudes towards science

Although this paper focuses on attitudes towards chemistry, we believe that the nature of attitudes towards chemistry serves as an example for all the natural sciences studied in school.

Osborne et al. (2003) claimed (regarding attitudes towards science) that:

> Even a cursory examination of the domains reveals that one of the most prominent aspects of the literature is that 30 years of research into the topic have been bedeviled by lack of clarity about the concept under investigation. (p. 1053)

In addition, Koballa and Glyn (2007), in their review of the literature, suggested that often attitudes are used interchangeably with terms such as interest, beliefs, curiosity, opinions, and other commonly used affective-related variables. Clearly, the concept of attitudes towards science (often referred to as constructs) is a conglomerate of several components. Osborne et al. (2003) summarized a range of studies (e.g., Gardner, 1975; Ormerod & Duckwort, 1975; Woolnough, 1994) related to the attitude issue and suggested a list of components used and incorporated a range of components in these studies including the following:

- the perception of the science teacher
- anxiety towards science
- the value of science
- self-esteem regarding science
- motivation for science
- attitudes of peers towards science
- enjoyment of science
- the nature of the classroom learning environment
- achievement in science and fear of failure in taking a science course
- preference of learning approaches (pedagogy)-subject preference courses and
- enrollment in science courses in school.

How are attitudes towards science measured?

Over the years many research instruments have been devel-

oped in an attempt to produce valid and reliable measures to assess attitudinal constructs toward science. It includes written questionnaires, (e.g., Lykert-type questionnaires in which students have to respond to statement such as *I enjoy learning chemistry, or chemistry is fun* and semantic differential polar-type items, personally structured and semi-structured interviews, as well as various measures that were developed and implemented to assess students' perceptions of various interactions that occur in the science classroom (and laboratory) learning environment. Another source of information is of course students' enrollment in the various scientific (non-compulsory) subjects. Osborne et al. (2003), for example, suggested that enrollment in science subjects is also a significant indicator of students' interest at the school level, especially in the post-compulsory phase of schooling. However, they suggested that enrollment in science subjects should not be used as the sole measure of attitudes toward and interest in the sciences, and researchers should also consider including in the studies measures such as economic opportunities, gender issues, and perceived difficulties of the various subjects. Regarding future career and employment in the sciences, Shringly (1990) concluded that in general research has failed to show a clear alignment between students' attitudes towards the sciences and choosing future careers in the sciences.

It is beyond the scope of this paper to provide a comprehensive and extensive picture of the research methodologies and findings that were noted in many of these studies. However, the reviews that were published over the years (Gardner, 1975; Shibeci, 1984; Simpson, Koballa, Oliver, & Crawley,1994; Koballa, & Glynn, 2007) presented rather confusing and inconclusive results. In this context, Simpson et al. wrote that:

> The science education literature contains hundreds if not thousands of reports [and] interventions designed to change attitudes. Development of programs to influence the likelihood of science–related attitudes is important because it is assumed that changes in attitudes will result in changes in behavior. Unfortunately, few simple and straightforward generalizations can be made about how and why science–related attitudes change. (p. 223)

This is highly related to the type of measures used, the methodological approach, the lack of control regarding other related variables used, as well as the lack of a relevant and aligned theoretical rationale for the studies (Koballa & Glyn, 2007). For example, some studies (e.g. Fraser, 1982; Webster & Fisher, 2000) revealed a positive correlation and a causal relationship between achievement in science and attitude constructs, whereas others revealed no clear (or negative) relationship between attitudes towards learning science and achievement (Osborne & Dillon, 2008). Very often researchers adopted and implemented measures where there was no clear indication regarding its validity and reliability. International studies have shown that students' attitudes towards scientific disciplines depend on the extent of their active participation in the learning process. When teachers show personal interest in their students and support them, and the lesson is given with an encouraging attitude, students opt to continue studying science (Piburn and Baker, 1993; Fraser, 1994; Simpson et al., 1994; Lee and Burkam, 1996; Shrigley et al., 1998). Students' positive perceptions are related to teachers' support, enthusiasm, innovative teaching strategies, and the opportunity for students' involvement (Fraser, 1994).

Attitudes towards Chemistry and Learning Chemistry

In general, almost all the issues that were discussed in the introductory section regarding attitudes towards science and learning science are relevant to the discussion related to learning high-school (and university) chemistry. However, we will highlight those variables and parameters that are unique and specific to the content and pedagogical approaches used in chemistry. We assume that the uniqueness of the subject is related to certain content, for example, technological applications, industry, environmental issues, health and nutritional issues, and other daily life applications. In addition, research has revealed that in some cases students exhibited different attitudes toward school, in particular, biology, chemistry, and physics (Osborne & Collins, 2000; Barnes et al., 2005).

Cheung (2009) conducted a thorough and comprehensive review of the literature and found that over the years, only nine studies examined secondary school students' attitudes towards chemistry taught in secondary schools. He wrote that although these studies were informative, they produced mixed and inconsistent results. For example, Hofstein et al. (1977) conducted one of the studies among 11 and 12th grade students in Israel. Interestingly, they found that there was a significant decline in students' attitudes towards learning chemistry when they progressed from grade 11 to grade 12. On the other hand, in the USA, Menis (1989) found the opposite, namely, that 12th grade students exhibited a more positive attitude than 11th grade students. One should note, however, that Hofstein et al. (1977) and Menis (1989) used different attitudinal measures. Cheung (2009) suggested that one possible explanation for the inconclusive results could be that gender (and its interaction with grade) was not assessed or considered in these studies. In addition, there are instructional techniques that are more effective in chemistry, for example, certain laboratory activities and approaches.

We decided to discuss "attitudes towards chemistry" in the context of the following three topics:

- The content of chemistry taught including organizational approaches.
- Use of various instructional techniques (pedagogy) often used in chemistry.
- Gender issues.

Different approaches to enhance students' attitudes toward and interest in studying chemistry

Making school chemistry more relevant to the learner

Research has shown that often chemistry teaching:

1. Is seen as unpopular and irrelevant in the eyes of students (Kracjik et al., 2001; Osborne and Collins, 2001; Pak, 1997; Sjoberg, 2001).
2. Does not promote higher order cognitive skills (Anderson et al., 1992; Zoller, 1993).
3. Leads to gaps between students' wishes and teachers' teaching (Hofstein et al., 2000; Yager and Weld, 2000; Holbrook and Rannikmae, 2002).
4. Does not change, because teachers are afraid of change and need guidance (Aikenhead, 1997; Rannikmae, 2001a).

The common factor linking all of the above seems to be the lack of relevance of teaching chemistry. Although school chemistry programs set out to develop conceptual understanding in students and an appreciation of the way scientists act as researchers, the relevance of the teaching in providing a useful education is not apparent (Pak, 1997; Champagne et al., 1985; Lederman, 1992; Ryan and Aikenhead, 1992). The emphasis of chemistry curricula on conceptual understanding and appreciating the nature of science tends to be irrelevant for our daily life functions, i.e., relevant to the home, the environment, and most definitely for future science-related changes and developments that might occur in our society.

We postulate that relevance and attitudes toward and interest in the subject they learn are related. In other words, if students find the science (in this case chemistry) content that they learn relevant to their daily life and to the society in which they operate, there is a good chance that they will develop positive attitudes towards the subject. Next, we will attempt to provide a theoretical background and rationale for these premises.

In recent years, the content and pedagogy of science education have repeatedly been scrutinized. Many science education researchers attempted to re-orient science education in the direction of meaningful, authentic, relevant, and contextualized chemistry education (Hofstein & Kesner, 2006; Gilbert, 2006; Holbrook, 2005; Holbrook & Rannikmae, 2007).

Today, there is much support for the idea that one major reason for the decline in interest in science in general and in physical sciences in particular (physics and chemistry), is directly related to the nature and content of the current curricula, regarding both the contents and their pedagogies (Eilks, Marks, & Feierabend, 2008; Gräber, 2002; Gilbert, 2006; Millar & Osborne, 1998). In many countries, school science curricula are described as being overloaded with content that exclusively emphasizes the inner content structure of the related academic discipline (Gräber, 2002). This often leads to curricula characterized by isolated facts detached from their scientific origins (De Vos, Bulte, & Pilot, 2002), and containing low levels of orientation towards relevant issues taken from students' everyday life or for societal concerns (Holbrook, 2005). As a result, pupils fail to make connections between the different facts and concepts presented and their practical applications, thereby missing the 'big picture' of science and never developing confidence in its relevance. Clearly, all these have potential to influence their attitudes and interests.

In the last decade, a whole wave of projects oriented towards context-based chemistry curricula have emerged in different countries (Pilot & Bulte, 2006). However, this has not automatically resulted in a real orientation towards the needs of society or in students always showing greater interest in science (Osborne, 2003). In reflecting on the reasons for that, one of the most important underlying questions is: Which characteristic of context might be termed 'good context' for promoting scientific literacy for all students by the means discussed above?

Some hints regarding this issue can be found in the literature (Bybee, 1997; Pilot & Bulte, 2006; Gilbert, 2006). In the case of chemistry in Israel, Shwartz, Ben-Zvi, and Hofstein (2005; 2006) provided a comprehensive definition of chemistry literacy. This definition explicitly includes a societal (contextual) component, i.e., issues (applications) related to chemistry such as nutrition, industry, environment, and health (medicine and drugs). In order to provide students with opportunities to engage in such issues, learners need teaching and learning scenarios that meet these criteria, make science teaching more relevant, support the development of cognitive and meta-cognitive strategies, as well as emotional and motivational dispositions in an interesting environment and with relevance to future life in a contemporary society and/or in prospective careers.

In 2006, in a special issue regarding the idea of context-based chemistry education, Gilbert listed several problems that he believes have the potential to affect attitudes toward and interest in learning chemistry. His list consists of issues such as overload of the subject matter, failure to present a holistic approach to chemistry (i.e., presentation of isolated facts), inadequate emphasis regarding selection and depth of topics taught especially for those who are not going to embark on a career in chemistry or chemistry-related sciences. Finally, he suggested that many programs suffer from lack of relevance. Gilbert wrote that:

> Many of those that do elect to continue to study the subject (chemistry) experience lack of relevance in it and seem to view it in an instrumental way, rather than because it is worthwhile in itself. (p. 958)

He also suggested that each of the above-mentioned obstacles for effectively learning chemistry poses a series of challenges

facing chemical education. In addition, he claimed that context-based chemistry curricula have the potential to address those challenges facing chemical education. For example, Gilbert suggested the following:

> The curriculum overload (in chemistry) could be reduced by selecting focal events that are relevant for the students and those parts of 'chemical language' that are needed for students to grasp the meaning of the chemistry involved in these focal events. (p. 961)

Note that the characteristics of the relevance issue are rather complicated and subjective. Van Aalsvoort (2004) defined four subcategories of relevance within the context of science education (Holbrook & Rannikmae, 2007):

- Personal relevance: education by making connections to pupils' lives.
- Professional relevance: education offering pupils a picture of possible professions that they might pursue in the future.
- Social relevance: education clarifying the purpose of science in human and social issues, and
- Personal/social relevance: education helping pupils become responsible citizens in the future.

Clearly this has the potential to serve as guideline for chemistry curriculum developers as well as for practicing chemistry teachers who believe that alignment exists between students' attitudes and their perceptions regarding the relevance of the content of chemistry that they learn.

Examples of relevant-oriented chemistry programs in three countries

In this section we present several examples of relevant-oriented (context-based) chemistry curricula in which the authors provided evidence for a change in students' attitudes towards chemistry in general and towards the learning of chemistry in particular.

In the UK, the *Salters* Chemistry, a context-based program was developed and implemented by the science education group at the University of York (Bennett & Lubben, 2006). The program was developed based on concern regarding the uptake of science subjects (including chemistry) beyond the compulsory level of schooling. Bennet and Lubben wrote that the development of the program in chemistry hinged on two fundamental design criteria:

> The ideas and concepts selected, and the contexts within which they are studied, should enhance young people's appreciation of how chemistry:
> — contributes to their lives or the lives of others around the world, or
> — helps them to acquire a better understanding of the natural environment (p. 1001).

Although no formal large-scale evaluation programs were designed and implemented for *Salters* Advanced Chemistry, several graduate (PhD and MSc) studies were conducted. For example, it was found that *Salters*' students expressed higher levels of interest in the course (content and pedagogy) compared with more conventional courses. Also, *Salters*' students who visited an industrial site (industrial chemistry) exhibited greater insight into the role and importance of chemical industry.

In the USA, the *Chemistry in Context* program was developed for the college level, mainly for those students who did not specialize in science (Schwartz, 2006). The program and textbook include chapters such as *the air we breathe, the wonder of water, solar energy, and energy chemistry and society*. Clearly, these chapters were selected to develop a sense of relevance in the learners' mind. Schwartz (2006) conducted a survey among non-science-oriented students in nine colleges. It included 20 statements investigating students' beliefs about chemistry as a topic of study. In general, it was found that enrollment in the chemistry-in-context program resulted in significant changes in attitude that were favorable regarding perceiving the importance of chemistry. For example, in six of the schools the students made a significant change regarding whether they agreed with the statement "I sometimes talk about issues involving chemistry with my roommate or family".

Historically, the *Chemistry in Context* program followed the *Chemistry in the Community* (ChemCom) program originally developed to be implemented in American high schools (Ware, 2001). This program was also developed and implemented to cater to the needs of non-science majors. It focused on presenting the learner with an accurate picture of chemistry and its related applications and how chemistry contributes to the quality of life on our planet. Thus, the program includes topics related to chemistry such as health, nutrition, agriculture, transportation, energy production, and industrial developments. According to Ware (2001), the program was developed in response to the most common claims made by many students who felt that in general, chemistry is too difficult, boring, and abstract. In addition, chemistry was perceived by students as irrelevant. Although we could not find clear evidence that the program provides a solution to all of the above negative claims, Schwartz (2006) reported that the program was a big success in schools in the USA. In addition, he reported a significant increase in the enrollment in high-school chemistry. This might result from the use of this curriculum and indicate students' attitudes toward and interest in chemistry.

Finally, in Israel, more recently, a module entitled: *I have Chemistry with the Environment* was developed by Mandler (2010) in the Department of Science Teaching at the Weizmann Institute of Science. The topic focused on two environmental chemistry issues, namely, "*water*" and "*carbon cycle*". These topics provided contexts for teaching quantitatively oriented analytical chemistry concepts.

The research population consisted of 12th grade students (N ~ 400) and 18 teachers in 18 classes and 16 schools who opted to major in high-school chemistry. The results of Mnadler's study indicated that the students underwent a significant change in their awareness of environmental issues. All the students mentioned that the unit influenced their everyday-life perceptions related to environmental issues. Another finding was that many students reported that learning the "*I Have Chemistry with the Environment*" unit encouraged them to learn chemistry. Most students reported that they enjoyed learning the unit more than their regular chemistry lessons. They wrote that they especially appreciated the feeling that they could discover things by themselves. In particular, they referred to a sense of purpose. Some students said that: "We were doing real experiments, with a purpose". Students indicated that the unit was meaningful, and that this "why and how" was missing in their regular chemistry lessons. From the results, it can be seen that students found that learning the unit was relevant to chemistry learning as well as to their personal lives. Most of them stated that they want to learn more about environmental issues in order to make changes and to improve the quality of their lives.

To sum-up, the data from the three countries reported in this section clearly indicate that teaching chemistry based on relevant context-based learning might provide an effective mean for enhancing students' motivation and also students' perceptions regarding chemistry as a relevant, important, and interesting subject to study.

A historically oriented approach to chemistry teaching

As previously mentioned (Pintrich, Marx and Boyle, 1993; Barila and Beet, 1999), students' motivation is an important factor that can lead to raising or lowering the status of conceptions. Similarly, Fairbrother (2000), claims that pupils learn only if they want to learn. If we want to achieve, even partially, the objective mentioned, i.e., to provide education resulting in a scientifically literate citizen, we are immediately faced with the difficult question of "how to do it".'

Some researchers felt that students' initial scientific knowledge is analogous to the knowledge of scientists in the ancient world, and that it consists 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 to which they adjust in their own world of knowledge and emotions. They believe in what they sense and tend not to believe in what is out of the scope of their senses. For example, Ben-Zvi, Eylon, & Silberstein (1986) tested 10th grade high-school students' perceptions of the structure of matter and chemical processes. They concluded that many students do not differentiate between the attributes of matter and those of a single particle. They tend to regard a single atom or a molecule concretely, as if each one is a "piece of matter". When they were asked to draw the contents of a container that held a gas compound, only 30.7% of the students sampled correctly conceived gas as a collection of particles, in its correct structure. In interviews conducted with the students on this subject, they claimed that the spaces between the particles were "simply air". It appears that both the concept of vacuum and the need to think of an accumulation of particles, rather than a single particle, are difficult to grasp. In characterizing matter, students tended to describe it as single particles, and many of them confused a mixture of various substances with elements and compounds (Ben-Zvi, Eylon, & Silberstein, 1986).

The obvious conclusion of various studies is that the science curriculum should develop a historical approach to the teaching of science (Erduran, 2001; Abd-El-Khalick, 2002). This approach, which integrates scientific development and a historical analysis of scientifically based events, might help students achieve a better understanding of the nature and methods of science (Elkanah, 2000; Hall et al., 1983; Holdford, 1985; Project 2061, 1989; Matthews, 1994; Irwin, 1996; Sparberg, 1996; Monk & Osborne, 1997; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). This was summarized by the National Research Council (1996) as follows:

> 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)

Based on the above, in the Department of Science Teaching at the Weizmann Institute of science, "*Science: An Ever-Developing Entity*" (1995; Mamlok, Ben-Zvi, Menis, & Penick, 2000; Mamlok-Naaman, Ben-Zvi, Hofstein, Menis, & Erduran, 2005), a module with a historical approach, was developed. This module (teaching unit) is 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 his efforts at self-improvement.

Thus, the module was developed with the following objectives in mind: (1) to enable students who did not opt to major in any of the scientific disciplines to familiarize themselves with the nature of science, (2) to enable students to better 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 dissemination of the module was followed by a comprehensive research study. The main objective of the study was to examine how learning the module "*Science*: *An Ever-Developing Entity*" affected 10th graders who did not opt to

study science (non-science-oriented students), in particular, regarding their attitudes towards science.

Based on the data analysis, we can conclude that for students who did not opt 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 than the conventional approach. Studying the concepts and their significance in various periods helped them achieve a better understanding of scientific endeavors throughout history. 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 viewed the instruction strategies as enjoyable, and increased 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 critical 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 opt to major in any of the scientific disciplines, since either they were bored by science studies in junior high school, or 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 believe that the historical approach may help students 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 students 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, 1994; Meyling, 1997; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). We believe that if students study a challenging curriculum, within an appealing environment (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.

Instructional techniques (pedagogical approaches) used in chemistry: Varying the classroom learning environment

The Chemistry laboratory: A unique learning environment

Laboratory activities have long played a distinctive and central role in the science curriculum and science educators have suggested that many benefits accrue from engaging students in science laboratory activities (Hofstein & Lunetta 1982; Tobin 1990; Lunetta 1998; Lazarowitz & Tamir, 1994; Hofstein & Lunetta, 2004; Lunetta, Hofstein, & Clough, 2007). More specifically, they suggested that, when properly developed, designed, and structured, laboratory-centered science curricula have the potential to enhance students' meaningful learning, conceptual understanding, and their understanding of the nature of science. In addition, the literature revealed a clear correlation between students' attitudes towards learning science and various modes of instruction in the science laboratory. Although the literature failed to provide a clear relationship between learning science and practical experiences in the laboratory, many research studies (summarized by Hofstein & Lunetta, 1982; 2004) conducted mainly during the 1960s and 1970s reported that students enjoy laboratory work in some courses and that laboratory experiences resulted in positive and improved attitudes and interest in science. However, as Hofstein and Lunetta (2004) suggested, throughout the 1980s the focus of scholarly research within the science education literature moved slightly away from the affective domain towards the cognitive domain in general and towards conceptual change in particular. This is unfortunate since scientific experiences (e.g. laboratory work) that promote positive attitudes could have very beneficial effects on interest and learning. As previously mentioned, this paper does not attempt to present an exhaustive review of the literature. Thus, we will provide a short historical overview of a few research-based examples that will support the claim that a positive relationship exists between chemistry laboratory-based experiments and various types of attitudes.

Charen (1966) and Smith et al. (1968) found that in general, laboratory work enhanced students' attitudes towards learning chemistry. Ben-Zvi et al. (1976) reported on a chemistry study in which chemistry students wrote that personal laboratory work (hands-on) was the most effective instructional method that they had experienced for promoting their interest in learning chemistry when contrasted with group discussion, teacher's demonstrations, filmed experiments, and teacher's whole-class frontal lectures. A study aimed at exploring students' attitudes towards the chemistry labora-

tory was conducted in Nigeria by Okebukola (1986) who adapted the *Attitude toward Chemistry Laboratory Questionnaire* developed and validated in Israel by Hofstein et al. (1976). Analysis of the students' responses revealed that a greater degree of participation in laboratory work may produce more positive attitudes towards the laboratory.

Another study conducted in Israel (Milner, Hofstein, & Ben-Zvi, 1987), aimed at exploring the reasons for students' enrollment in more advanced (post-compulsory) courses in high-school chemistry, showed that one of the key reasons for enrolling in chemistry courses was that students were able to participate in practical activities in the chemistry laboratory and thereby gain valuable experience. It is suggested that the decision to study (or not study) additional subjects (e.g., Chemistry) is at least a partial attitudinal indication. The 1990s were rather sparse in research studies in which attitudes towards chemistry in general and towards learning chemistry in laboratories, in particular, were investigated. Nevertheless, according to some science educators' studies, laboratory work is an effective learning environment for enhancing attitudes, stimulating interests and enjoyment, and motivating students to learn science (Freedman, 1997; Thompson & Soyibo, 2002). In 2004, *The Attitude towards Chemistry Laboratory Questionnaire* (developed by Hofstein Ben-Zvi & Samuel, 1976) was used in a comparative study. The questionnaire was administered in a study in which two groups of high-school chemistry students were compared (Kipnis & Hofstein, 2005). The first group conducted inquiry-type experiments (Hofstein, Shore, & Kipnis, 2004), whereas the second group performed more conventional, confirmation-type activities. The students in the inquiry group developed more positive attitudes towards learning chemistry than did those students who had experienced a more conventional chemistry program.

To sum-up, based on research conducted over a period of almost 50 years, it is clear that the laboratory has a potential to contribute significantly to shaping and enhancing students' attitudes towards chemistry. Clearly, the magnitude of the attitudinal behaviors is a function of the instructional approach adopted by the curriculum developers, by the type of measure used, and by the teachers' behavior and practice in their classroom.

The classroom laboratory learning environment: Students' perceptions

Since the early 1970s, researchers have studied students' perceptions of *the classroom learning environment* and its relationship to outcomes such as student achievement and attitudes (Fraser, 1991). In general, these measures were developed in order to obtain information on three types of interactions that exist in the classroom: student-student, teacher-students, and student-learning materials. A valid and reliable measure to assess students' perceptions of the classroom laboratory learning environment, the Science Laboratory Environment Inventory (SLEI), was developed and validated by a group of researchers in Australia and used subsequently in studies conducted in several places around the world (Fraser et al. 1993). Fraser et al. also reported that Australian students' perceptions of the laboratory learning environment accounted for significant differences in the variance in students' learning of science content beyond that attributed to differences in their abilities. A study conducted in Israeli high-school chemistry classes (Hofstein et al., 2001) revealed that high-school students who experienced a series of inquiry-type laboratory investigations in chemistry (Hofstein et al., 2004) found the laboratory learning environment to be more open-ended and more integrated with the conceptual framework they were developing than did those students enrolled in a more conventional laboratory courses (control). In the inquiry group the gap between the actual learning environment and the students' preferred learning environment was significantly smaller than in the control group. These findings suggested that some kinds of practical experiences (i.e. inquiry-type) can promote a positive and healthy leaning environment. If students' positive perceptions of the science laboratory learning environment, i.e., cooperative learning and developing a community of inquiry are among the important outcomes of school laboratory experiences, then these outcomes should be assessed by the teacher as a regular part of course evaluation. Teachers can use the SLEI as a tool for determining how their students perceive their classroom laboratory learning environment.

Using web-based learning in chemistry

In the last decade we have observed a rapid development in the use of the internet in education (Wagner, 2000). The great potential of a web-based learning environment in education has been documented in the literature (Hoffman et al., 2003). Kinzie et al. (1996) suggested that the internet learning environment could change the nature of learning by increasing the access of students to learning materials in a variety of ways. In addition, the online information obtained has the potential to make available to the learners the most current information including modeling, simulations, and visualization tools that demonstrate abstract chemistry phenomena. This facilitates analyzing and examining online data in new ways and has the potential to increase students' understanding of science (chemistry) concepts (Kracjik, 2000; Barnea & Dori, 2000; Sanger & Badger, 2001; Frailich, Kesner, & Hofstein, 2007; 2008).

A web-based environment in which the students are provided with clearly defined and focused activities promotes an environment in which the students become active participants in the learning process, assisted by their teachers and peers. Active learning is defined as learning that strengthens student involvement in the learning process and has had a positive impact on student attitudes and achievements (Bonwell & Eison, 1991; Felder & Brent, 2003; Moore, 1989). Several very significant interactions occur when students are engaged in web-based activities while working in small groups:

interactions take place between the student and the learning materials, between the students themselves, and between the students and their teacher. It was suggested in the literature that social aspects are important components of learning processes (Johnson, Johnson, & Smith, 1998ab; Mayer, 1999; Semple, 2000). We believe that all these lead to effective, more meaningful learning and to a more in-depth understanding of the science topics being studied.

In Israel, Frailich et al. (2007; 2008) investigated how integrating a website into chemistry teaching affected 10th grades students. More specifically, the study explored students' perceptions of the classroom learning environment, their attitudes regarding the relevance of chemistry, and their understanding of the chemical bonding concept. The subject matter was presented using a context-based approach (including industrial and environmental issues). Several qualitative and quantitative tools were developed in order to gather information on students' achievement and attitudes. In the comparative study (experimental students who used the website along with a control group who were not exposed to the media), it was found that the experimental group outperformed the control group in all the researched categories: understanding the chemical bonding concept, attitudes towards and interest in chemistry as a relevant subject in general and learning chemistry in particular, and the students' perception of classroom learning environment. The findings related to web-based learning are in line regarding the use of computer-assisted instruction in general as a vehicle for developing positive attitudes (Soyibo & Hudson, 2000).

Gender issues related to attitude towards and interest in chemistry

General discussion

Surveys conducted in Europe (Osborne and Dillon, 2008) among large groups of young students clearly showed that girls and boys differ in their interest in science-related topics. For example, boys showed interest in topics such as *Explosive chemicals, how it feels to be weightless in space, how the atom bomb functions, biological and chemical weapons and what they do to the human body*. In contrast, girls showed interest in *Why we dream when we are sleeping and what the dreams might mean, cancer – what we know and how we can treat it, how to perform first aid and use basic medical equipment, and how to exercise the body to keep fit and strong*. Although problematic, this and similar information should not be overlooked by curriculum developers in their attempt to design science curricula catered to *all* students' needs and interests.

Gender issues in chemistry education

A review of the literature over a period of almost 40 years revealed mixed findings regarding gender and attitudes towards chemistry. In some cases girls exhibited more positive attitude towards chemistry, and in other cases, the opposite picture prevailed.

Cheung (2009) conducted a comprehensive review of the literature regarding gender issues related to chemistry education. He noted that probably the first research that was conducted on gender differences in secondary school was conducted in Israel by Hofstein et al. (1977). This study was conducted on 11th and 12th grade students using an adopted version of the Chemistry Attitude Scale originally developed by Tamir et al. (1974). The study revealed that girls had a more favorable attitude towards studying chemistry than did boys.

A meta-analytic investigation was conducted by Steinkamp and Maehr (1984); it showed that regarding chemistry education girls had more positive attitudes compared with boys. In addition, in Australia Shannon (1982) reported that girls found chemistry more enjoyable than did boys. On the other hand, several studies conducted in Israel by Menis (1983), Harvy, and Stable (1986) in the UK, and by Barnes et al. (2005) in Australia, revealed the opposite, namely, that the attitudes of boys towards chemistry was more positive than were those of girls.

It is suggested that the main reasons for these inconsistencies is related to the type of measure used by the researchers, the nature of the content and of the chemistry curriculum, the instructional techniques often used in the chemistry classrooms, and the students' grade-level (Cheung, 2009). He suggested that gender differences may vary across levels. Cheung conducted a study among chemistry students in Hong Kong with the goal in mind of investigating whether there is significant interaction between grade level and gender regarding students' attitudes towards chemistry. More specifically, he found that significant interaction exists between grade level and gender regarding the various attitudinal variables (*liking for chemistry theory lessons; liking for laboratory work; evaluative beliefs about school chemistry; and behavioral tendencies to learn chemistry*). However, he found that there were mixed finding regarding the various scales assessed in relation to grades in which the students learned chemistry. Whereas in the lower secondary schools the boys exhibited more positive attitudes, no differences were revealed in the upper ones.

To sum-up, although the research findings were mixed, the "good news" is that in some studies and in some countries and regarding some programs the attitude of boys and girls towards chemistry is equal. These are encouraging since there is great concern regarding the number and contributions of women in the sciences (mainly the physical sciences) (Kahle & Meece, 1994).

Summary

Although there is little doubt that throughout the last decade substantial progress has been made in identifying students' learning behaviors, the effectiveness of instructional techniques used in the science classroom, and other variables that can promote meaningful learning consistent with contemporary standards, the question still remains: What promotes attitudes toward and interest in chemistry remains unequivo-

cal. In this paper an attempt was made to review and analyze the literature related to the attitudes toward and interest in learning chemistry. However, we as authors are a bit confused regarding the information we have gathered. In summarizing our paper, we can conclude that one can identify certain indications, but that there are no clear-cut recommendations that will guide future researchers, chemistry curricula developers, and decision makers. Apparently, certain content-related pedagogical approaches are more effective than others in an attempt to enhance affective goals. However, more research is needed in order to be able to provide the research community with a set of recommendations as to how to construct future chemistry curricula.

More attention should be drawn to the differences related to the learners. Future development in chemistry teaching and learning should pay more attention to different students' gender, motivational patterns, and learning styles. Clearly, different students have different preferences for different instructional techniques. Some students prefer more student-centered instructional techniques whereas others prefer teacher-centered instructional methods (Hofstein & Kempa, 1995). This is in fact a call to vary the chemistry classroom learning environment so that it will cater to different students as described above (Hofstein & Walberg, 1995). Also, based on the literature, it is clear that girls (as opposed to boys) prefer a more cooperative learning environment as opposed to whole-class learning (Zohar & Sela, 2003).

Here we have examined several areas that have potential to enhance learning science in general and chemistry in particular. However, to date we do not have a clear causal framework that will provide the science education community with an applicable picture regarding how attitudes influence motivation and how motivation influences science learning (Koballa & Glynn, 2007). More research is needed in order to advance our knowledge regarding attitudes that were accumulated thus far.

Finally, we believe that the call made by Shulman and Tamir in 1973 almost 40 years ago that:

> We are entering an era where we will be asked to acknowledge the importance of affect, imagination, intuition, and attitude as outcomes of science instruction as at least as important as their cognitive counterparts. (p. 1139)

is still valid and educationally important at the beginning of the 21st century.

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