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OVERVIEW OF THE STEM EDUCATION IN ISRAEL

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Abstract. In this study, we provide an overview of the STEM education in Israel, the formal and the informal, the strengths and challenges, the problems, and the national plans to solve them. STEM education in Israel is an interesting phenomenon, as the State of Israel is considered a start-up nation, even though students have scored mediocre on the PISA tests over the years compared to the OECD average. The paper is based on literature review of position papers written for decision makers in the Israeli education system and for the purpose of comparison with other advanced education systems in the world.

Keywords: STEM; Israel; national programs

Introduction

STEM education in Israel is a unique phenomenon that interests many researchers. On the one hand, the State of Israel is the "Start-Up Nation", the number of start-up companies in relation to the number of residents is the highest in the world, only second to the Silicon-Valley in California USA, and on the other hand, the performance of students in the PISA tests is not in the top group, but only in the third group.

This paradox has attracted the attention of researchers and the education system. In this review, we will focus on the characteristics of STEM education in Israel, the challenges and the activities undertaken in recent years to promote it.

STEM subjects, mathematics, science and technology, are defined as core subjects in the educational system. About 10 years ago, a decline in the teaching of these subjects was noted, and as a result, several national programs were launched to strengthen these studies. Most of these programs have achieved their goals, especially in science and math subjects, but there are still gaps in several areas, especially technology and the number of teachers in the system.

Culture

Historical background

The State of Israel was founded in 1948, but two important academic institutions were established as early as 1924/5, the Technion (Israel Institute of Technology) in Haifa and the Hebrew University in Jerusalem. These institutions offered degree programs in a variety of STEM fields and are still considered the leading academic institutions in Israel and are also on the lists of the best universities in the world.

Society position

The Israeli public, institutions and the business community express great confidence in Israeli science, technology, and innovation, and thus in STEM education and its impact on the labor market. The high-tech boom and the resulting economic prosperity have given a boost to this process, and the STEM professions are now considered highly desirable occupations[1].

Israeli parents cite the professions of engineer, doctor, and scientist as the 3 professions they want for their children.

In order to make the world of STEM accessible to the entire population and not just the superstars, numerous science museums have been established in Israel, many curricula and experimental teaching strategies have been written in the field of STEM[1].

However, despite all these investments in the development of STEM skills, the subjects of mathematics and science in schools are still perceived by students as difficult and uninteresting, and there are even significant gender differences in these subjects[2].

Even though, approximately 17% of Israel's population is Ultra-Orthodox religious, who do not participate in the state education system or the workforce, and therefore are not represented in STEM education[3].

The STEM education "pipeline" in Israel

STEM track includes military service, which is mandatory in the State of Israel. All the citizens of State of Israel at the age of 18 are obliged to complete two years (girls) or three years (boys) of military service or national service. These years delay the start of post-secondary education, but foster skills and a work culture that led to innovation and entrepreneurship[3]. Figure 1 illustrate the Israeli STEM pipeline vs the typical one.

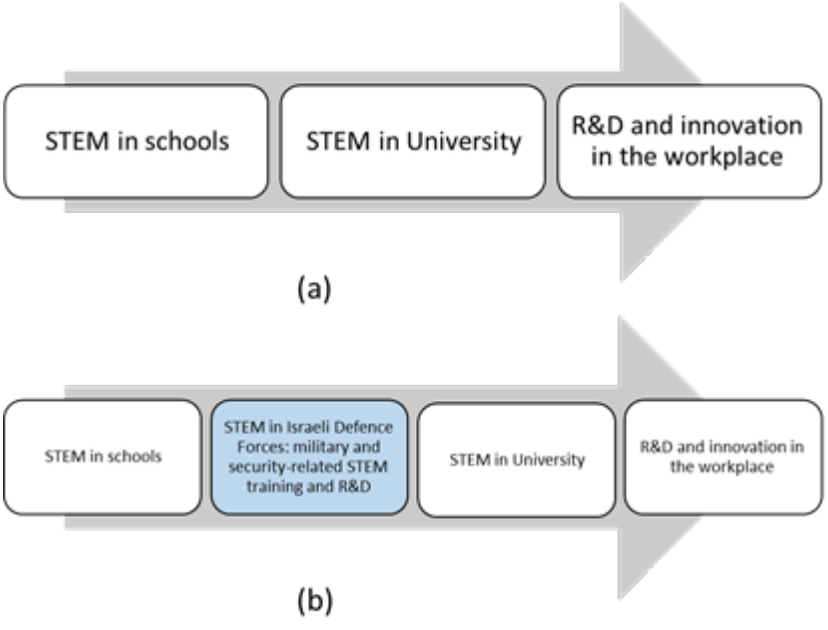


Figure 1. Israeli STEM pipeline (b) Vs. typical one (a)

Education system (Landman 2017)

a) Kindergarten (to Age 6)

The main objectives of most activities at national level start in kindergarten and aim to introduce children to science and technology, to familiarize them with scientific methods and the environment, and to instill in them the desire to experiment, explore and learn.

Recognizing that STEM must begin in education, the Ministry of Education is developing a national curriculum to create, as much as possible, a continuum between the science and technology programs in kindergarten and those in elementary school. The programs are based on the pedagogical principles of learning by doing and problem-based learning.

The curriculum focuses on two main areas and their fusion: knowledge and research processes and knowledge and technological design.

b) Elementary Schools (Grades 1st – 6th, Ages 6 – 12)

Mathematics, science and technology are defined as core subjects by the Israeli Ministry of Education (together with Hebrew and English). During the elementary school years, students learn a variety of general sciences.

The main goal and focus of elementary school is to give students the opportunity to gain experience. The science and technology curriculum, STEM, emphasizes direct experimentation as a key learning strategy for building knowledge, understanding and skills. These experiences reinforce learning through scientific inquiry and problem solving and form the basis for the whole process of scientific inquiry and problem solving that they engage with in Year 6. These experiments have a positive impact on students' attitudes towards science and technology.

c) STEM in High School (Grades 7th – 12th, Ages 13 – 18)

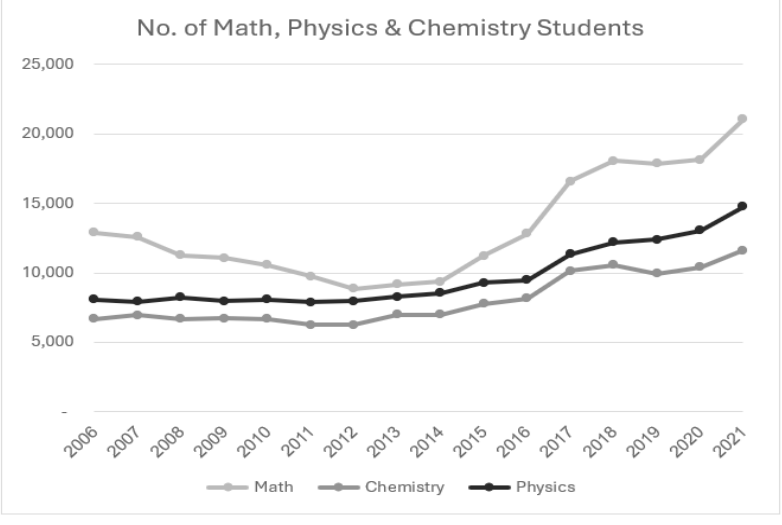
In secondary schools, students are offered a variety of study clusters: (1) the science cluster, which includes physics, biology, and chemistry; (2) the technology cluster, which includes computer science, information technology, electrical engineering, mechanical engineering, computer-aided manufacturing systems, and energy; (3) the math cluster, which includes a variety of traditional math subjects such as algebra, geometry, trigonometry, calculus and more.

All of these subjects can be taken in high school in the foundation stage (3 units) or in the advanced stage (5 units), while mathematics is also offered in the intermediate stage (4 units). Eligibility for the school-leaving certificate is based on learning and examination achievements totaling at least 21 units, and of all these subjects, only general science and mathematics are compulsory subjects for the matriculation examination and only at a minimum level, all other subjects are electives. The main instruction in science and technical subjects takes place in grades 10th – 12th (15 – 18 years).

Due to the great shortage of teachers in STEM subjects, there are many schools that do not offer all STEM subjects to their students, but only some of them. Since the State of Israel attaches more importance and prestige to academic-theoretical studies than practical-technical studies, most schools offer the science subjects physics, biology and computer science, while only a minority of schools offer the other subjects.

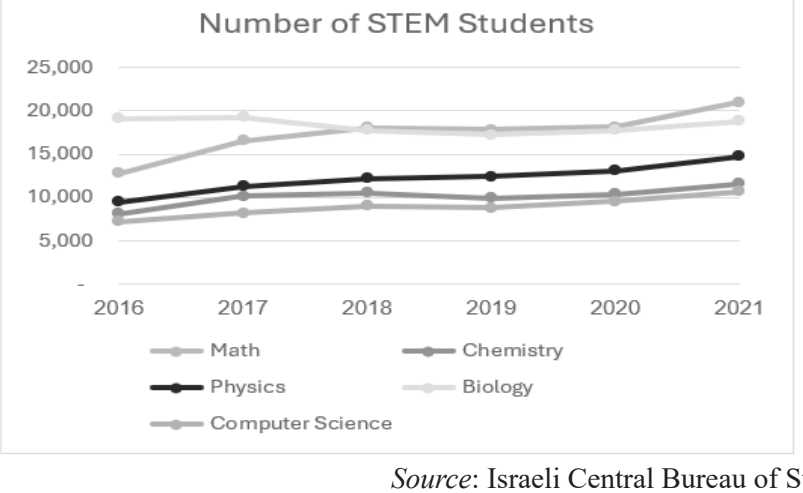
An alarming phenomenon was observed in the period 2006 – 2012. The number of high school graduates studying mathematics at an advanced level declined steadily. In physics, the numbers remained more or less stable, and it also became clear that only a third of high schools offered advanced level physics studies and only half of the schools offered chemistry studies.

In light of this data, an educational coalition consisting of the Ministry of Education, the Israeli Ministry of Science, philanthropic institutions and others was formed to initiate comprehensive educational programs to address this alarming data. The "5x2" math support program was a great success, and the number of students learning math at the 5-unit level doubled within 5 years (Fig. 2, Fig. 3, Fig. 4).



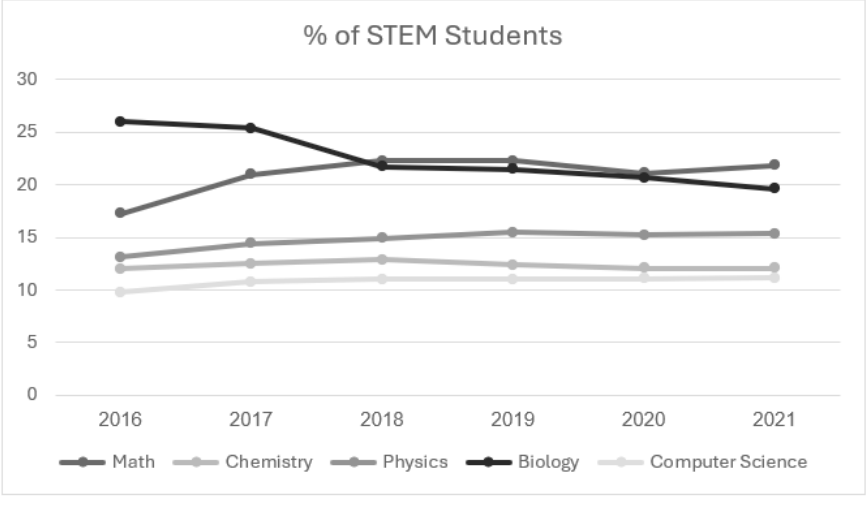
Source: Israeli Central Bureau of Statistic[4]

Figure 2. Number of math, physics & chemistry students 2006 – 2021



Source: Israeli Central Bureau of Statistic[4]

Figure 3. Number of STEM students 2016 – 2021



Source: Israeli Central Bureau of Statistic[4]

Figure 4. Percentage of STEM students 2016 – 2021

d) High School Technical Education (Grades 13th – 14th, Ages 19 – 20)

After completing the 12-year school, students can complete vocational training as technicians and engineers in years 13 – 14. This study takes place at technical colleges, together with all technical engineering students (non-academics). These students make up about 20% of all students in these disciplines. The main fields of study are mechanical engineering, automotive engineering, electrical and electronic engineering, and others.

This course of study is coordinated with the military authorities and its graduates are integrated into military service in technical formations. As part of their military service, students gain very important practical experience.

The technical course of study, which also includes vocational training, technicians and engineers, has declined sharply in recent years. Only around 3% of high school graduates choose this path. This course is only open to students who have completed the technical course in high school.

e) Non-Formal Education

During secondary school, there are a significant and growing number of informal activities to support STEM education. These activities are conducted by a variety of nongovernmental organizations such as science museums, philanthropic associations, community centers, and others.

Competitions, science fairs, national teams, etc. provide a high level of exposure and motivation to hundreds of thousands of students from kindergarten through the

end of high school. During the elementary school years, these competitions have become a powerful tool to increase curiosity and enthusiasm for the study of STEM subjects. These activities take place in conjunction with the formal education system, such as the FIRST competition (robotics), the Cyber Olympics, summer camps in national priority areas and in the geographical and social periphery.

f) The Military service

The army plays a central and dual role in scientific, technical, and technological education in the State of Israel. On the one hand, it is the recipient of the graduates of these programs, and on the other hand, it also educates and trains them as part of their military service.

One path promoted by the military authorities is the deferment of military service for the purpose of academic studies in the fields of science and technology and the completion of a bachelor's degree before enlistment. Under this pathway, 800 – 900 college students study academic subjects in the field of science and engineering before their military service. The graduates of this pathway are integrated into military service in the army's research and development departments.

In recent years, the Army has launched an initiative to increase the number of students opting for this path, which is the main engine for the growth of military technological innovation, given the significant increase in the scientific and technological needs of the Army's research and military units. To this end, Army agencies, in coordination with the Department of Education, are reaching out directly to high school students, promoting, and supporting the study of math and science in high school, sponsoring and supporting entire classes and low-performing students, with a focus on underserved populations such as girls and marginalized groups, and the results are visible on the ground.

The strategy pursued by the army often bridges high school, higher education and high-tech businesses to increase and strengthen the workforce needed to continue the high-tech engine of Israel's economy.

A large proportion of Israeli start-up companies were founded by graduates of military service in the elite technical units.

Mathematics and science literacy and PISA

Although the State of Israel is a scientific and technological country and a start-up nation, student performance on the PISA test is not among the best in the world (Fig. 5, Fig. 6).

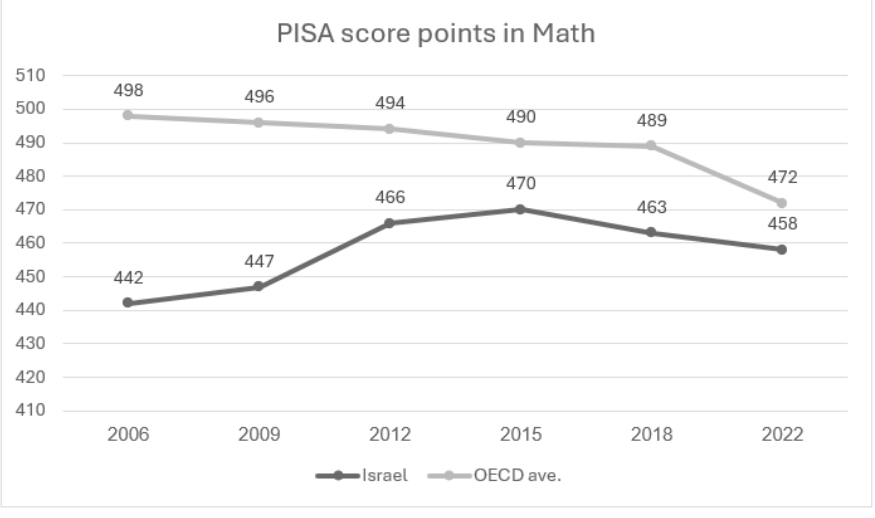


Figure 5. Math PISA scores (PISA[5])

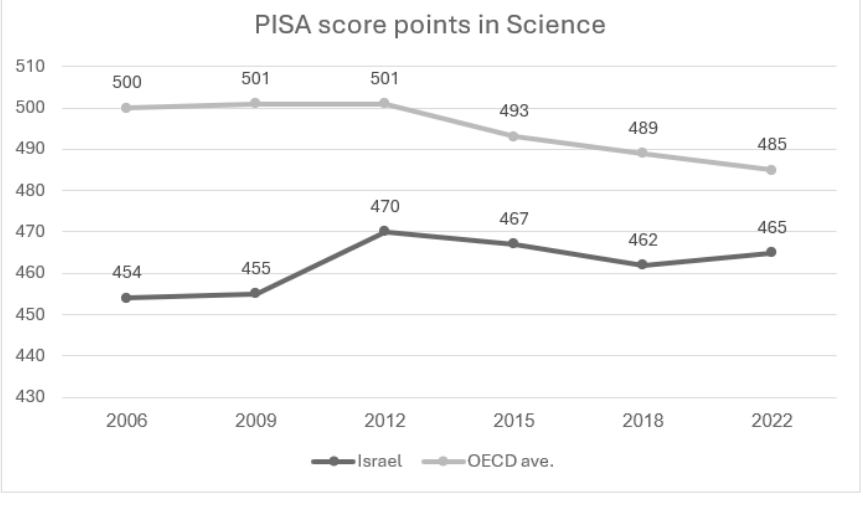


Figure 6. Science PISA scores (PISA[5])

The reason for these results is probably that much emphasis is placed in the school curriculum on mathematical and scientific knowledge, and less on the skills and abilities needed to apply the knowledge to realistic problems, such as

interdisciplinary integration[6].

In recent years, curricula and pedagogy have been changed to emphasize these skills, mathematical and scientific literacy, and the ability to apply them across disciplines, even if at the expense of disciplinary knowledge.

National education programs to promote STEM

a) Mathematics and science in secondary education (Landman 2017)

In 2010, the Ministry of Education established a strategic plan to strengthen science and technology education in middle school. The program is aimed at students seeking a high-level certificate in science and technology and includes subjects at the 5-unit level in mathematics, in a science discipline (biology, physics or chemistry) and in another science or technology discipline. The program is based on the premise that excellence depends primarily on motivation, perseverance, and investment. As part of the program, 148 middle schools each received two additional hours per week in math, physics, and computer science in grades 7^{th} – 8^{th} – 9^{th}, while high schools received additional hours primarily in math, physics, and technology. These additional hours will be used to divide classes, provide one-on-one instruction, increase enrollment, and reduce dropout rates. The schools also received a basket of resources for equipping robotics and computer labs, teacher training courses and much more.

In 2015, a national program to promote excellence in mathematics, the "Five by 2" program, was launched with the aim of doubling the number of students learning mathematics at a high level in secondary school within five years. The program includes recruiting math teachers from the high-tech ranks, supporting the opening of new classes in schools where there were no high-level math classes, creating smaller classes, and supporting virtual classes for students in schools where there were no 5-unit level classes[7].

The efforts, the formal programs, and the informal programs to promote math education have been successful, and the program has achieved its goals and even more. The number of students has doubled (as shown in figure 2), with a focus on the periphery.

b) Technological education

In 2014, the Ministry of Education launched a program to increase the number of students in technological tracks until 2024. Under the project, students from 9th to 12th grade (ages 14 to 18) will complete an education that combines a high school diploma with certification as a technician. These students can complete an additional year of study to qualify as a senior technician, with the option to continue their studies. The program is supported by an increased budget, additional instructional hours for existing classes, and the division of large classes[7].

c) Literacy and interdisciplinarity in junior high school

In recent years, officials in the State of Israel have begun to notice the paradox

between the high level of education and student performance on the maturity exams and the relatively low performance of Israeli students on the international PISA exams. The analysis of the results revealed that in the educational system of the State of Israel, in the fields of mathematics and science, great emphasis is placed on teaching the students the disciplinary knowledge, but less emphasis is placed on interdisciplinary integration skills and the application of knowledge to realistic problems solving. As a result, students have difficulty on the PISA tests, which test students' ability to apply knowledge in an interdisciplinary manner to realistic situations.

This also results in many students not understanding the importance of learning these subjects at a high level and therefore avoiding these studies given the high investment required.

In recent years, starting in 2020, several philanthropic organizations and companies have made it their mission to promote the subject of mathematical and technological literacy in an informal way. Most of these programs are conducted in collaboration and coordination with the formal education system. Examples include Space Week, satellite workshops, robotics competitions, biotechnology research projects, and the National Projects and Problem-Solving Fair.

The lack of good teachers in middle and high school

There is a serious problem of teacher shortage in the State of Israel for STEM subjects in middle schools and high schools[1]. Despite the increase in the number of students, the number of teachers has almost not increased accordingly. All teachers are required to have academic qualifications, but in practice some of the teachers at technical schools lack pedagogical skills, and teachers at secondary science schools lack experience in the field.

The demand for graduates of the subjects STEM in the private market reduces the possibility of hiring teachers for these subjects.

To address these challenges, the Ministry of Education, in collaboration with foundations and nongovernmental organizations, is training science teachers in a variety of degree programs and is also working to retrain high-tech professionals to teach math and science. A solution is still being struggled for the problem of technology teachers.

Other programs include training engineers from the industrial sector and retired military engineers to teach math and science as a second profession. The Technion also operates a program that combines teacher training in science, mathematics and engineering with the study of these subjects.

The programs are supported by funding for retraining studies, loans, and stipends for teachers to continue for at least 3 years after retraining.

Untapped populations

There are 3 populations in the State of Israel whose STEM education is low and which some see as untapped opportunities[3].

a) Female population

STEM subjects are considered male subjects and subjects in which it is difficult to manage a household at the same time. As a result, many girls avoid these subjects in high school and, as a result, in academia. In recent years, many formal and informal programs have been implemented to encourage girls to study STEM subjects in high school and college.

b) Geographic and social periphery

Populations in the social periphery have less access to quality education. The lack of teachers makes it more difficult to open classes in the periphery and thus more difficult for students to learn about and study these subjects. To address this challenge, the official education system and philanthropic organizations are providing many resources to these populations, opening virtual classrooms, etc.

c) The ultra-orthodox population

In the State of Israel, a significant part of that population does not participate in the state education system and in the workforce, and therefore does not participate in STEM education. In recent years, the state has engaged in a dialog with the leaders of this sector in order to integrate them, so far with only partial success.

Conclusions and summary

The State of Israel defines the STEM subjects, mathematics, natural sciences and technology, as core subjects of the education system. About 10 years ago, a decline in the teaching of these subjects was noted, whereupon several national programs were launched to strengthen these subjects. Most of these programs have achieved their goals, especially in science and math subjects, but there are still gaps in a number of areas, especially in technology and in the number of teachers in the system.

This can be an example of how the education system is analyzed, the key problems identified and dealt with at national level until completion.

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