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AUTHOR	Dori, Yehudit Judy; Hofstein, Avi	
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ABSTRACT

Reform in science and technology education started in Israel in 1992 with the release of the "Tomorrow '98 Report." The report featured 43 recommendations for new programs, special projects, changes, and improvements that are both educational and structural in the areas of curriculum development and implementation, pedagogy of science, and professional development of science teachers. This paper focuses on the recommendations that concern the teaching and learning of 'Science and Technology for ALL' (MUTAV), a program for high school students who opt not to specialize in any of the science disciplines (biology, chemistry, or physics). (Contains 29 references.) (CCM)

The Development, Implementation and Initial Research Findings of *'Science and Technology for All'* in Israel

Yehudit Judy Dori
Department of Education in Technology and Science
Technion, Israel Institute of Technology
Haifa 32000, Israel
&
Center for Educational Computing Initiatives
Massachusetts Institute of Technology
Cambridge, MA 02139, USA

and

Avi Hofstein
Department of Science Teaching
The Weizmann Institute of Science
Rehovot 76100, Israel

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The Development Implementation and Initial Research Findings of 'Science and Technology for All' in Israel:

Theoretical Background

In recent years science educators and curriculum developers have realized that science is taught not only in order to prepare students for academic careers in the sciences, but also to become citizens in a society that is highly dependent upon scientific and technological advances.

Harms and Yager (1981) suggested that we should teach science in order to attain the following major goals:

- Science for meeting personal needs;
- Science for resolving current societal issues; and
- Science for assisting with career choices.

To attain these goals, science curricula needs to be reorganized with a new paradigm in mind, one that encompasses content, structure, and pedagogy. In the past, the various science disciplines were taught (especially in the upper classes of secondary school) using domain-specific concepts and vocabulary that emphasize the particular structure of the various science disciplines.

To achieve scientific literacy for all, the science curricula should be relevant to students' personal life and to the society in which they live. Such programs have the potential to improve the classroom learning environment as well as increase students' motivation to learn science (Byrne and Johnston, 1988; Hofstein and Walberg, 1995).

During the last decade, consensus has been emerging with respect to education reform in general and science education in particular (AAAS, 1994; NSTA, 1993; U.S. Dept. of Education, 1991; Yager, 1993; Yager and Hofstein, 1986; Yager and Tamir, 1993). An important means for achieving this reform is the incorporation of Science-Technology-Society (STS) aspects into science teaching (Bybee and Ben-Zvi, 1998; Solomon, 1993).

A major goal in STS education is the development of students' scientific and conceptual understanding, critical thinking and problem-solving capabilities through dealing with real-world problems (Ben-Chaim and Zoller, 1991; Dori and Herscovitz, 1999; Keiny, 1995; Kesner, Hofstein and Ben-Zvi, 1997). The STS approach advocates incorporating societal and economical considerations as well as value judgement and decision making.

Another aspect of STS education is the development of students' thinking skills in the context of science. The relationships among science, technology, environment and society can help citizens become scientifically and technologically literate (Solomon, 1993; Zoller, 1990; Tal, Dori, Keiny and Zoller, 2000).

New standards in science and mathematics education are being advocated. These standards reflect the current vision of the content, classroom environments, teaching methods and support necessary to provide high quality science education for all students (NRC, 1996).

Science for All in Israel

Reform in science and technology education has started in Israel in 1992 with the release of the "Tomorrow '98 Report" (1992). The report includes 43 recommendations for new programs, special projects, changes and improvements that are both educational and structural in the areas of curriculum development and implementation, pedagogy of science, and professional development of science teachers.

In this paper we focus on the recommendation that concerns teaching and learning of 'Science and Technology for All' (**MUTAV**) – a program for high school students who do not opt to specialize in any of the science disciplines (biology, chemistry, or physics). The program consists of interdisciplinary modules. Each of these modules presents a certain scientific topic with its technological, societal and personal applications.

The Tomorrow '98 committee appointed by the Ministry of Education and Culture considered the need to make science an integral part of the education for all citizens, suggesting that: "*Modern socioeconomic problems require understanding of their scientific background. Other questions arise when we discuss the division of resources and world wealth, different environmental issues and other topics that require the individual to demonstrate an understanding based on having acquired a basic education in the sciences.*" (Tomorrow '98, 1992. pp. 34).

Relevant science curricula have been developed using interdisciplinary and multi-disciplinary approaches. To make science relevant to students, the science curriculum provides opportunities to cope with interdisciplinary issues such as energy, environment, health, nutrition, genetic engineering, and water.

The Development of Science Curriculum for Non-Science Majors

The reform in science education in Israel resulted in the development of learning materials that are tailored to the needs, interests and abilities of those students who opted to not to specialize in scientific streams.

The question has been raised as to the interpretation of the term 'non-science majors'. Scientists and science teachers tend to describe science majors in positive terms, claiming that these students choose to study science and therefore they are interested in understanding scientific concepts and phenomena. Non-science majors, on the other hand, are viewed as those who are not interested in science and do not understand scientific concepts and phenomena.

Contrary to this view, Tobias (1990), in her book titled "*They Are Not Dumb, They Are Different*", claimed that the student population referred to as 'non-science majors' are simply interested in different topics than science and mathematics and in different careers than scientists. She has claimed that many students are rejected from science studies due to the quantitative nature of the subject matter. We accept and support this view.

In her study amongst non-science oriented students, Mamlok (1997) has found that students claim that the main reason for not opting to study science is their interests in other subjects and the way science was presented to them in the past (See also Hofstein, Mamlok, and Carmeli, 1997). The study was conducted following the development and implementation of the module *"Science As an Ever-Developing Entity,"* which was one of the modules developed as a result of the 'Tomorrow '98" Report. As one student put it, *"I wish science would deal with more words and not with formulas that complicate it very much."*

Exemplary Modules of 'Science and Technology for All'

Some 20 modules were developed in seven curriculum development centers in Israel. Exemplary modules titles include 'Light and Color', 'The White Gold in Deep Soil', 'Biotechnology, Environment and Related Issues', 'Radioactivity', 'The Age of Plastic', 'Progress as a Tension between a Blessing and a Curse', 'The Black Gold' and 'Brain, Medicines and Drugs'.

Since it is beyond the scope of this paper to present all the modules that were developed, we choose to introduce two exemplary modules. The first, *Energy and the Human Being,* was developed at The Weizmann

Institute of Science and the second – *The Quality of Air around Us* – was developed at the Technion, Israel Institute of Technology.

The following guidelines were at the basis of the modules:

- The target population is 10^{th} and 11^{th} grade non-science majors (age 15+)
- Each module focuses on a scientific issue or topic with societal ramifications and personal implications.
- The modules are interdisciplinary in nature. They present various aspects or concepts derived from different scientific as an integral entity.

Energy and the Human Being

This mo(Ben-Zvi, 1999) presents an intuitive notion of the concept of 'Free Energy'. It introduces the idea that while energy can be one form to another, but each transformation is associated with loss due to heat that decreases the ability to perform useful work. Work is performed when a spontaneous process is coupled with a non-spontaneous process, thus causing it to happen. The amount of work we can get from a given system varies and is dependent on various factors, including our technical ability, but there are always upper limits to the amount of work we can extract from the system.

The teaching sequence starts with presentation of some ideas regarding the importance of energy in the lives of all of us. Examples include transportation, household and kitchen appliances, and food and dieting. The latter issue is of special interest and important for this age group.

In this context, students become acquainted with the law of energy conservation, which is used in the framework of eating and dieting.

The discussion continues with the links that exist between the welfare of a society and the energy it has at its disposal. Comparison is conducted between different societies at different stages of human history and between different nations regarding energy resources, consumption and conservation.

The implementation of this module was accompanied by assessment of students' achievements and perceptions regarding this module. Overall, we found that by using appropriate (non-mathematical) language and appropriate learning and instructional models, non-science majors were able to cope with complicated thermodynamics concepts and develop positive attitudes towards learning them (Ben-Zvi, 1999).

The Quality of Air around Us

In this study, science teachers developed a module titled *The Quality of Air around Us*, which incorporates cases studies that are presented through the Jigsaw cooperative learning method (Dori and Herscovitz, 1999). This module was developed as part of "Science, Technology and Environment in Modern Society" (STEMS) project (Tal, Dori, Keiny and Zoller, 2000). The objective of the study was to foster question posing capabilities through case-based teaching/learning method.

Questions at a high complexity level were generated as a result of student-student interaction and construction of new knowledge while being exposed to new learning situations through case studies.

The research problem was whether and how students' question posing capabilities, enhanced through the case study approach, can be used as an alternative evaluation method.

We examined the effect of the *Air Quality* project on students' question posing capability, whose three indices were the number, orientation, and complexity of questions a student posed before and after the treatment.

To determine the question complexity as systematically and as objectively as possible, we have developed and applied a quantitative method for calculating the complexity of each question and the student aggregate question complexity.

The results show that the *Air Quality* project has brought about a significant increase in students' question posing capability. The increased capability is significant at all three academic levels and is reflected in the aspects of total number of questions, orientation and complexity. Through the study of the *Air Quality* topic, students gained a more complex view of real-world problems. Bringing students to understand conflicts like those presented in the case studies may encourage them to critically read a daily or scientific article and question the quality of the given information. The improvement in question posing capability indicates an improvement in the students' verbal expressive power.

The significance of the improvement in question posing capability indicates that this capability can be effectively used as an alternative evaluation tool for assessing the extent to which students understand and analyze a topic and make a value judgment regarding a related case study. The contribution of this study is based on the fact that students, at all three academic levels significantly improved both their knowledge and their question posing capability.

Teachers' Conceptual Change for 'Science and Technology for All'

Teachers who were originally trained to teach certain scientific discipline have to break the boundaries and teach interdisciplinary topics. The interdisciplinary nature of the subject matter included in the STS type modules is very demanding. Teachers who are required to teach these modules need to develop high standards regarding their content knowledge as well as pedagogical content knowledge (Shulman, 1986).

Traditional professional development of science teachers both in the pre-service and in-service stages rarely touches upon the teaching of STS based courses.

Hofstein, Aikenhead and Riquarts (1988) identified the following problems concerning the implementation of STS-type programs:

- The interdisciplinary nature of the content and unfamiliarity of the teacher with a subject matter in which they were not originally trained;
- Unfamiliarity of teachers with required teaching strategies; and
- Inappropriate professional development techniques and procedures for pre- and in-service training.

Several projects attempted to overcome these obstacles by involving teachers in the process of curriculum development, as well as in the development of instructional techniques and its respective and relevant assessment methods. Development of learning and curricular materials by teachers is recognized nowadays as an important and effective method of professional development of teachers (Ben-Peretz, 1990). Sabar and Shafriri (1982), claimed that: *"Participation of teachers in curriculum development is likely to take the teacher from a conscious to one greater autonomy and internalization" (p.310).*

We describe two examples of workshops in which teacher were actively involved in the development and implementation of the learning material for this program. It was hypothesized that by involving teachers in the process of "bottom-up" as opposed to "top-down" curricular procedures one would reduce the level of anxiety that often exist amongst teachers who are expected to teach unfamiliar subject matter.

Teachers as curriculum developers of Science and Technology for All Programs

In this program (Hofstein, Mamlok and Carmeli, 1997), 22 science teachers who volunteered to participate in a three-year workshop aimed at the development and implementation of content and pedagogical interventions for science for all programs.

The teachers' scientific background was chemistry, biology agriculture, nutrition technology, and physics. The teachers were cooperatively involved in the development of learning materials and in the tailoring of the subject matter to students interests and abilities regarding the following topics: Radioactivity, Plastics, Food and Nutrition, Chemical and Biological extermination and Light and Color.

All these topics originate from important scientific discoveries they have important technological applications and are relevant to the students personally as well as to society. The teachers were involved in the development of pedagogical methods with the aim of varying classroom procedures and the improvement of classroom learning environment (Hofstein and Walberg, 1995).

In the second phase of the project, each teacher taught the module which he or she developed, while in the third phase, few teachers became regional tutors and leaders regarding further implementation of these modules.

Although this project was time consuming it was seen as an effective procedure for developing science teachers who are going to teach 'Science For All' STS type programs. More specifically, the teachers perceived that the experience in which they were involved was an effective method to express and utilize their teaching experiences and their profound acquaintance with the milieu, which most of the subject matter experts who develop learning materials do not have. Most of them praised the cooperative efforts and the effect that they were an integral part of a community.

The fact that every group was heterogeneous in respect to the teachers scientific background made teachers feel that they had a unique impact on the work done and that they learnt a lot from their peers' experience in other fields.

In a second workshop teachers were involved in the development of assessment tools for various type of learning and teaching modes. For the first time, teachers gradually developed matriculation examinations geared toward non-science majors (Dori, Tsaushu, and Tal, 2000). Until then, such examinations were developed exclusively for science majors.

The examinations consisted of student projects, critical reading of scientific articles, simulation games, cooperative assignments, and mini-research. It was extremely important for the teachers to match each of the pedagogical methods with adequate assessment tools.

The teachers who developed the examinations later implemented them in their respective schools. The research findings were used to refine and improve the non-science major matriculation examinations. Involving teachers in the process of development of assessment tools proved to be an effective strategy (Dori and Tal, 2000; Tal, Dori and Lazarowitz, 2000) to develop teachers' awareness to the pedagogical potential of the STS approach in general and to different modes of assessment in particular.

Summary

Achieving scientific literacy for all has become a national goal for education in many countries. Although admirable, the goal represents a challenge for science teachers and for those who are responsible for science curriculum development and implementation. There is no doubt that achieving this goal must be accompanied by the reform in the way science is taught in school as well as in its related content.

The interdisciplinary nature of the content necessitates the implementation of both intensive and comprehensive professional development activities. Thus far the literature is limited in regard to effective professional development models. Thus, we recommend that there should be an international effort to share and disseminate information regarding methods and strategies that have the potential in enhancing the professionalization of science teachers especially those who are going to teach students who are going to be the clients of "science for All" programs.

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