

Engineering and Excellence: An Old-New Agenda for Technology Education in Israeli High Schools

Moshe Barak

Ben-Gurion University of the Negev

Abstract

Israel is currently facing the era of socio-economic changes and educational reforms. Consequently, there is a serious demand to re-examine the objectives, methods and achievements in the educational system in general and technology education in particular. This paper addresses three educational perspectives essential to reinforce technology education in Israel. Firstly, educators need to find new ways to enroll competed pupils in technology education at high school. Secondly, technology education should address engineering as the main paradigm in high school studies. Thirdly, computer-based technological projects should become a major component in teaching education. Experts in the field expect that the emphasis on these educational approaches will strengthen the role of technology education in developing pupils intellectual competencies, such as analytical thinking, creative thinking, problem-solving abilities, independent learning and teamwork.

Introduction

In an era of socio-economic changes and educational reforms, as is currently prevailing in Israel, there is ongoing pressure on the educational system in general, and technology education in particular, to re-examine their objectives, methods and achievements. Educational professionals and decision-makers have raised questions regarding the aims of technology education, its contribution to preparing high school graduates for successful integration into today's complex and dynamic society, promoting excellence and reducing socio-economic gaps.

In Israel, as in several other countries, the roots of technology education of about 30 years ago have been in arts and crafts studies for young children, and vocational education for high school pupils. The most important change in teaching technology in primary and junior high schools took place in the mid 1990s, when an integrated program entitled "Science and Technology" for these schooling levels replaced the separate programs for science and technology previously in use. The current programs for primary and junior high schools represent a moderate version of the Science-Technology-Society (STS) approach (Yager, 1996) and comprise specific technological topics, such as design, systems and communications. Adopting the integrated curriculum for science and technology in primary and junior high schools has increased cooperation between experts in science education and technology education, encouraged combined projects for curriculum development, and fostered joint programs for teachers' pre-service and in-service training. Consequently, this reform in the curriculum has increased the community of scholars who are interested in questions such as: What is science? What is technology? What are the relationships between science and technology in the curriculum (Gardner, 1994)? Although the extensive efforts in developing new curricula and training teachers for the new program nationwide helped in breaking down walls between science teachers and technology teachers, the majority of teachers continue to stick to their areas of specialization. Consequently, the degree of teaching technological subjects in the combined curriculum in practice depends, largely on the background of the teachers in each school.

Technology studies in high schools are elective; they are taken by about 50% of the pupils having a wide range of scholastic achievements and from diverse socio-economic backgrounds. The Israeli high school system is unique in that the majority of pupils study in comprehensive high schools, and not in separate schools for general education or in vocational schools as was customary until the late 1960s. Under the title of technology education, very talented pupils study advanced engineering-related subjects such as electronics and computers; lesser achieving pupils learn subjects such as electricity, mechanics or architectural drafting. Crafts, like woodwork or metalwork, are found less and less in Israeli high schools. All of the pupils study general subjects, such as mathematics and languages, and take matriculation exams at different levels in the all the subjects they study, including those related to technology.

In light of the growing public and professional criticism regarding the achievements of Israeli education, the government established a national committee, called the National Task Force for the Advancement of Israel's Education (NTAIE, 2004), which examined the entire structure and achievements of K-12 education. This committee recommended a major reform in K-12 education that involved, for instance, eliminating junior high schools, reorganizing high school studies and matriculation exams, and modifying teacher training frameworks. Towards implementing this reform, now would be the right time to ask the following questions again: What are the objectives of teaching technology to high school pupils? How could technology education respond to the expectations and needs of pupils having a wide range of scholastic achievements? To what extent do technology studies impart the essential knowledge and skills to pupils to help them integrate into modern life? This paper aims to address these questions in light of the processes taking place in the Israeli educational system at the beginning of the 21st century.

Technology Education and Excellence

As technology education in Israel serves a very heterogeneous population, one of the most important missions faced by scholars in technology education is to attract high-achieving pupils to major in technology studies in high school, the final stage before entering a higher education framework. The class of pupils taking an elective subject

such as technology in high school determines the status of this subject in the eyes of the pupils, the parents, the educators and the decision-makers. Therefore, having a layer of very competent pupils studying technology in high school is critical for strengthening the discipline in the long run and for ensuring its status as a central component of K-12 education.

Since Israeli high schools are very demanding and most of the high-achieving pupils major in mathematics, and often in science, the question arises as to why a competent pupil would study technology education. To answer this question in part, let us briefly review the processes that have characterized electronics studies, one of the 'engines' of technology education in Israel, over the past two decades. In the early 1980s, one of the peak periods in the development of the electronics and computer industries, many talented pupils opted to study electronics in high school. Coming from industry, many teachers brought to schools a spirit of enthusiasm and inventiveness, working with their pupils on the design and construction of advanced technological systems, such as mini-robots and other types of electro-mechanical machines. Schools all over the country used to hold final-year ceremonies and exhibitions of pupil projects aimed primarily at younger children, candidates for registering in the same school, and their parents. In the early 1990s, the projects were eliminated almost entirely from the lab work and the matriculation exams due to a reform in the curriculum that placed more emphasis on theoretical studies and standardized lab experiments. Later, many talented pupils expressed disappointment in their electronics studies, and a decrease in the demand for electronics studies by competent pupils was observed (Barak, 2002). In the late 1990s, schools, with the support of the mainstay of education, reinstated the preparation of mini-projects in electronic studies during the 10th and 11th grades, and final projects as part of matriculation exams taken in the 12th grade. Consequently, the number of pupils preparing final projects in electronics nationwide increased from under 50 in 1999 to over 1,000 in 2004. This "back-to-projects" phenomenon gained rapid success since it had been initiated by the teachers rather than as the result of a top-down decision and had responded to needs from the field. This case demonstrates that competent pupils frequently study technology education because they hope to be involved in the design and construction of sophisticated systems and artifacts that trigger their imagination, fulfill their dreams and realize their ambitions. Project-based learning has gained increased attention not only in

electronics studies but also in other areas of science and technology education in Israel. Computer-based projects in technology are increasingly becoming a major tool for catching the attention of competent students to technology education, as will be described below in more detail.

Technology Education and Engineering

Underlining engineering as the main paradigm for technology education has numerous advantages for the future of technology education Israel, for several reasons.

Firstly, engineering is the natural learning environment for technology education at high school, since pupils expect that technology studies will take place in a sophisticated laboratory equipped with modern instrumentation. Educators recognize that the era of building simple technological models using pieces of cardboard, wood or plastic is behind us. Even the use of building block sets like Lego or Fisher-Technick, as is common in many technological labs, is significant for today's technology studies when these systems comprise electronic components, like motors and sensors, and are interfaced to computers. High school pupils use professional instrumentation for their technological projects as a means for the design, construction and testing of electronic circuits, software packages for the design and simulation of electro-mechanical systems and industrial programmable controllers (PLCs). Having engineering-based laboratories in school is important not only for facilitating pupils' work or enabling them to design more sophisticated systems. Through being involved in an authentic engineering world, a pupil is likely to become a member in a community of professionals, feel confident to request help from practitioners, and learn to use books, catalogs and on-line databases targeted at engineers and scientists. Many high schools in Israel share well-equipped technological labs with technical colleges located on the same campus.

Secondly, the alignment of technology education with engineering is natural for the training of technology teachers. One of the main aspects of the reform in the Israeli educational system expected shortly (NTAIE, 2004) is the requirement that every teacher completes a full academic degree (B.Sc. or B.A.) in his/her field of

specialization, such as mathematics, physics or electrical engineering. The B.Ed. degree, currently provided by academic colleges of education, will be eliminated. In addition to completing a bachelor's degree in engineering or science, a teacher will have to study an existing program towards an "Academic Teaching Certificate," which consists of courses in education, psychology and teaching methods. As there are neither faculties for technology nor a bachelor's degree in technology, it is obvious that in the upcoming years, the vast majority of new technology teachers will be engineering graduates.

Thirdly, pupils, parents and decision-makers understand the term engineering much better than the term technology (Liao, 2000; Hacker, 2000). Israeli society greatly appreciates engineering, which is often associated with an academic education and a higher socio-economic status. The high-tech industry is very central to the economy, and engineering faculties in universities are often highly esteemed and among the most difficult gain admission to. Although technology education is not aimed solely at preparing pupils for higher studies in engineering, many people hope that studying technology will develop pupils' learning and thinking skills in the areas of science and technology, and help them to decide more knowledgeably about their future.

What Kind of Engineering?

Although it is felt that the term technology is broader than the term engineering, it is useless to seek exact definitions for each of these terms or determine how they differ from one another. Definitions of these terms in dictionaries, encyclopedias or professional books frequently overlap each other. For example, according to *Encyclopedia Britannica* (2005):

- **Technology** is the "Application of knowledge to the practical aims of human life or to changing and manipulating the human environment. Technology includes the use of materials, tools, techniques, and sources of power to make life easier or more pleasant and work more productive."
- **Engineering** is the "Professional art of applying science to the optimum conversion of the resources of nature to the uses of humankind."

Many countries, for example the United States, Britain, Canada, Australia, New Zealand and Israel, comprise standards for technology education elements in their curriculum that relate directly to engineering, such as engineering design, energy and control, information and communications, system thinking, modeling and optimization. According to *Benchmarks for Science Literacy* (AAAS, 1993): “In its broadest sense, engineering consists of construing a problem and designing a solution for it. The basic method is to first devise a general approach and then work out the technical details of the construction of requisite objects or processes.”

In Israel, pupils study general technological concepts such as design and control in primary and junior high schools in the compulsory “Science and Technology” program mentioned above. The technology education curriculum in high schools is arranged traditionally according to specific engineering fields. For example, electronics studies for the 11th and 12th grades comprise subjects such as analog and digital electronics, energy conversion, control and communication systems. Recently, more updated subjects, such as cellular and satellite communications, computer networks and the analysis of sound and pictures, are being introduced into the high school curriculum. Engineering indicates not only the use of mathematics and science for the design of technological systems, as do engineers, but also the use of the ‘language’ and tools used by engineers such as formulas, drawings, simulation software or programming tools. Thus, engineering provides a learning environment that is likely to support, rather than undermine, the development of pupils into creative designers and proficient problem-solvers.

Excellence, Engineering and Advancing Low-Achieving Pupils

Emphasizing technology as an area for competent pupils and adopting engineering as the main paradigm for technology studies does not necessarily mean neglecting the low- to mid-achieving pupils. A number of studies in Israel (Barak, Yehiav and Mendelson, 1994; Barak and Doppelt, 1999) have shown that engineering-related technological studies might be a successful platform for raising pupils’ self-esteem and motivation to learn, as well as fostering their learning skills. Since many people confuse the terms technology education and vocational education, technology studies for low-achieving pupils are often understood as being vocational education.

Stevenson (2003) mentions several aspects frequently used in discussing the differences between technology education and vocational education: imparting general knowledge vs. specific knowledge, theoretical knowledge vs. practical/functional knowledge, conceptual understanding vs. proficiency in skills, creative abilities vs. reproductive abilities, intellectual skills vs. physical skills, preparation for life vs. preparation for work. Stevenson examines each of these dualities and shows that this type of differentiation between vocational education and technology education is questionable. For instance, the separation of theoretical and practical knowledge is at odds with the ways in which people learn; there seems to be little substantive basis for the cognitive separation of physical and intellectual skills, and it is increasingly problematic to impose a division between preparation for life and for work. Specifically, the low-achieving pupils might benefit from a rich, flexible and non-stigmatizing learning environment, which enables them to work individually or in teams on authentic projects, and in this way break out of the circle of failure and despair many of them experienced in conventional teaching frameworks. A recent study on the impact of projects in electricity and electronics on low- to mid-achieving pupils (Barak, 2004b) showed that pupils might gradually develop from being fully dependent on their teachers to becoming more autonomous learners and creative thinkers. Therefore, identifying technology with engineering and excellence is vital for providing an adequate education not only to high-achieving pupils, but also to pupils who start high school with relatively low achievements and motivation to learn or poor learning skills.

Departure from Traditional Teaching-Learning Technology Frameworks

One of the most significant changes characterizing technology education in Israel in the past two decades is the departure from traditional teaching-learning technology frameworks. As previously mentioned, an integrated program for the study of science and technology in primary and junior high schools was introduced in the mid-1990s. This reform reduced the borders between the two areas and increased cooperation between experts and teachers from both fields. One example of this cooperation is the hot-air balloons program, in which high-achieving pupils in junior high schools studied physics and technology through the design and construction of electronically-controlled hot-air balloons (Barak and Raz, 2000). Frank (2004) presented an example

of a pre-service training course for teachers aimed at establishing cooperation between science teachers and technology teachers around scientific-technological projects. Another example of strengthening links between the learning of science and technology is the “Physics and Industry” program that was initiated by physics teaching experts (Eylon, 2002). In this program, talented high school pupils work during one year on final projects supervised by scientists and engineers from advanced industries, and get credit for their projects as part of the matriculation exam in physics. According to Eylon, departing from the traditional frameworks of science and technology education, projects and joint high school-industry programs are likely to increase pupils’ interest in the world of science and technology, develop their learning competencies, and provide them with a more realistic perception of the work of scientists and technologists. A third example is the program entitled “Integrated Technology,” in which high school pupils study advanced courses in technology and science, and prepare a final project under the supervision of experts from academia or industry. These pupils get credit for their projects as part of the matriculation exam in technology.

A different aspect of the changes in learning technology in Israel has been the increasing participation of Israeli high school pupils in national and international contests for the design of sophisticated scientific-technological artifacts. For example, Israeli pupils are frequent participants in the Annual Trinity College Fire-Fighting Home Robot Contest (TCFFHRC, 2005). The goal of this contest is “to encourage inventors of all ages and levels of skill to develop an autonomous fire-fighting home robot that can find, and put out as quickly as possible, a fire in a model house.” Since 1998, pupils from all over Israel have participated in the annual national contest, which precedes the international competition. The fact that Israeli pupils have frequently won top prizes in the international competition has attracted the attention of a variety of schools and fostered technological activities by pupils and educators who had previously not been involved in technology education (Verner and Hershko, 2003).

The Role of Computers and Information Technologies in Technology Education

One of the most significant changes that took place in technology education in Israel during the past two decades was the wide-spread use of computers and the Internet. In recent years, most technological laboratories have been equipped with computers connected permanently to the Internet. Accordingly, technology teachers and pupils have almost unlimited access to these means, and are often the most extensive users of computer technologies in their schools.

The educational literature has pinpointed many expectations regarding the contribution of computer technologies towards enhancing learning. For instance, Salomon (1998) mentioned four aspects of how intelligent technologies contribute to improved learning:

- Computers and communication systems are not only knowledge-transfer technologies but also knowledge-building technologies.
- Computer technologies are not knowledge-receiving technologies, but rather they facilitate the intellectual partnership between the learner and the sophisticated and intelligent tools (Pea, 1993).
- Computer technologies are not restricted to the individual learner, but rather they present opportunities for shared thinking and knowledge construction.
- Novel computer technologies do not constitute tools for structured teaching, but rather encourage open learning, and challenge the learner with enormous knowledge resources when confronting challenging problems.

In technology education, computers are not just a means for data collection, analysis or presentation, but often an integral part of the technological systems pupils design and build. Thus, integrating computers into technology education is likely to create a constructivist learning environment that promotes meaningful learning through knowledge construction, conversation, articulation, collaboration, authentication and reflection (Jonassen et al., 2000).

The most meaningful impact of computer technologies on learning technology has been in project work. Recently, the majority of projects pupils design and build

comprise computerized control systems. For their projects, pupils use a variety of professional interfacing cards and means of data measurements, A/D conversion and power amplification. Barak (2004a) found that pupils working on computer-based projects tend to adopt flexible strategies, such as creating new ideas, risk-taking, improvisation, using trial-and-error methods for problem-solving, and rapid transition from one design to another. In contrast, pupils working on non-computerized projects are more likely to progress along a linear path: planning, constructing and troubleshooting. Moreover, pupils working on computer-based projects tend to cooperate and exchange ideas with their friends more than pupils working on hardware-based projects mainly because the development of software is more flexible and challenging. Actually, the broad use of computers in project work has put into practice the model suggested by Johnson (2002) aimed at creating “a powerful learning environment” by: (1) addressing individual differences, (2) motivating the pupil, (3) avoiding information overload, (4) creating a real-life context, (5) encouraging social interaction, (6) providing hands-on activities and (7) encouraging pupil reflection.

Yet, the mere use of computers in school does not ensure better learning. For instance, although Israeli pupils and teachers use computers and the Internet extensively, computerized means have not caused significant changes in the way theoretical topics are learned. Teachers and pupils still prefer conventional frontal lessons for learning theoretical topics, especially in the first stages of teaching new concepts (Barak, 2004b). At times, the use of simulation becomes a substitute for practical lab experiments, and the use of the Internet has become a cover-up for superficial learning.

Concluding Remarks

Resnick (2002) mentioned that there was much talk in the 1980s about the transition from an “industrial society” to an “information society.” In the 1990s, people started talking about a “knowledge society.” They began to realize that the key is not in the information itself but in how it is transformed into knowledge and how this knowledge is managed. For today, Resnick suggests the concept “creative society,”

since success in the future will be based not on how much we know but on our ability to think and act creatively.

It is widely accepted that one of the major goals of technology education is to develop pupils' intellectual competencies such as analytical thinking, creativity, problem-solving abilities and teamwork. This objective is not just rhetoric or a matter of educators' intentions, but rather the main desire of the pupils themselves. To achieve this goal, the following guidelines are suggested for technology education in the coming years:

- Involve pupils in the design and construction of advanced technological systems, emphasizing state-of-the-art technologies such as communications, robotics and biotechnology.
- Link technology studies to the advanced industries, academia and the community.
- Encourage teamwork of pupils, teachers and experts both inside and outside the schools.
- Strengthen ties between the study of technology, computers and the natural sciences.

An important challenge for scholars in technology education is to intensify the research of the influence of technology studies on developing pupils' intellectual competences, such as independent learning, teamwork and creative thinking.

References

- American Association for the Advancement of Science: (1993). *Benchmarks for Science Literacy*, Science for All, American online, Chapter 3: The nature of technology. URL: <http://www.project2061.org/tools/sfaol/chap3.htm>.
- Annual Trinity College Fire-Fighting Home Robot Contest (TCFFHRC) (2005). URL: <http://www.trincoll.edu/events/robot/welcome.asp>.
- Barak, M. (2002). Learning good electronics, or coping with challenging tasks? Priorities of excellent students, *Journal of Technology Education* 14(2), 20-34.
- Barak, M. (2004a). From order to disorder: The role of computer-based electronics projects in fostering higher-order cognitive skills. *Computers & Education* (in press).
- Barak, M. (2004b). Issues involved in attempting to develop independent learning in pupils working on technological projects. *Research in Science and Technological Education* 22(2), 171-183.
- Barak, M & Doppelt, Y. (1999). Integrating the Cognitive Research Trust (CoRT) program for creative thinking into a project-based technology curriculum. *Research in Science and Technological Education* 17(2), 139-151.
- Barak, M. & Raz, E. (2000). Hot-air balloons: project-centered study as a bridge between science and technology education. *Science Education* 84 (1), 27-42.
- Barak, M., Yehiav, R. & Mendelson, N. (1994). Advancement of low achievers within technology studies at high school. *Research in Science and Technological Education* 12(2), 175-186.
- Encyclopedia Britannica online (2005). UTL: <http://www.britannica.com/>
- Eylon, B. S. (2002). Breaking the learning frameworks in teaching science and technology, the potential and problems. *Workshop for encouraging science and technology education, the National Israeli Academy for Science*, Jerusalem, 14-15 (in Hebrew).
- Frank, M. (2004). Project-based technology in the science and technology curriculum: a teaching approach for developing technological literacy. *Paper presented at the National Association for Research in Science Teaching (NARST) Conference*, Vancouver BC, April, 1-4.
- Gardner, P. (1994). Representations of the relationship between science and technology in the curriculum. *Studies in Science Education* 24, 29-47.

- Hacker, M. (2000). The politics of technology education. *International Conference on Technology Education*, WOCATE & UNSECO, Braunschweig, Germany, September 25-27.
- Johnson, S. D. (2002). A model for enhancing thinking through technology education, In: G. Graube, M. J. Dyrenfurth and W. E. Theuerkauf (eds.), *Technology Education, International Concepts and Perspectives*. New York: Peter Lang Press, 51-62
- Jonassen, D., Peck, K. & Wilson, B. (2000). *Learning with Technology: A Constructivist Approach*. Upper Saddle River, NJ: Prentice Hall.
- Liao, T. L. (2000). Engineering-based paradigm for K-12 technology education, *International Conference on Technology Education*, WOCATE & UNSECO, Braunschweig, Germany, September 25-27.
- National Task Force for the Advancement of Israel's Education (NTAIE) (2004). Jerusalem: Ministry of Education and Culture.
- Pea, R. D. (1993). Practices of distributed intelligence and designs for education. In: G. Salomon (ed.), *Distributed cognition*, NY: Cambridge University Press, 47-48.
- Resnick, M (2002). Rethinking Learning in the Digital Age, In: G. Kirkman, *The Global Information Technology Report: Readiness for the Networked World*, Oxford University Press, 32-37.
- Salomon, G. (1998). Novel constructivist learning environments and novel technologies: Some issues to be considered. *Research Dialog in Learning and Instruction* 1(1) 3-12.
- Stevenson, J. C. (2003). Examining Cognitive Bases for Differentiating Technology Education and Vocational Education, In: G. Martin and H. Middleton (eds.), *Initiatives in technology education: comparative, proceedings of the American-Australian technology education forum*. Brisbane: Centre for Technology, Education Research, 194-206.
- Verner, I. & Hershko, E. (2003). School graduation project in robot design: a case study of team learning experiences and outcomes, *Journal of Technology Education* 14(3), 40-55.
- Yager, R. E. (ed.) (1996). *Science/Technology/Society as Reform in Science Education*, Albany, NY: State University of New York Press.