

# From Early Learning to Workforce

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## The STEM pipeline in Israel

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Submitted by



BEYACHAD  
Stella and Yoel Carasso  
Family Foundation







We hope that the report combined with the hard work of a mosaic of funders, the government, and providers will provide significant resources and inspire deep conversations, ultimately resulting in ensuring even greater impact on STEM in Israel.

The Samueli Foundation is a leading philanthropic partner in developing large-scale Science, Technology, Engineering and Mathematics (STEM) initiatives involving education, workforce development, and professional development across systems with diverse stakeholders. In the past year, we have worked together with communities across the United States to help drive conversations that are reshaping the vision of STEM. Discussion and planning that include students, teachers, parents, government, funders, and business and focus on how to cultivate cross-platform, collaborative systems beginning from early learning up thru workforce.

Much of this work relies on understanding the STEM landscape in the communities - mapping assets, identifying strengths, opportunities, and gaps. That is why we are excited to work with Beyachad: Stella and Yoel Carasso Family Foundation in partnership with The Rashi Foundation, Jewish Funders Network and Sheatufim to support an environmental scan of STEM assets in Israel.

The report and its findings are critical to understanding the STEM landscape – successes, opportunities, strategies and challenges in building out the STEM pipeline in Israel. We hope that the report combined with the hard work of a mosaic of funders, the government, and providers will provide significant resources and inspire deep conversations, ultimately resulting in ensuring even greater impact on STEM in Israel.

We are grateful to Hubert Leven, Chairman of Rashi, the team at Sheatufim led by Shlomo Dushi and Debra London, Atar Razy Oren from Beyachad: Stella and Yoel Carraso Family Foundation, our philanthropic advisor Shalom C. Elcott, and the entire professional team at Jewish Funders Network for their efforts to conceive, guide and produce this mapping and conversations.

Sincerely,







We hope that the STEM mapping will provide new knowledge, set new targets for action, and facilitate relevant steps that need to be taken. We all stand to benefit from a renewed perspective on what already exists and from forging new partnerships.

Yoel and Stella Family Foundation is a young Israeli family foundation affiliated with a company engaged in the automotive and real estate industries. We experience the changes that technology has brought and can identify the transformations that the job market is going through before our very eyes.

We therefore chose to focus our philanthropic efforts on technology education and vocational training for young adults. We would like to increase the appeal of Practic-Tech professions, resulting in a greater demand by young adults for quality and sustainable employment in those fields. Such a career horizon will offer them social and economic mobility and will strengthen Israel's industrial sector and the economy as a whole.

Our decision to join the Samueli Foundation in the mapping reflects our belief that a broad-based approach to the issue is lacking. One that crosses government ministries, professional associations, employers and institutions of academic and technological education. We require a frame of reference that sees the entire spectrum of the Israeli vocational track – starting from the child in kindergarten until he or she integrates in a workplace. That frame of reference can examine what is needed to motivate young adults to enter the job market in an engineering or technology-related profession, or one that is associated with the sciences in general. Additionally, young adults, men and women alike, need to see the opportunity inherent in those professions, including what the industry, commerce and services sectors offer them.

We hope that the STEM mapping will provide new knowledge, set new targets for action, and facilitate relevant steps that need to be taken. We all stand to benefit from a renewed perspective on what already exists and from forging new partnerships. Our deep appreciation to the Samueli foundation which started this initiative, and the partners that gave their unique contribution so we could join forces now: The Rashi Foundation, Sheatufim, the Jewish Funders Network and Broadcom Company.

We look forward to cooperating with you together.



BEYACHAD  
Stella and Yoel Carasso  
Family Foundation

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Executive Summary January 2017

# General Overview and Rationale

According to the World Economic Forum, the world is living its Fourth industrial revolution, which is the combination of cyber-physical systems, Big Data, the Internet of Things, and the Internet of Systems. Alongside great benefits, concerns emerge such as the fact that many jobs and disciplines will disappear and automation, computers and machines will replace workers across many industries, and the gaps between the skills learned and the skills needed is growing. Excellence and literacy in STEM (Science, Technology, Engineering and Math) are considered essential tools for students to measure up to the challenges of the 21st century.

This exponential change will require skills that weren't given enough weight, if any, in teaching programs at all levels, whether at school, university or work: excellence, innovation, creativity, entrepreneurship, world experience, critical thinking, etc. In recent years key stakeholders and experts in Israel have been warning about growing shortages:

- In skilled students in the education system, as well as in the higher education system that develops STEM tracks;
- In a skilled workforce capable of fulfilling technology-based positions in the military and in industry in the next 10 years; and
- The limited scientific literacy among the general public.

STEM education has thus recently become the focus of an intensive public discussion and debate that can be gauged from increasing government attention and cross-sector initiatives.

An inter-ministerial committee headed by Israel National Economic Council outlined unequivocally the direct link between science and technology literacy at a young age, quality of high school diplomas, the number of students studying relevant fields in higher education, and the flow of a skilled workforce in knowledge-intensive industries, as well as minimizing the socio-economic gaps.

Outstanding university graduates with degrees in computer science and technology, with work experience, are clearly in great demand. In parallel, the private sector, the Association of Manufacturers, the IDF and other stakeholders point to a similar gap that exists in the practice-tech industry, from the training of technicians and practical engineers to their employment: the demand for skilled technicians and practical engineers. In the past 20 years the technological education system was significantly cut back and stigmatized, and none withstanding some exceptional schools, made technological education a last-choice for students.

The gaps between the edge that Israel has had and its ability to meet current needs has to be bridged. Accordingly, the pipeline from kindergarten to career is surveyed in the context of the drivers of STEM education, considering students and teachers, and then employers.

## Aims of Report

This report aims to provide an overview of the current status of the STEM eco-system and pipeline in Israel by mapping the main stakeholders and activities, as well each phase of the continuum:

- Kindergarten and elementary school
- Junior high- and high school
- Postsecondary training
- Army
- Higher education
- Workforce and employment

It seeks to examine the warnings of a diminishing scientific and technological reserve force in Israel, claims about the lack of skilled workforce and the generally inferior level of STEM literacy in Israeli society. Moreover, this overview is intended to provide insights into trends and challenges and identify the gaps and opportunities for change.

## The Main Players on the STEM Continuum



*\*The report was written before the responsibility for technological education was transferred from the Ministry of Economy and Industry to the Ministry of Social Affairs and Social Service*

# Insights, Gaps and Opportunities Along the STEM Pipeline

## Kindergarten and Elementary Education

**Current gaps:** In the formal sphere, the goal of the Ministry of Education is to develop scientific and technological literacy among children, mainly through curricula, to encourage a positive attitude to the field, and to emphasize practical experience. The Ministry of Education has changed curricula in a manner reflecting their recognition of the need to start STEM education at an early age.

In the informal educational sphere, there are diverse activities in cooperation with the technological educational networks, NGOs, science museums, the Youth Science Units in the universities and academic colleges, such as science competitions and Olympics. However, by in large, informal educational organizations, industry and philanthropists, have yet to become engaged in this arena. Most of the attention remains focused on junior high school, and even more on high school, where results are already evident.

**Opportunity for change:** The relevant entities, from all sectors, should be made aware of the real need and potential that can begin to be tapped from kindergarten as a catalyst for long term improvement in the results at the end of the pipeline.

## Secondary School

**Current gaps:** Over the past decade, there has been a decline in the number of secondary school students achieving the highest levels of matriculation in mathematics, physics and chemistry, which are the base of all technological and technical studies. There has also been a decline in the number of students studying in the technological tracks and schools. Accordingly, the Ministry of Education's current focus is on increasing the number of students taking high-quality matriculation examinations in these subjects, with emphasis on math. The point of departure of the Ministry of Education is that excellence is influenced mainly by motivation, perseverance, and hard work.

There is also a highly-developed informal ecosystem involving philanthropy, NGOs, and organizations that cooperate in order improve science and technology literacy and excellence.

**Opportunity for change:** Despite some national-level efforts, technological education at that stage hasn't received a parallel focus or budget. And while it depends on training and on close cooperation with the world of employment and with academia, in practice, only a low proportion of students receive industry training.

## Quality Skilled STEM Teacher Shortage

**Current gaps:** Quality teachers are a critical driver for change throughout the STEM pipeline. Currently, the educational system faces a significant shortage of quality STEM teachers at junior high and high school levels. The shortage in quality skilled teachers is the most strategic issue across the pipeline, and one of the main avenues for change and action, since teachers have

a tremendous influence over their students' educational and professional choices. Efforts are being pursued on a national level to train quality teachers and provide incentives for career changes for industry personnel. This needs to be addressed through quality training preservice for teachers, through the teachers' training colleges, and not just in service training, after being enrolled as a teacher. New training methodologies and content need to be introduced, as well as tighten the entrance criteria for STEM teachers.

**Opportunity for change:** Investment in all other teachers in STEM and STEM-related fields along the pipeline from junior high school to higher education is limited. The problem becomes exacerbated in technological tracks and colleges where there is sometimes a tradeoff between pedagogy and experience, as a result of which the graduates of these programs are shortchanged and less prepared than they could be for entering the labor force in STEM fields.

## Post-secondary Education

**Current gaps:** At the post-secondary stage in the STEM pipeline, programs have been developed to allow students to continue their studies for technician and practical engineer diplomas in 13<sup>th</sup> and 14<sup>th</sup> grades. However, it is the Army who decides on the quotas for the number of students who continue to 13<sup>th</sup> and 14<sup>th</sup> grades, which are 20% of technical and practical engineering students. This track is under the supervision of the Ministry of Education and has its own qualification and accreditation system, independently of the Ministry of Economy and Industry system's (in charge of adult technician and practical engineers tracks), creating de facto two, unequal tracks. Finally, technicians and practical engineers need a strong hands-on experience, and in general, the students should be much more involved in projects, training, and internships in the industry and the army.

## IDF

**Current gaps:** The IDF estimates its shortages in technologically skilled incoming soldiers in the thousands. The IDF (and employers) find the graduates lacking the ability to meet their needs. Accordingly, the IDF provides training for high-end, as well as practical -tech and low-tech skills needed in the course of the compulsory military service of high school graduates.

Within the STEM pipeline, the IDF has been identified as a crucial linking factor between the education system's graduates, higher education, and the labor market. The army plays a key and double-edged role in science, engineering, and technology education. On the one hand, it is a consumer of graduates of these tracks; on the other, it also trains them during the course of their service.

**Opportunity for change:** Despite its importance, currently, the IDF is almost considered as an obstacle on the STEM continuum. However, the IDF should be thought of as leverage, a bridge for career development, which can open the door to more in-depth and scalable cooperation with the Ministry of Education and the industry, to tackle issues of accreditation and qualifications.

## Higher Education

**Current gaps:** The past decade has seen an increase in the number of graduates in fields that do not reflect the market needs. Clearly higher education has been unable to respond to the demands of the industry.

In order to address the need to train students in the STEM professions, particularly computer science and engineering, the Ministry of Finance and the Budget and Programs Committee amended the budget and created incentive packages for universities that manage to increase the number of students. Universities have also developed virtual courses and learning platforms.

However, some substantial gaps remain: The university's acceptance criteria in science and technology should reflect the importance of skills and knowledge, and include such criteria as project work, critical thinking, innovation and creative thinking etc.

The universities entrance bonuses do not reflect the necessity to encourage STEM studies. They give a 35% bonus for students with 5 points matriculation in mathematics , 25% for students with 5 points matriculation in sciences and only 20% for other 5 points ,articulation for all other disciplines including technology and engineering studies. This difference gives those studying math and sciences a real advantage compared to those studying technology. Hence, students have less incentives to study technology. Changing the bonus difference sends a clear message that technology is as important as science in STEM education.

In some of the OECD countries, Israel included, it has been reported that there is a mismatch between the graduates of the academia and the requested work force in the labor market.

**Opportunity for change:** More effort and investments are required to integrate industrial practice in the engineering curricula. In additional, Practical engineers who would like to peruse their engineering studies in Israeli universities should be accredited with more academia credits, which will enable them to complete an engineering degree 2-2 1/2 years as it is in American or European universities.

## Technological Secondary and Post-secondary Education

**Current gaps:** A number of issues interfere with gaining the most effective results from the technological education pipeline:

The duplication between the Ministries of Education and Economy and Industry, has created a political decision-making rather than a collaborative environment in terms of knowledge, skills and attitudes.

The degree of government funding is lower for teachers in the technological tracks than in academia. The budget for technological colleges is a 1/3 of the academic college's budget, per student per year. This is also the case for teachers, labs, etc.

The technological education has a bad reputation and a positioning problem. In the current state of affairs, the biases, stereotypes, and negative attitudes towards the technological tracks will continue, unless the public sees and believes the field is taken seriously.

Insufficient commitment and involvement on the part of the private sector with respect to different methods of training - employment, mentorship, apprenticeship, etc., from the early stages of technological education – leaves unaddressed needs

**Opportunity for change:** High profile campaigns similar to the Math efforts, defined as high priority and backed by dedicated additional budgets, should be a possible model to duplicate. Encouraging a growing role for the private sector in STEM education should prove beneficial for students, teachers and employers.

## Employment and Workforce Development

**Current gaps:** Whereas every year, an additional 7,000 new jobs are added to the hi-tech sector, the number of high school graduates with satisfactory math skills is 6,600 students a year, and the number of graduates in computer disciplines from universities and colleges is only 4,500 a year. The indicators of the shortage are the numerous available positions with high salaries, the insufficient high school graduate flow and industry reports of difficulties in recruiting personnel.

In parallel, the hi-tech and practic-tech industries lack thousands of technicians and practical engineers. The Ministry of Economy and Industry is very much aware that employers need to be more engaged and the Israeli background report itself assesses employer's involvement in funding, curriculum development and work-based learning as weak.

**Opportunity for change:** Compared to developed countries, graduates of non-academic postsecondary studies in Israel do not receive the tools needed for integrating in quality positions in the job market. Additionally, the higher education system does not manage to fully address the needs of the economy, articulated in a shortage of engineers in the hi-tech industry.

Finally, jobs of the future will add additional stress on the system, because they will require new knowledge and skills if industries want to lead economic and technologic developments. Israel has to choose the market structure and labor relations that are conducive to addressing 21st century challenges.

## Untapped Populations - Providing Solutions for Women, Arab, Haredi, and the Periphery

**Current gaps:** Sectorial deficits are very often due to a combination of education, culture, opportunities, and budget allocation. In order to increase the quantity and quality of STEM students and workers, national efforts are being made to tap into the potential population that lag behind in general, and in STEM education in particular: Women, periphery, Arabs, and Ultra-Orthodox Jews.

**Opportunity for change:** Although targeted programs exist on the national and local levels, the gaps between sectors and geographical lines are still so distinct and will not disappear without external intervention, that the need to further address these gaps and be proactive through affirmative action programs is an imperative. Additionally, there are not enough efforts of coordination and synchronization between the Ministry of Education, the local municipalities and academia to increase the participation of these populations and address motivation and incentives for education and technological training.

## Continuum, Synchronization and Coordination

**Current gaps:** The continuum along and across the STEM pipeline is fragmented and lacks continuity. Along the pipeline, the different stakeholders in each phase are not accountable and responsible to each other, as they work towards achieving their own goals, with no general overview of the entire pipeline. For example, junior high school and high school have been identified as a critical intervention point on the STEM pipeline, however, all stakeholders need to strengthen the connections between each of the continuum phases beginning with kindergarten through high school and into post-secondary.

Equally important will be the need to look and assess future needs – IDF, higher education, employment - in terms of content and skills, in order to create a second strong continuum from high school to employment through IDF and higher education.

**Opportunity for change:** Across the pipeline, there is a lack of synchronization and cooperation between the formal and informal education. STEM excellence and literacy, require the mobilization of concurrent circles: school, family and community. Hence, the necessity to strengthen the coordination and common activities between the education system and the diverse education NGOs, science museums, educational networks, universities, research centers that operate complementary, and sometime parallel, programs.

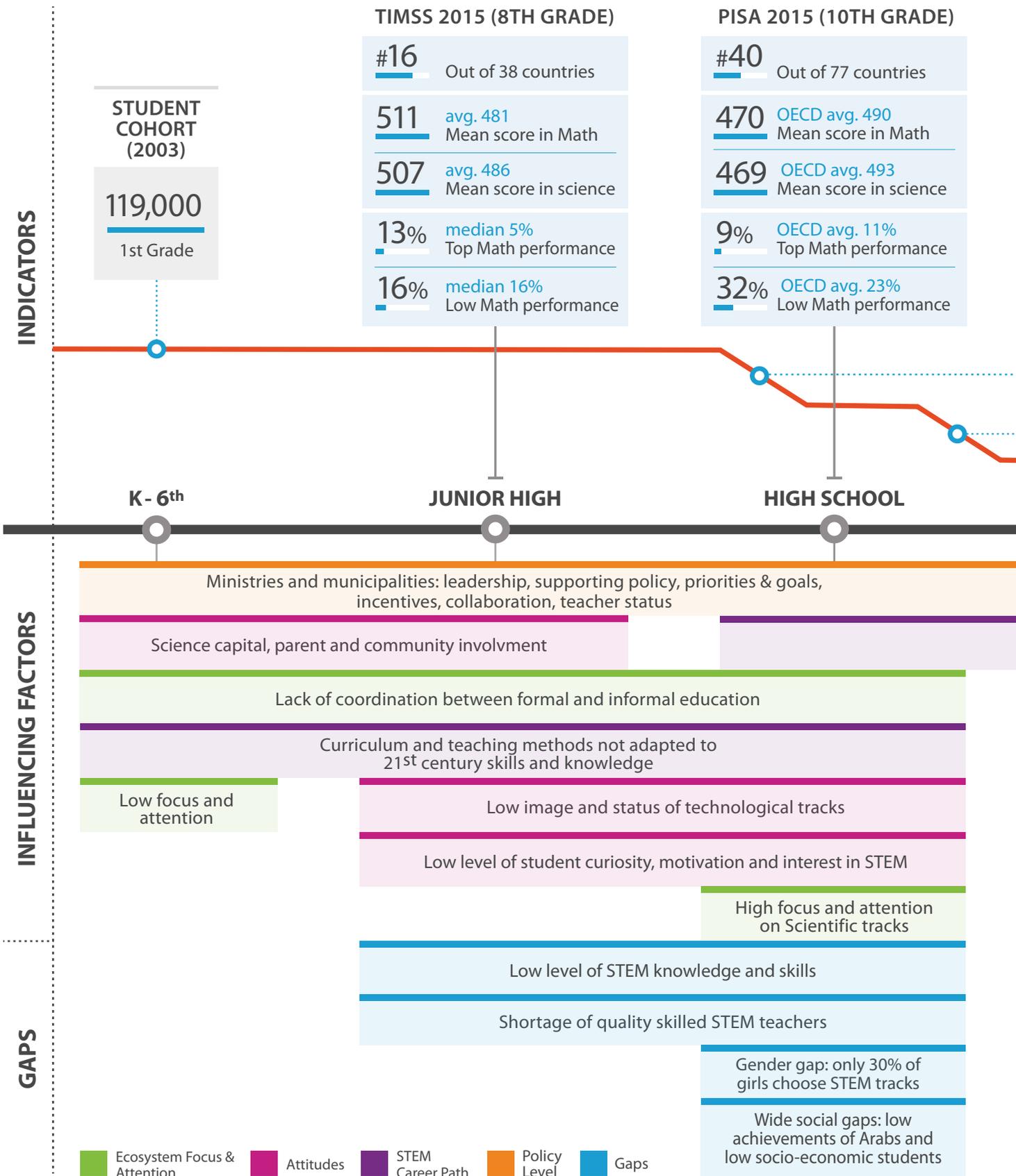
## Final Remarks

The goal of mapping the STEM pipeline was first to highlight the current state of STEM education from kindergarten to employment in Israel. Although there is at almost any given crossroad a real understanding and action on the national level of the need to improve scientific and technological literacy and excellence, gaps remain. Implications of the mapping then provide a frame of reference within which plans of action for the future can be considered:

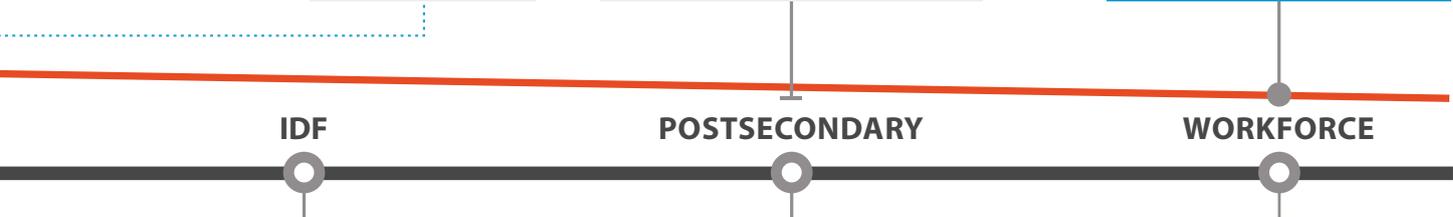
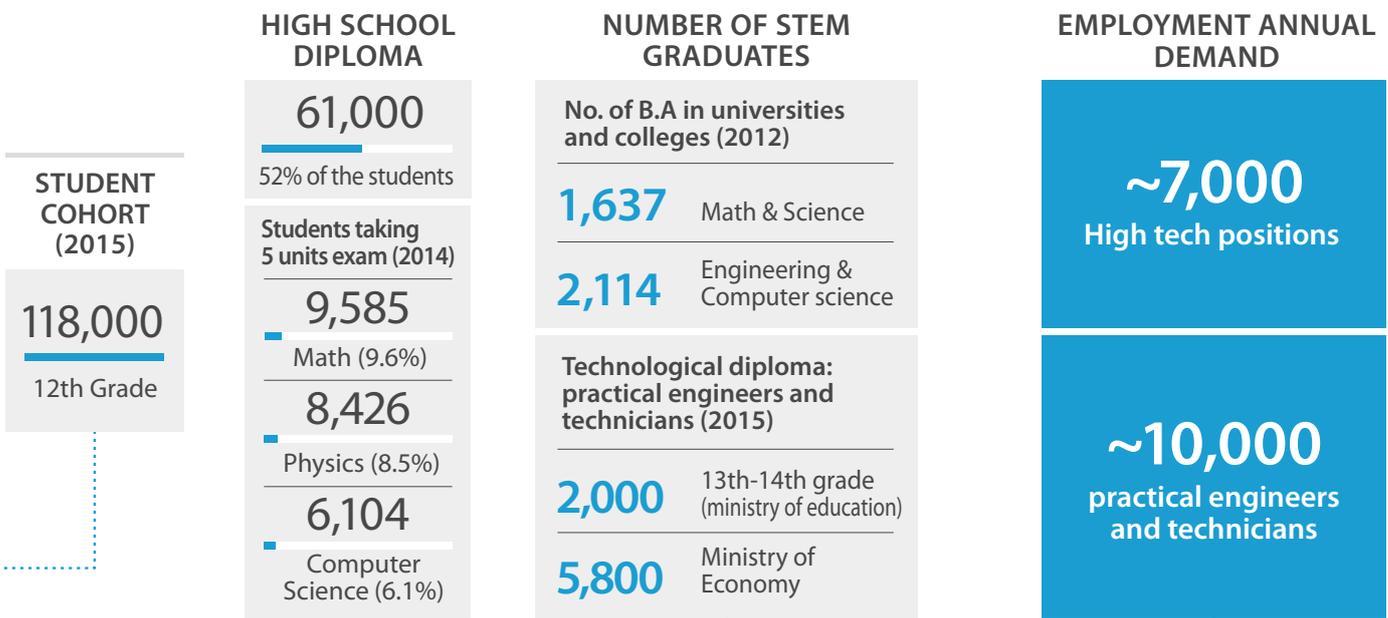
Despite the gaps, we are witnessing some positive trends in STEM education which are indicative of a real momentum for change. This is evident in the increasing number of students taking the 5-unit math and quality matriculation, as a direct result of the collaboration between a national cross-sector coalition (5\*2) and the national plan implemented by the Ministry of Education, among other recent policy changes.

The STEM issues can only be tackled by moving from an ego-system approach, in which each stakeholder looks at the pipeline from his perspective and agenda, to an eco-system that includes all STEM stakeholders along and across the pipeline, so as to create a real, comprehensive continuum, where the strategy takes into account each phase. A concerted effort, will attract more quality women and men along the STEM pipeline to ensure sustainable change for Israel's future.

# The STEM Pipeline in Israel



\* Created by Inbar Hurvitz, Sheatufim



Ministries and municipalities: leadership, supporting policy, priorities & goals, incentives, collaboration, teacher status

Gaps in curriculum content to meet STEM career path requirements

IDF experience & training not fully integrated into STEM career path

Low incentives for students in technological tracks

Low number of STEM faculty positions in universities

Shortage of skilled STEM personnel

Shortage of STEM internships and work-based learning opportunities

Low number of graduates in STEM tracks: Scientists, engineers, practical engineers, technicians

Gender gap: less than 30% of STEM students are women

Shortage of skilled STEM personnel

Gender and Social gaps: only 25% women and 3% Arabs employed in High tech STEM positions



# **From Early Learning to Workforce**

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The STEM pipeline in Israel

# I. Background and Introduction

Israel's economy is knowledge-based, with strong achievements in science, technology and research. However, in the past several years, experts and stakeholders have been warning about a growing shortage in a skilled workforce capable of fulfilling technology-based positions in the military and in industry in the next 10 years and the limited scientific literacy among the general public <sup>1</sup>.

According to the World Economic Forum, the world is living the Fourth industrial revolution, which is the combination of cyber-physical systems, Big Data, the Internet of Things, and the Internet of Systems.

Alongside great benefits, concerns emerge such as the fact that many jobs and disciplines will disappear and automation, computers and machines will replace workers across many industries, so much so that some estimate that as many as 47% of US jobs are at risk. <sup>2</sup>STEM (Science, Technology, Engineering and Math<sup>3</sup>) knowledge and skills are considered essential tools for students to measure up to the challenges of the 21st century.

The World Economic Forum report also suggests that the gap between the skills learned and the skills needed is becoming increasingly obvious, as traditional learning falls short of equipping students with the knowledge and skills they need to thrive<sup>4</sup>:

## 21st Century Skills - Lifelong Learning



1. Manny and Rosen, "Teaching Sciences in Israel," 5.

2. Marr, "Why Everyone Must Get Ready."

3. STEM subjects also include: physical sciences, life sciences, and computer science. In some curricula, STEM subjects may also appear under the titles of physics, biology, chemistry, earth/environmental sciences, astronomy, and IT

4. Soffel, "What are the 21st century."

This exponential change will require skills that weren't given enough weight, if any, in teaching programs at all levels, whether at school, university or work: excellence, innovation, creativity, entrepreneurship, world experience, critical thinking etc. STEM education has thus recently become the focus of an intensive public discussion and debate that can be gauged from increasing government attention and cross-sector initiatives<sup>5</sup>. In August 2014, an inter-ministerial steering committee commissioned by the then Ministry of Trade and Labor (today the Ministry of Economy and Industry) to study the lack of skilled manpower in the hi-tech industry<sup>6</sup>, which suffers from a serious shortage of high-quality academic graduates in engineering, computers, and science, concluded that the main reasons for the shortage is the rapid growth in knowledge-intensive industries, while growth rate of the labor force in these areas remains insufficient, with an emphasis on R&D positions. In particular there is a need for outstanding university graduates in software and hardware with work experience.

Its findings are unequivocal. There is a direct link between science and technology literacy at a young age, quality of high school diplomas, the number of students studying relevant fields in higher education, and the flow of a skilled workforce in knowledge-intensive industries, as well as minimizing the socio-economic gaps.

The reports also highlights the direct link between the quality of the matriculation certificate ("Bagrut" in Hebrew), higher education and employment. A quality scientific-technologic Bagrut, significantly increases the chances that a student will pursue its higher-education degree in a field relevant to the high-tech industry, for example<sup>7</sup>. Furthermore, Traditional low-tech industries - metal, machinery, electrical, electronics, automotive - have changed over the past 15 years and become increasingly automated leading to a new industrial field, practic-tech. In parallel, in the past 20 years the technological education system was significantly cut back: funding was cut substantially and the system targeted disadvantaged students (tracking), and none withstanding some exceptional schools, made technological education a last-choice for students. Increasing efforts are being made to fill in the gaps in the practic-tech industry, from the training of technicians and practical engineers to their employment. Practic-tech training is crucial to create a pool of skilled workers, technicians and practical engineers.

The gaps between supply and demand are increasingly being addressed at different levels by the government, foundations and NGOs, and the private sectors through national programs targeting untapped populations; increasing the numbers of those choosing STEM career paths; increasing the number of high school students graduating with high quality science and technology matriculation certificates; exposing children and adolescents to science and technology; and increasing the relevant teaching force.

This paper will map the STEM-pipeline so as to understand the situation in Israel, and will identify gaps and opportunities for action. The following chapter will give an overview of the STEM pipeline in numbers. The third chapter will present the main drivers of STEM education in Israel, and the fourth chapter will explain every stage of the pipeline in depth. The final chapter will conclude, summarizing the gaps and highlighting opportunities for action.

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5. Kearny, *Israel National Response*, 6.

6. "Increasing the supply of a skilled labor force in the hi-tech industry, steering committee report, *The Ministry of Economics*," 2014

7. "Increasing the supply of a skilled labor force in the hi-tech industry, steering committee report, *The Ministry of Economics*," 33-34

## II. The main players in STEM continuum

### Key Points

1. There are numerous and significant players in the STEM field in all sectors: government, private, third sector, and educational networks, all of which influence the field and constitute engines for change. Each has its own key function and added value in both the formal and the informal arenas. Cooperation between all the players is vital in order to secure change in all areas.
2. In recent years, the Ministry of Education has strengthened science education significantly and begun to increase the number of students in the relevant tracks. Actions include developing dedicated programs, improving curricula, and enhancing teacher training. At present, the main focus is on high schools and on increasing the number of students completing a science matriculation at a level of 5 units, with an emphasis on mathematics. The ministry has also presented a comprehensive plan for 2017-2020 in the field of vocational-technological training. However, implementation in this case does not include the substantial resources and partners seen in the field of science for outstanding students.
3. On the STEM continuum, the IDF is the first main employer and consumer of STEM graduates. Followed by the hi-tech and practic-tech industries, as well as service providers. It should be noted that the involvement of industry across the pipeline is limited and significantly below that required.
4. Philanthropic foundations, coalitions, and private individuals all provide support for joint initiatives between the various players, influencing and shaping policy regarding STEM. Although they play a significant role in promoting STEM across the pipeline, their main involvement focuses on junior-high, high school, and teacher training.
5. The existing coalitions in this area focus on specific stages and areas across the pipeline.

## A. Public sector

### Ministry of Education

The Ministry of Education supervises the general academic and technological tracks of upper secondary education – high school, as well as post-secondary technicians and practical engineering tracks (namely, 13th and 14th grades).

The role of the Ministry to advance STEM and increase the pipeline, includes adapting education programs, recruiting and training STEM teachers, promoting policy through cooperation with the other bodies, such as the Council for Higher Education, foundations, IDF, Industry etc. The Ministry of Education has put STEM education as a national priority, through budgeting, school curriculum and reinforcement programs, dedicated national programs such as the scientific and technological reserve.

### Ministry of Economy and Industry <sup>8</sup>

At high school level, the Ministry supervises 3% of students in technological tracks and schools mainly targeted at students who dropped out of the Ministry of Education's high schools. Their goal is to complete the requirements which will allow them to pursue a technician/practical engineer path.

Additionally, the Institute for Training in Technology and Science (MAHAT), under the Ministry of Economy and Industry, supervises training, budgeting, services, curriculum, supervision, exams and accreditation of technicians and practical engineers for 67 postsecondary technological colleges<sup>9</sup>.

At the employment stage, the Ministry of Economy and Industry offers vocational courses, intended primarily to facilitate integration or reintegration into the labour market<sup>10</sup>.

### IDF

The army plays a key and double-edged role in science, engineering, and technology education. On the one hand it is a consumer of graduates of these tracks; on the other, it also trains them during the course of their service. Despite its importance, currently, the IDF is almost considered as an obstacle on the STEM continuum. However, the IDF should be thought of as leverage, a bridge for career development, which can open the door to more in-depth and scalable cooperation with the Ministry of Education and the industry, to tackle issues of accreditation and qualifications.

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8. *The report was written before the responsibility for technological education was transferred to the Ministry of Social Affairs and Social Services*

9. *"Technological Colleges – facts and budget," the Knesset Center for Research and Information, 1-2.*

10. *Musset, Kuczera and Field, "A Skills beyond School," 17.*

## The Council for Higher Education and The Planning and Budgeting Committee (PBC)

The Council is an independent and autonomous body in charge of higher education policy planning in Israel. The Council grants permits to open and operate a higher-education institution (college or university), accredits institutions, authorizes to grant certain type of degrees, assess quality of fields of study and more.

The PBC is in charge of the higher education budgeting, including allocation according to national priorities and industrial and economic needs.

## Municipalities

The Ministry of Education is responsible for setting the policy, and the local authorities' main responsibility is to ensure the infrastructure fits the Ministry's requirements. However, in recent years the Ministry of Education has been increasingly transferring some of its responsibilities to the local authorities, and they were given much more room for maneuver in fields, including education programs and services<sup>11</sup>.

Municipalities support STEM education mainly through local initiatives and cooperation with the ministries and private sector.

## Israeli Ministry of Science, Technology and Space

The Ministry of Science, Technology and Space supports many initiatives in cooperation with different formal and informal partners, ranging from scholarships to robotics competitions, Space Week and more, upon which we will elaborate below.

## Ministry for the development of the Galilee and the Negev

The Ministry is in charge of implementing national strategic plans to strengthen the periphery in the north and in the south of the country. Two of the Ministry's focus areas are to strengthen academia and research, and develop and strengthen employment, industry and innovation. Programs include opening new academic and research centers; cooperation with the industry to train practical engineers, from education in one of the institutions to employment.

# B. Private sector

## Hi-tech and practic-tech industries

The hi-tech industry is present along the entire STEM pipeline. First and foremost, it is the main employer of STEM students, and it also provides training and internships. Due to the challenges of STEM education, some hi-tech companies have also undertaken supporting science and technology education, in order to ensure its future, through joint programs with the relevant ministries, acting as a knowledge and motivational expert.

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11. Veissblai, "The relationship between heads," 4.

Companies like Intel, Broadcom, SanDisk, Marvell, Microsoft, Amdocs, Cisco, Qualcomm, IBM, Amdocs, Google and many others — multinational and native Israeli companies — are teaming up to provide mentors, funding, curricula, summer camp experiences, extracurricular programs, and scholarships to students who choose STEM education. As part of their activities, 40 hi-tech companies and startups joined the Business Coalition of 5\*2, a collective impact initiative to expand STEM excellence, focusing on increasing the motivation of students to select STEM majors through lectures of volunteers and tours<sup>12</sup>.

One of the partners, Broadcom, a US manufacturer of networking equipment with a large presence in Israel, through the Broadcom Foundation, provides scholarships for high school students who excel in STEM. Likewise, it funds post-graduate engineering research as well as workshops for girls and teachers. It sponsors Israeli junior high school students' participation in the Broadcom MASTERS (Math, Applied Science, Technology and Engineering for Rising Stars) annual science competition in Washington, DC, as well as many other fairs and competitive events.

However, there is no national level systematic consultations between the industry, and the ministries of education and of Economy and Industry.

Finally, of the 38% of high school students enrolled in technological and vocational paths, only 4% of them receive training with employers during their studies. At the postsecondary level, work-based learning is equally rare. Given a relatively limited vocational system overall, job-related skills are commonly developed informally on the job, while formal education concentrates on general knowledge and competencies<sup>13</sup>.

## Associations and unions

The Ministry of Economy and Industry and other government ministries and agencies are actively working to put vocational education and training on a statutory basis by legislation. The different stakeholders outside the governments, namely the industry, associations such as the Manufacturers Association and unions have been trying to engage more fully in the vocational education and training system<sup>14</sup>.

In general, there is a need for a coordinated eco-system and a balance between the influence of different stakeholders – employers, trade unions and the government. The government, associations and trade unions can balance the needs of industry (specific narrow skills for each industrial branch), while supporting the interest of students, the industry at large and the economy, by teaching students general transferable skills, including literacy, numeracy and soft skills<sup>15</sup>.

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12. Shamah, "Tech education crisis pushes Intel."

13. Musset, Kuczera and Field, "A Skills beyond School," 59-60.

14. Musset, Kuczera and Field, "A Skills beyond School," 23.

15. Musset, Kuczera and Field, "A Skills beyond School," 54.

## C. Nonprofit sector

### Technological Education Networks:

About half of the technological schools are managed by technical education networks, such as ORT, AMAL, Amit (national religious), and Badarmeh. Those networks operate mainly in the periphery. The operating budget, including wages, is mainly paid by the state, based on student numbers, the range of study tracks, and the expertise and seniority of the teaching staff<sup>16</sup>.

### Educational organizations: formal & informal arenas

NGOs are very active in the formal and informal education arena. They are involved along the entire pipeline, from kindergarten, through the army to employment, executing and initiating programs to advance STEM education.

Science museums play an important role in cultivating curiosity and interest in STEM subjects among children, students and their families, although they are not part of the curriculum and they present logistic challenges. In Israel there is a network of 5 science museums across the country. Science museums also develop educational programs in collaboration with the Ministry of education and the Israeli Ministry of Science, Technology and Space, as well as materials, tools and trainings for science and technology teachers.

## D. Funding sources and Philanthropy

Foundations are crucial to sustaining the STEM pipeline in Israel. Often they have the comprehensive picture in mind, and they can exercise far greater flexibility and freedom than the government. Hence, when foundations identify challenges that need to be addressed, they assume the role of initiating joint-ventures with the government, private sector, NGOs and municipalities.

They bring additional funding, but also a refined expertise in their fields. In deference to their work with grassroots initiatives on the one hand, and decision-makers on the other, foundations have an extensive capacity to influence and shape policy.

## E. Coalitions

In the past three years there is a growing attention of all key stakeholders to the urgency and need to act together in order to change current trends in STEM education. Following are the main coalitions that operate at the national level:

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16. Musset, Kuczera and Field, "A Skills beyond School," 18.

## 5\*2: National level STEM excellence initiative

5\*2 is a broad cross-sector coalition dedicated to enhancing STEM excellence and to doubling the number of students in Israel completing high level of Math, Physics, Chemistry & Technology. It was launched in 2013 by philanthropic and business organizations, led by the Rashi Foundation, Trump Foundation and Intel. Since 2014, it operates as a partnership with the Ministry of Education and in 2015, the Ministry and 5\*2 launched the National program to advance Excellence in Math and the Science.

5\*2 operates according to collective impact methodology and approach, seeking to mobilize leading institutions from the public, business and social sectors to establish a joint platform of operation to advance common vision and goals.

The 5\*2 steering committee is composed of leading STEM education organizations and funders including: Trump Foundation, The Rashi Foundation, World ORT-Kadima Mada, The Davidson Institute, Hotam (Teach for Israel), The Technion, The Israel Center for Excellence, The Bloomfield Science Museum in Jerusalem, The IDF, Intel, SanDisk, Microsoft and the Toronto Federation.

The broader network includes about 100 organizations including the Ministry of Defense, municipality representatives, universities, school networks, educational organizations and business companies. As part of the network, a business coalition includes 40 of the leading hi-tech companies in the country. The backbone organization is Sheatufim (NGO) with experience in managing complex result based cross-sector initiatives<sup>17</sup>.

## The task forces to advance technological education

Initiatives in the core technological tracks (practical engineering and technicians) are relatively small-scale. Two such initiatives targeted at technological education are specified below:

The Forum of Technological Colleges which represents dozen of colleges, teaching 28,000 students, under the supervision of the Mahat aims to advance technological education in Israel on the pedagogical, administrative and budgetary levels. One of its main challenges is that being under the supervision of the Ministry of Economy and Industry, it is outside of the education continuum. One of its main achievements has been the establishment of an accreditation program.

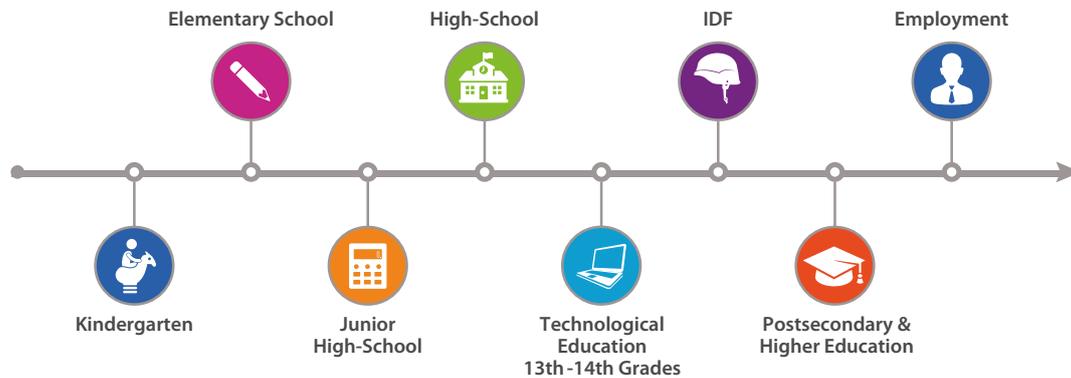
The automotive industry has been undergoing tremendous changes in the past few decades. Essentially every vehicle requires attention with technological knowledge. Therefore, this field is classified as practic-tech industry. In Israel, there are 28 schools that train auto tech workers. However, automotive tracks have been shut down, their curriculum is irrelevant and not adapted to industry needs. There are no opportunities for training and interning within the industry. The industry is perceived negatively by students and parents, and students choose this track for lack of any other option. Additionally, there are very few partnerships. It is against this background that the car importers have created **a task force to advance technological education in the car industry.**

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17. Sheatufim, "The 5x2 Initiative - "Expanding the Circle of Excellence in Science-Technology Education"

## III. STEM Continuum

In order to increase students' access to high quality STEM learning opportunities we must have a comprehensive perspective that looks across the entire education continuum from Kindergarten to Career. This chapter will focus on the following stages:



### A. Kindergarten (age 5) and Elementary school

#### Key Points

1. In the formal sphere, the goal of the Ministry of Education is to develop scientific and technological literacy among children, mainly through curricula, and to encourage a positive attitude to the field. In elementary schools, an emphasis is placed on practical experience.
2. In the informal sphere there are diverse activities in cooperation with the technological educational networks, NGOs, science museums, the IACC, and the Youth Science Units in the universities and academic colleges, such as science competitions and Olympics. These activities expose children to the world of science and technology and seek to stimulate motivation in the field.
3. The existing activities are very sparse and are inadequate both in terms of content and the methods used to teach, including learning technologies, and in terms of scope. The main reason for this is that the players do not emphasize these age groups.

# 1. Kindergarten

## Primary goals

Most activities on the national level start in kindergarten and are meant to expose children to science and technology, and to introduce them to scientific methods and environment, as well as instilling love of research and learning.

## Channels for change

As part of the understanding that STEM literacy has to start early, the Ministry of Education has developed a national curriculum so as to create a continuum, to the extent possible, between kindergarten's and elementary school's science and technology programs. It is based on the pedagogical principles of learning by doing and problem-based learning<sup>18</sup>. The curriculum focuses on two main fields and how they merge with one another: 1. scientific knowledge and research/investigative processes, 2. technological knowledge and design processes.

The Ministry of Education, Lockheed-Martin aerospace tech firm, the Beersheba Municipality, and The Rashi Foundation sponsored Israel's first science kindergarten as an experiment to develop STEM skills at a young age and is keen on replicating the model<sup>19</sup>.

# 2. Elementary school (grades 1-6)

## Primary goals

The focus in elementary school is to provide students opportunities for experimenting in STEM. The curriculum in science and technology emphasizes direct experimentation as a major learning strategy for building knowledge, understanding and skills. The experimentation reinforces the learning process by scientific research and problem solving, and is a cornerstone for entire processes of experimentation in scientific research and problem solving that they will have to confront in 6th grade. Those experiments positively influence the students' attitude towards science and technology<sup>20</sup>.

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18. The curriculum was developed based on the following assumptions (although the scientific literature on the matter is not advanced enough): Children take interest in natural phenomena and technology, young children display scientific and technological thinking capabilities, early childhood exposure to scientific phenomena and technological activities improves children's understanding of scientific and technological concepts taught at later stages, developing scientific and technological thinking necessitates planned and targeted pedagogical activities, teaching science and technology naturally improves logical-scientific thinking and develops creativity, early exposure to science and technology is likely to develop positive attitudes towards those fields, the best way to teach children science and technology is to start with subjects that are close to them and that they can recognize from their daily life.

19. Shamah, "Israel opens first-ever hi-tech kindergarten."

20. Main experimentation, 1st-6th grades, Ministry of Education, September 2015.

## Channels for change

### Ministry of Education

The Ministry of Education's policy goal is to provide "science and technology education for the entire student population," seeking to train active citizens able to contribute to the functioning and growth of society. This is mainly achieved through the science and technology studies curriculum (with an emphasis on stimulating active and experiential learning, team work, intense thinking, investigative processes and problem solving<sup>21</sup>), and enrichment programs, competitions and fairs, often in cooperation with NGOs, science museums and the industry.

### Informal education

There is an increasing number of informal activities to support STEM education during and after school hours. Those activities are carried out by a wide variety of NGOs, including science museums, The Company for the Centers of Culture, Youth and Sport (umbrella organization for community centers).

Competition and science fairs create extensive exposure and motivation to STEM among hundreds of thousands of students ranging from kindergarten to end of high school. During elementary school these competitions became a powerful tool to increase curiosity and excitement around STEM subjects. These activities operate in conjunction with the formal education system. Among them are: the FIRST competition, the Cyber Olympics<sup>22</sup> and summer science camps that take place in regions of national priority and in peripheral regions<sup>23</sup>.

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21. Kearny, "National Response: Israel," 29-30.

22. The Israel Advanced Technology Industries (IATI) began a program to expose kids from as young as 3rd grade to programming. Its success has been phenomenal. In 2015, some 60,000 elementary school pupils took part in a coding game and this year the number has jumped to 270,000. Cyber Olympics for 11th and 12th graders attracted 3,000 students last year and 10,000 this year. Evyatar, "Taking 'start-up nation'"

23. Kearny, "Israel National Response," 25.

## B. Junior high school and high school (grades 7-12)

### Key Points

1. Studies have shown a close correlation between a high-quality matriculation certificate and academic studies in the field of science and engineering. Accordingly, the Ministry of Education focuses on increasing the number of students taking high-quality matriculation examinations in these subjects; in the initial stage, the emphasis is on math. According to recent official publications, the efforts in this area are proving successful and there has been an increase in the number of students taking mathematics at 5 units.
2. The Ministry of Education has identified junior-high schools as the key stage for students to be encouraged to take a high-quality science matriculation.
3. Junior-high and high schools have received additional resources for classes, private teachers, and cutting the number of students in the class. The point of departure of the Ministry of Education is that excellence is influenced mainly by motivation, perseverance, and hard work.
4. There is also a highly-developed informal sphere involving foundations, NGOs, and organizations that cooperate in order to increase the number of students. Activities are diverse and are mostly run in cooperation with the relevant ministries and with national and local authorities.
5. Technological education depends on training and on close cooperation with the world of employment and with academia. In practice, only a tiny proportion of students receive industry training.

### Goals

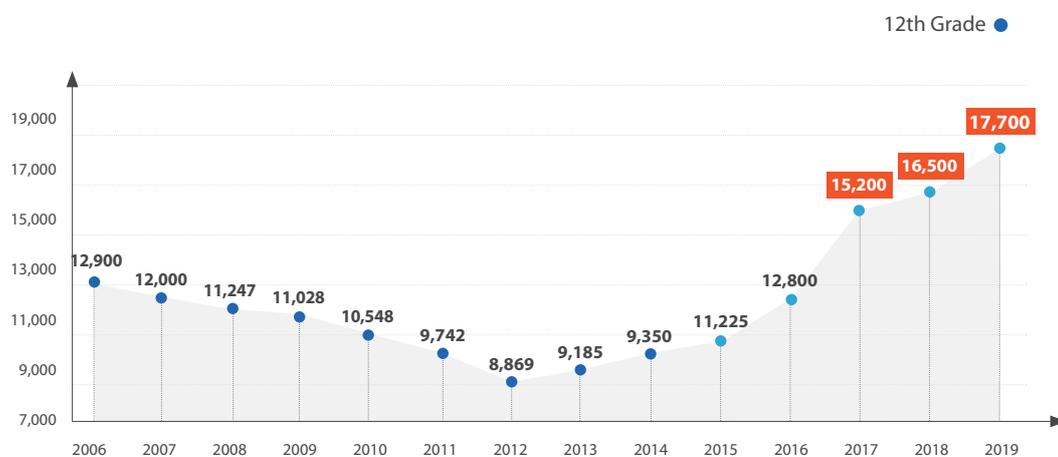
As previously specified, all the research shows a strong link between excellence and literacy in science and technology, and the flow of a skilled labor force in the hi-tech industry. The national focus of the different ministries involved is therefore to increase the number of students graduating with high quality diplomas in science and technology tracks on the one hand, and to develop the technological tracks on the other. At the conclusion of 9th grade and before entering high school, students are required to choose the composition and level of their matriculation certificates, whether scientific, technological or both.

## Theoretical-scientific tracks

### In numbers

Over the past 10 years, the numbers of graduates in advanced math has continually decreased and less than 10,000 students take the advanced math track. In physics, the numbers remain more or less stable. As for school capabilities to support excellence in science, only a third offer physics, and half offer chemistry.

Nonetheless, the National program of Math and Science Excellence in partnership with the 5\*2 initiative show that the focus given to increasing and improving the number of students taking the 5-unit math exam, is working, as can be seen from the table below (source: Ministry of Education):



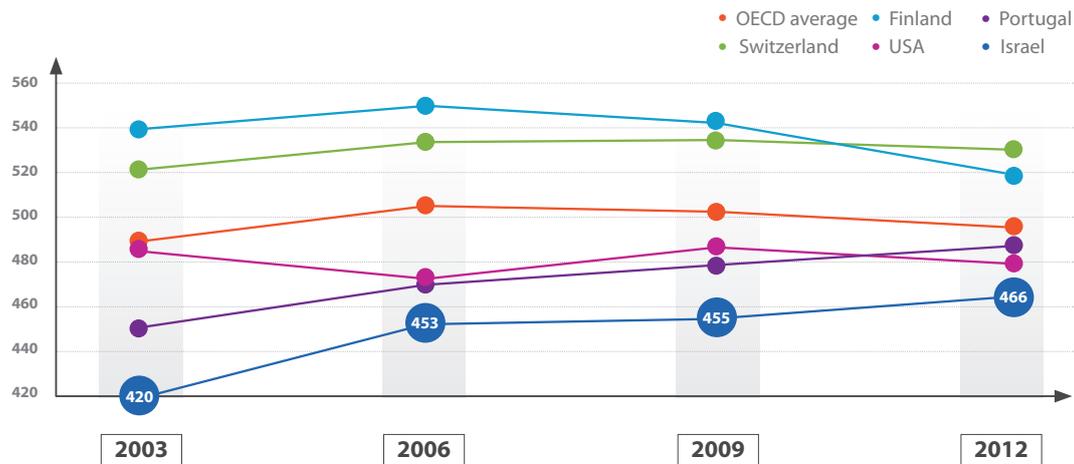
### International Benchmarks

International benchmark tests in science excellence and literacy seem to support the findings on Israel's STEM education. Israel's performance in PISA 2015 is below the OECD average. Nevertheless, the focus on STEM education in recent years, is already showing. In mathematics, Israel has made the greatest improvements in student performance among all OECD countries, with an average improvement of more than 4 score points between 2006 and 2012<sup>24</sup>. This improvement can also be seen in the TIMSS Mathematics survey results in 2011, arriving in seventh place among 42 (up from 17th place in the previous survey)<sup>25</sup>.

24. "Education Policy Outlook Israel," 5.

25. Kearney, "Efforts to Increase Students," 24.

## PISA Comparative Math Results 2003-2015



### Strategies concerning mathematics and sciences in secondary education

The Ministry of Education has been supporting the necessary infrastructure through updating the curriculum and supporting resources: policy guidelines, approved books, presentations, activities, observations and experiments developed by teachers, evaluation tasks, multimedia resources, websites. Math curriculum is currently under revision with the purpose of cultivating reasoning, argumentation, and making a choice among strategies.

In 2010, the Minister of Education designed a strategic plan to strengthen science and technology studies through the scientific and technological reserve which sets the criterion for a high quality science and technology matriculation diploma. The criterion consists of three exact science subjects at the five unit level: 1. mathematics; 2. one scientific discipline (biology, physics or chemistry); 3. scientific or technological discipline<sup>26</sup>.

The premise of the program is that excellence depends first and foremost on motivation, perseverance and serious work.

Furthermore, on September 1, 2015, upon the opening of the school year, the Minister of Education launched a campaign to explain the National Program to Advance Math Excellence. Entitled Ten Chamesh, Hebrew for "Give Five," its purpose is to double the number of students in secondary education who choose the intensified mathematics program (5 units for the matriculation diploma), in five years. The program includes recruiting math teachers from among hi-tech professionals, establishing smaller classes, support for virtual classrooms for students whose schools do not offer a 5 unit program in mathematics (mainly schools in periphery regions unable to recruit adequate teachers) and more<sup>27</sup>.

26. Electrical engineering, mechanical engineering, robotics and aviation, software engineering, technological sciences, biotechnology, auto-tech, digital information technology, civil engineering and architecture, vehicle mechanics and electricity, control systems and energy, computerized production systems, and marine systems, Rimon and Romanov, "Trading on diamonds."

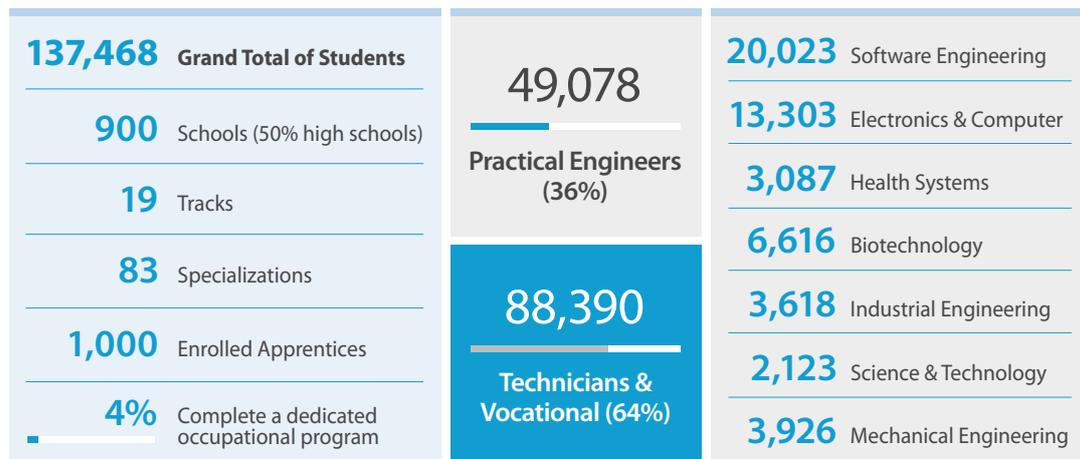
27. Kearny, National Response: Israel,"18.

In addition to the national plans, there are many informal activities to encourage scientific and technological excellence and literacy. Most programs are conducted by NGOs and the private sector, in cooperation and/or coordination with the relevant institutional entities. Such notorious program is the Virtual High School, a 50 Million NIS collaborative enterprise between the Ministry of Education, the Center for Educational Technology (CET), and the Trump Foundation, providing online instruction and tutoring for approximately 1,000 physics and mathematics students from approximately 130 schools in the periphery where there is no 5-unit teachers.

The recent formal and informal efforts made since 2012, show that the focus given to increasing and improving the number of students taking the 5-unit math exam, is working, and a gradual but steady increase can be seen. The Minister of Economy and Trade announced the official results in the 5-unit math exam: A total of 12,800 12th grade students took 5 units in math. A 2,000 students increase compared to last year. A total of 15,800 11th grade students took 5 units math. A 4,000 students increase compared to last year. Additionally, a huge increase can be seen in the periphery: Increases in Netivot – 56%, Yerucham 68%, Rahat 104%, Shfaram 96%. There is also an increase of 700 students in the past couple of years among non-Jewish populations.

## Technological tracks<sup>28</sup>

### In numbers



### Technological skills shortage

Approximately 37% of Israeli pupils participate in a technology education framework, in contrast with an average of 49% in the EU19 countries. Of those studying in technology tracks in Israel, 55% study in a clear technology track such as communications systems, mechatronics, system design and programming. Despite growing pressures about the importance of a technological provision funding in the sector is inadequate and sometimes declining. These concerns are strongly voiced by the IDF and the Manufacturers' Association of Israel, which claim that "virtually all the industrial professions face skills shortages, and the IDF alone are missing

28. Presentation to the Steering Committee on vocational and technological education in Israel, plan for 2014-2024, Ministry of Education

some 7,000 practical engineers. Some have also suggested that there is a shortage of 15,000 practical engineers alone per year. Data from the Manufacturers' Association of Israel indicate a considerable shortage of technicians in Israel, estimated at around 5,000<sup>29</sup>.

## Strategies concerning technology

The Ministry of Education has launched a strategic plan to advance the technological and professional education in 2014-2024. It includes increasing the number of students studying on technological tracks to 47% (50% including the Ministry of Economics schools) and designing a system of accreditation with significant diplomas for practical engineering, technicians and vocational education.

<sup>30</sup>One such project is TOV -Technician and Matriculation (Hebrew acronym for "technician and matriculation"), which is a study track from 9th grade through 12th grade that provides students with the opportunity to be qualified and certified as technicians and to earn the matriculation diploma. Such students will be able to complete an additional one-year study track and graduate as practical engineers with the option of continuing towards degrees in higher education<sup>31</sup>.

Additionally, NGOs, the business sector and some individual philanthropists have taken upon themselves to further technological literacy in an informal manner. Most programs are conducted in cooperation/coordination with the relevant formal structures. Examples include: circles of study on space, satellite workshops, excellence in the technological schools' networks, biotech research project, robotics competitions, and The National Fair for Scientific Investigative Projects and Problem-Solving<sup>32</sup>.

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29. Musset, Kuczera and Field, "A Skills beyond School," 28.

30. Presentation to the Steering Committee on vocational and technological education in Israel, plan for 2014-2024, Ministry of Education.

31. Kearny, "National Response: Israel," 13.

32. A variety of activities are carried out related to space and satellites including circles of study for experiential activities with children, workshops in the school framework dealing with building space satellite models, a program of courses in space related sciences at the technological schools' networks including lectures, demonstrations and experiments (grades 7 to 12). Kearny, "National Response: Israel," 21-25.

## C. STEM Quality Teacher Shortage in Junior high school and high school

### Key Points

1. Despite some increase in the numbers of students there has been no commensurate increase in the numbers of teachers.
2. All teachers are required to have academic qualifications though in vocational technological schools teachers tend to lack pedagogical skills and in other high schools, teachers lack field experience.
3. The demand for STEM graduates in the private sector impedes teachers' recruitment.
4. In order to address these issues, the Ministry of Education, in cooperation with foundations and NGOs, is training science teachers in various tracks and programs, as well as hi-tech employees as teachers. The subject of technology teachers has not yet received a systemic response.
5. There is a need for more quality STEM teachers in all strands of STEM education so students are more and better educated and prepared.

### Challenges

Four main challenges can be identified at the teachers' level:

#### Number of teachers

26 out of 1,080 university graduates in mathematics/statistics/computer science became teachers.

The past decade has witnessed a significant decline in the number of pure science teachers, and this is reflected in a 40%-54% drop in most STEM subjects, resulting in a tremendous shortage in the teaching system (Ministry of Education 2012).

22% of math teachers who are academicians under the age of 45 earned a bachelor's degree in math, in contrast with 42% who did not study math, math instruction or science at all. This statistic indicates relatively poor quality teachers in the STEM disciplines.

## Aging teachers

Additionally, the age of science teachers is clearly rising, while there is a shortage in new, and young teachers. The same trend can be seen for teachers in computer science and technology<sup>33</sup>.

## Teacher quality

It is generally agreed, even among science teachers, that their disciplinary-professional background is not strong enough by the end of their training. The 2015 National Plan, cited the low level in math training among teachers in elementary and junior-high school. There is a need for a much more selective acceptance process to STEM teacher training colleges. Moreover, the teacher training colleges need to improve their curriculum to include innovative perceptions, knowledge, skills, and develop creative methodologies in STEM teaching and learning.

## Demand in the private sector

Those teachers who do arrive with an undergraduate or graduate degree in sciences, need to deal with low salary, low social standing, and no real prospect for professional advancement, especially compared to the options in the private sectors for undergraduate and graduates from STEM tracks. In order to compete and attract quality teachers, there is a need for a stronger system of incentives and bonuses, and creative thinking on making teaching STEM appealing.

## Strategy for change

Several policies and initiatives are currently operating to significantly improve the quality of teaching for those who choose it as their profession and complete their professional training in the relevant institutions. The universities and the teacher training colleges are the institutions in which such preparation is offered. Effort is being applied to raising the quality demands of both kinds of institutions and making the demands uniform. Likewise, there is an effort underway to subject the teachers' training colleges to regulation by the Council of Higher Education and placing their budget allocations under the CHE's main operational arm, the Committee for Planning and Budgeting.

Additionally, the Ministry of Education has initiated training programs in cooperation with the third and business sectors, to train engineers from the industrial sector and retired IDF engineers as math and science teachers<sup>34</sup>. Other programs include training people who hold degrees in engineering and for students with honors degrees, mainly for primary and secondary school teachers<sup>35</sup>. Other programs, in cooperation Today, there are approximately 800 hi-tech career changers are in training in 10 residency clinical programs across the country.

The Trump Foundation has launched more than 150 programs in the past five years, harnessing talent into teaching, nurturing clinical expertise of teachers, and creating partnerships with government, charters, districts and municipalities. The Technion has funded the "Views" Program (Mabatim) that provides an opportunity for Technion alumni to earn an additional undergraduate degree as teachers of mathematics, science or technology.

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33. Manny Ikan and Rosen, "Teaching Sciences in Israel," 7.

34. "Increasing the supply of a skilled," 35-36.

35. Musset, Kuczera and Field, "A Skills beyond School," 87.

## Technological tracks

The quality of the teaching and training profession is as critical in the technological tracks as it is in general education. For vocational teachers there are often challenges in meeting the demanding dual requirement of pedagogical skills and practical, professional expertise<sup>36</sup>.

The technician and practical engineering programs are under the supervision of both the Ministry of Economy and Industry and the Ministry of Education, an academic qualification is required for all teachers, although the requirement differs between the two ministries.

For teachers under the Ministry of Economy and Industry, there are, in general, no requirements for pedagogical training and experience in the vocational subjects.

Consequently, vocational teachers under the Ministry of Economy and Industry may lack pedagogical training, while those under the Ministry of Education may lack industry knowledge and professional competence, as the entry requirements and initial training are more academic<sup>37</sup>.

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36. Musset, Kuczera and Field, "A Skills beyond School," 84.

37. Musset, Kuczera and Field, "A Skills beyond School," 84.

## D. Postsecondary technological education: 13th and 14th grades

In 2014, there are 4,800 students enrolled in those tracks that include vocational, technicians and practical engineering<sup>38</sup>, compared to the 148,000 students in technological tracks, i.e., only 3% of high school graduates chose to continue to 13th and 14th grades<sup>39</sup>. By law, those grades are only accessible to high school graduates from the technological and vocational tracks, which constitutes a significant regulatory barrier<sup>40</sup>. The main study tracks are mechanical engineering, auto tech, electricity and electronics, but other tracks are vocational<sup>41</sup>.

At the post-secondary stage, programs have been developed to allow students to continue their studies for technician and practical engineer diplomas in 13th and 14th grades. However, It is the Army who decides on the quotas for the number of students who continue to 13th and 14th grades, which are 20 % of technical and practical engineering students. This track is under the supervision of the Ministry of Education and has its own qualification and accreditation system, independently of the Ministry of Economy and Industry system's (in charge of adult technician and practical engineers tracks), creating de facto two, unequal tracks. Finally, technicians and practical engineers need a strong hands-on experience, and in general, the students should be much more involved in projects, training, and internships in the industry and the army.

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38. "Students in post-secondary education," CBS, 2013 -2014

39. Presentation to the Steering Committee on vocational and technological education in Israel, plan for 2014-2024, Ministry of Education.

40. "Improving the accreditation system," 2.

41. Porat, "Training Practical Engineers," 4.

## E. Army

### Key Points

1. The army plays a key and double-edged role in science, engineering, and technology education. On the one hand it is a consumer of graduates of these tracks; on the other, it also trains them during the course of their service.
2. the IDF should be thought of as leverage, a bridge for career development, which can open the door to more in-depth and scalable cooperation with the Ministry of Education and the industry, to tackle issues of accreditation and qualifications.
3. The IDF's academic reserve of skilled soldiers (who acquire a degree or diploma before enlisting for compulsory military duty) includes approximately 800-900 science and technology students, and a substantial number of students in the technology reserve which forms technicians and practical engineers. All reserve graduates are integrated in the IDF technological positions.
4. There is a shortage of high-quality personnel in all three fields. The IDF has launched programs to enhance cooperation with academia and with the colleges and relevant industries in order to train the necessary personnel. The cooperation is currently confined to individual initiatives, but those involved recognize the need to expand this area in order to increase the number of technicians, practical engineers, and engineers and to train them and improve their standard of knowledge.

## Overview

The infusion of technical and technological skills cultivated during military service, into the civilian economy may have contributed significantly to Israel's hi-tech takeoff in the early 1990s. The IDF's academic reserve of skilled soldiers (who acquire a degree or diploma before enlisting for compulsory military duty) includes approximately 800-900 science and technology students, and a substantial number of students in the technology reserve which forms technicians and practical engineers. All reserve graduates are integrated in the IDF technological positions.

Nonetheless, the IDF estimates its shortage in skilled manpower in the science and technology fields in the thousands. As a result, it has to increase its resources to find and train high school students who lack relevant background. Accordingly, the shortage in students in science and technology tracks also creates difficulties for drafting personnel to the reserve tracks, which are the growth engine of military technological innovation. Indirectly, that is also the industry's growth engine. The main shortages are found in the fields of electronics, electricity, computer science, and mechanical engineering, primarily in the Intelligence, medical, engineering and other technological units and corps.

## In numbers

As many as 15% of soldiers learn high-end technical skills during military service. This seems to be the case particularly for soldiers from disadvantaged backgrounds. The low-tech field – mechanics, electronics and weaponry – accounts for 20% of IDF occupations for its 180,000 strong force. Ideally, from the IDF point of view, all personnel in the technical and technological fields should be graduating from a technological track. In practice, 50% of its personnel in the field do not have a technological background. While many skills are acquired during military service, arrangements for certifying and recognizing those skills are inadequate<sup>42</sup>.

## Strategies

The IDF is often a bridge between high school, higher education and employment and cooperate with the different ministries and industry partners to identify, form and train the adequate workforce. Despite apparent success in training a skilled workforce that is integrated and lead the market, especially in the science and technology fields, the lack of official certification for the technicians and practical engineers tracks, results in lost opportunities for some when confronted by employer requirements. The OECD has even suggested that Israel would benefit from an approach which would allow skills learned in the IDF (and other settings) to be assembled into qualifications, recognized in the labor market<sup>43</sup>.

Although links between the military and the Ministry of Education, as well as the private sectors have always existed, in recent years, the nature of the cooperation has changed, and a coordination mechanism has been established. The Ministry of Education is now much more open to joint initiatives and results are already visible on the ground. Notably, 30% of the technological education is linked to the army, and the IDF is training more than 50 classes in the schools. Despite cooperation, gaps remain, and real changes will only be evident in the long term.

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42. Musset, Kuczera and Field, "A Skills beyond School," 39-40.

43. Musset, Kuczera and Field, "A Skills beyond School," 40.

## F. Higher Education

### Key Points

1. Over the past decade there has been an increase in the number of those studying for degrees that do not reflect the needs of industry, such as business management, law, or industry and management.
2. Educational institutions and employers have failed to create mutual connections in order to correlate the needs of employers and the education young people choose. This creates a situation where there are numerous graduates in some tracks but unmet demand in others.
3. Moreover, most of the universities and colleges have not done enough to develop cooperation with the business sector – industry and employers – in order to ensure that the curricula and programs reflect the needs of the economy in the relevant fields.
4. In order to address the need to train students in the STEM professions, particularly computers and engineering, the Ministry of Finance and the Budget and Programs Committee amended the budget and created incentive packages for universities that manage to increase the number of students. Universities have also developed virtual courses and learning platforms.
5. Despite this, the rate of growth of STEM students in the universities and academic colleges is slower than in other subjects, though this is also due to changes in the high-tech and practic-tech market.
6. The technological colleges have substantially lower budgets than is usual in academia. This situation leads to glaring discrimination against those studying in technicians and practical engineering tracks. The standard of teachers, laboratories, and practical experience are all significantly lower.
7. The image of technological education is also poor after high school, and the low budgeting of the technological colleges makes it difficult to recruit good teachers and to create classrooms and infrastructures meeting the needs of technicians and practical engineers.
8. Only 3% of high school graduates choose to continue to technological education in 13th and 14th grade classes.

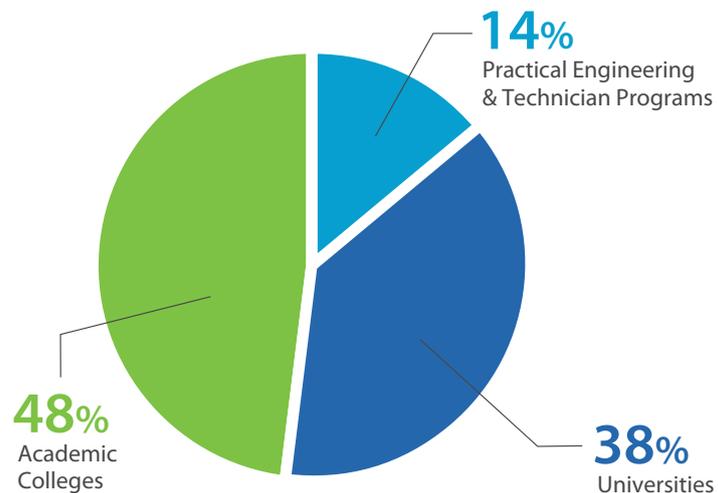
# 1. Universities and Academic colleges

## Background

Postsecondary education has grown very quickly in Israel in the past two decades, and the academic colleges have absorbed the bulk of the increase. Academic higher education institutions have grown from 21 in 1990 to 66 in 2008, and the number of students tripled<sup>44</sup>.

### Types of institutions and programmes

First year student enrollments at the beginning of the school year 2011-2012, OECD



Musset, Kuczera and Field, "A Skills beyond School," 33.

Data published by the Central Bureau of Statistics from 2013 show the number of students enrolling in engineering programs in academic colleges and universities has declined in the past 15 years (by about 4% per year in general, and by over 10% per year in the fields of computer engineering, industry and management engineering, materials engineering, biotechnology, and information systems)<sup>45</sup>.

This is mainly due to two reasons. The first is the increase of students enrolling in colleges in tracks other than science and technology. It should also be mentioned that colleges offer degrees in engineering and computer science but not in math, physics and agriculture<sup>46</sup>. Second, the past decade has seen an increase in the number of graduates in fields that do not reflect the market needs, such as law and business. Finally, Israel has come to saturation in the number of students that enroll in an undergraduate program. Therefore, higher education is unable to respond to the demands of the industry.

In most cases, universities and colleges do not invest resources and efforts in cooperating with the industry. They are not inclined to create joint curricula which will be adapted to industry needs, nor to establish industry specialization tracks. Likewise, career counselling, graduate placement in the industry, as is practiced by career centers in the UK and the US is not common.

44. Musset, Kuczera and Field, "A Skills beyond School," 33.

45. Musset, Kuczera and Field, "A Skills beyond School," 29.

46. "The Higher Education in Israel, 2014," 38-39.

Some in the industry have suggested that the curricula is not necessarily bad, however the professional level of graduates is not good enough<sup>47</sup>.

## In numbers

28% of students enrolled in undergraduate science and technology tracks<sup>48</sup>.

Data below on Science and Technology tracks in Higher Education include the following: Math, Statistics and Computer Sciences, Biological sciences, Physical sciences, Agriculture, Engineering and Architecture.

The fluctuations of the hi-tech industry are reflected in the number of students enrolling in the relevant tracks. Since 2001/2, when 8.3% of all undergraduate students studied math and computer science, the numbers dropped to 4.7% in 2006/7, while they were rising, reaching 5.7% in 2013/4. The number of engineering undergraduates has remained more or less stable in the past year and is estimated to stand on 18% of undergraduates<sup>49</sup>.

## Strategy and regulation for change

During the 2013/14 school year, and following the interministerial report on the shortage of a skilled labor force in the hi-tech industry, the program to increase the number of engineering students was launched. The Ministry of Finance and the Council for Higher Education's Planning and Budgeting Committee formulated an incentive plan to motivate universities to increase the number of undergraduates in the fields of electrical engineering, electronics, computer science, and information systems. In 2014/15, the number of first year undergraduates in the fields increased by 280. This plan is the continuation of previous plans that have been implemented exclusively in the engineering colleges<sup>50</sup>.

Some academic institutions develop virtual courses and learning platforms, learning through virtual conferences, and online teacher-student communication. These means are more developed in universities than in colleges, and are more common in natural science and engineering<sup>51</sup>.

Furthermore, it has been proposed that incentives be created for students to take courses in computer science, giving them the basic knowledge necessary for navigating the hi-tech industry. Another option proposed was to create a training course for students not studying science that will give them relevant training. These types of programs need to be developed with the industry<sup>52</sup>.

Finally, national foundations, such as the Israel Science Foundation, are in charge of supporting basic research, mainly through grants in a variety of topics, including science and technology<sup>53</sup>.

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47. "Shortage of a skilled labor," 37-38.

48. "The Higher-Education in Israel, 2015," 22.

49. "The Higher-Education in Israel, 2015," 22.

50. "The Higher-Education in Israel, 2015," 94-95.

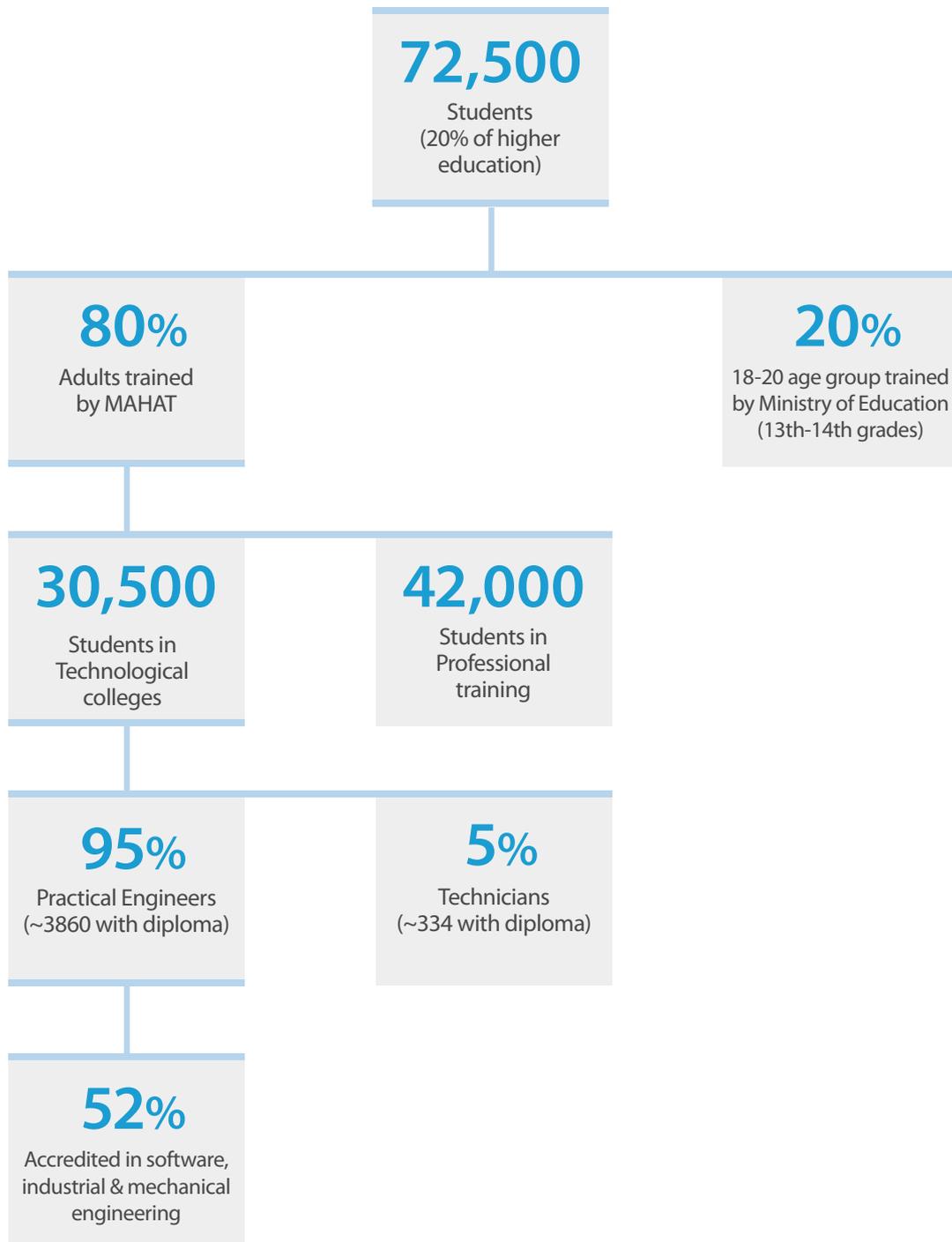
51. "The Higher-Education in Israel, 2015," 52.

52. "Increasing the supply of a skilled," 24-25.

53. "The Higher-Education in Israel, 2015," 60.

## 2. Technological colleges

### In numbers



Sources: Training Practical Engineers in the past Decade based of follow-up Surveys of Mahat's Graduate. Presentation to the Steering Committee on vocational and technological education in Israel, plan for 2014-2024, Ministry of Education

## Background

The same arguments have been made for the technological colleges regarding a feeble link to the industry and lack of focus on orienting students to the fields for which the industry is in demand<sup>54</sup>. Globally, developed countries display a growing demand for postsecondary qualifications involving less than a bachelor's degree, reflecting the fact that some occupations involve more than upper secondary qualifications but less than a bachelor's degrees. On the surface, the Israeli system thus contains a substantial gap in provision, or alternatively, an over-provision of bachelor's degrees for jobs that do not require three full years of training.

In Israel, different strands of the VET system are divided between the Ministry of Economy and Industry and the Ministry of Education. Other ministries, such as the Ministry of Tourism and the Ministry of Agriculture, have their own set of programs, although on a smaller scale. Therefore, practical engineering and technician programs in the same fields may vary significantly, and lead to different formal qualifications. This is in contrast to the arrangements in many other countries where programs are embodied in a well-defined set of programs or institutions that typically provide a visible definition for the sector.

Finally, the level of state funding per student (in comparable fields) is lower in practical engineering programs than in (academic) engineering programs in universities. In colleges under the Ministry of Economics, the average governmental spending per student is NIS 8,500, and NIS 6,370 in those under the Ministry of Education, compared with NIS 27,500 in academic engineering programs at a university. Some financial aid is available, but it varies between the two different frameworks. There is no government funding for the technician tracks. This leads to recruitment of unqualified, undertrained and underpaid teachers, obsolete labs, and it reinforces the negative image of those tracks<sup>55</sup>.

## Tracks

There are 67 technological colleges that train their students for technician and practical engineering accreditations, under the supervision of MAHAT<sup>56</sup>.

The entrance requirements for the practical engineering and technician programs are 12 years of schooling and passing grades in matriculation exams in math, Hebrew and English at the minimum level. These programs do not require a full matriculation certificate like universities, but in some colleges, students have to pass an additional admission exam<sup>57</sup>.

Graduates of practical engineering programs can continue their education in a university with a bachelor's degree, although this transition depends on individual arrangements between institutions. This transition is considered one of the main constraints to encouraging practical engineering students to pursue higher education (by law, tertiary education institutions such as universities and colleges cannot offer both higher education and VET courses)<sup>58</sup>.

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54. "Shortage of a skilled," 41.

55. Musset, Kuczera and Field, "A Skills beyond School," 35-37.

56. "Technological Colleges – facts and budgets," 1.

57. Musset, Kuczera and Field, "A Skills beyond School," 72.

58. Musset, Kuczera and Field, "A Skills beyond School," 51-52.

## G. Employment

### Key Points

1. Whereas every year, an additional 7,000 new jobs are added to the hi-tech sector, the number of high school graduates with satisfactory math skills is 6,600 pupils a year, and the number of graduates in computer disciplines from universities and colleges is only 4,500 a year.
2. The Ministry of Economy and Industry is very much aware that employers need to be more engaged and the Israeli background report itself assesses employer's involvement in funding, curriculum development and work-based learning as weak.
3. Compared to developed countries, graduates of non-academic postsecondary studies in Israel do not receive the tools needed for integrating in quality positions in the job market.
4. The higher education system does not manage to fully address the needs of the economy, articulated in a shortage of engineers in the hi-tech industry.
5. Jobs of the future will add additional stress on the system, because they will require new knowledge and skills if industries want to lead economic and technologic developments.

### In numbers

Israeli industry is the economy's growth engine<sup>59</sup>:

- In 2016, there are 283,000 Israelis working in the hi-tech industry, which represents 12% of salaried employees: 11% in R&D; 26% in electronics and computer science; 6% in pharma; 8% in aircrafts; 12% in communication; 37% in software<sup>60</sup>.
- Industrial sales (2015 estimate) - \$106.2 billion
- Industrial exports - \$45.3 billion
- Industrial product – an increase of 2.2% (the 2015 average compared to the 2014 average)
- The number of employed in industry (2015 estimate) – approximately 367,000 people (in addition to tens of thousands of service providers)
- 12% of all salaried employees work in the hi-tech industry
- Average industrial wage – NIS 13,331 (compared to NIS 9,591 in the economy overall)

59. Lotan, "What is the Connection," 2.

60. Globes Services, "The Ministry of Finance."

## Israel as a knowledge-intensive economy

The hi-tech industry has become the "locomotive" that pulls Israel's industry and economy forward. No one disputes that science and technology - and consequently science and technology education - are critically important to science-intensive (hi-tech) industries, modern agriculture, public wellbeing, and the maintenance and advancement of security. In those areas, Israel has proven accomplishments and is admired worldwide<sup>61</sup>.

Knowledge-intensive industries contribute to Israel's economy and to its standing and image in the world. That standing brings the top technology companies to the country, which set up R&D centers and manufacturing firms here. Knowledge-intensive industries account for about 50% of all industrial exports and position Israel as a country at the forefront of science and technology ("startup nation"). According to a report published by the Ministry of Economy in August 2014, for several years there had been an increase in the number of people working in the hi-tech industry - in 2011, they accounted for 10% of all employed persons in the economy (the highest number among all OECD countries). However, since 2011, there has been a slowdown in the pace of growth of the hi-tech industry. According to a report published by the Ministry of Finance in February 2016, 283,000 Israelis work in h-tech, accounting for 12% of all salaried positions. The hi-tech industry contributes 9% of the GDP and is responsible for 40% of total exports. The remainder of the GDP is contributed by a variety of traditional industries and services. However, because productivity in traditional industries and services is lower, workers also earn a low wage. Therefore there is a need to upgrade to a skilled workforce in technology and science, graduates of colleges and universities, two-year postsecondary institutions and schools for practical engineers and technicians. Furthermore, upgrading and training this needed manpower embodies tremendous potential for integrating large parts of the sectors which are now outside the workforce, such as ultra-Orthodox men, Arab women, as well as sections of the urban and geographical periphery<sup>62</sup>.

## Jobs of the Future

Rapid technological developments are expected to transform the future world of employment. There is, however, considerable uncertainty regarding the nature and scope of the changes, and employees and companies that will be unable to adapt to them will experience difficulties<sup>63</sup>. The World Economic Forum predicts that 35% of the skills required to succeed at a workplace today will undergo change during the next five years due to automation processes<sup>64</sup>.

Educated and skilled workers who know how to work in a digital environment and acclimate to rapid technological changes are expected to have an advantage in the "new" world<sup>65</sup>.

Compared to developed countries, graduates of non-academic postsecondary studies in Israel do not receive the tools needed for integrating in quality positions in the job market.

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61. "The Science, Technology, and Scientific-Technology", 11.

62. "The Science, Technology, and Scientific-Technology", 11.

63. "Strategic Economic-Social Assessment 2015," National Economic Council, 22.

64. Thomson, "The most important skills."

65. "Strategic Economic-Social Assessment 2015," National Economic Council, 10.

Additionally, the higher education system does not manage to fully address the needs of the economy, articulated in a shortage of engineers in the hi-tech industry<sup>66</sup>.

Israel has to choose the market structure and labor relations that are conducive to addressing 21st century challenges. International experience has shown that a policy that focuses on cultivating employees and imparting skills, coupled with job market flexibility (in northern European countries) is preferable when measured according to any parameter, to a policy that focuses on safeguarding permanent workplaces (in southern European countries)<sup>67</sup>.

## Technological and vocational training

A research study conducted by the Taub Center<sup>68</sup> mapped out the occupations in the Israeli labor market according to their computerization risk level. It found that around one million Israeli workers are at high risk of being replaced by computers or machines. The replacement of workers engendered by computerization trends has also ushered in new opportunities in the job market. Vocational training is a policy tool that could make it easier to cope with the expected changes in the labor market and prepare the population for employment opportunities in new, low-risk fields.

Programs of that kind already exist, both in the form of courses provided by the Vocational Training Division at the Ministry of Economy, as well as the issue of vouchers that can be used to subsidize vocational training. A number of training programs are run in cooperation with employers, including OJT, Classroom in the Factory, and the Starter Program (a pilot run in cooperation with JDC Israel Tevet, in which the employer pays the intern's salary during the training period)<sup>69</sup>.

Nonetheless, there is a critical need for expanding these services: out of the approximate 500,000 unemployed persons who come to the Israeli Employment Service every year, less than one percent are referred to these training courses<sup>70</sup>.

Furthermore, the subjects taught in the vocational trainings need to be updated. The findings of a survey conducted by the Israeli Employment Service indicate that the most common subjects studied by the workers who receive the training vouchers are at high computerization risk – for example, bookkeeping and payroll accounting. Expanding the vocational training programs and customizing them to the future needs of the labor market will ensure that the population, and in particular its most vulnerable members, will benefit from guaranteed employment options in the long term<sup>71</sup>. Based on data from the Manufacturers Association of Israel, Israeli industry suffers from a serious shortage of quality manpower at all levels, whether production floor workers, technicians and practical engineers, or engineers. Around 80%-85% of all employers cite the difficulty they face in recruiting skilled workers. The working assumption is that the shortage will become even more severe when many skilled and quality workers, and

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66. "Strategic Economic-Social Assessment 2015," National Economic Council, 23.

67. "Strategic Economic-Social Assessment 2015," National Economic Council, 25.

68. Madhala-Brik, "Analog in a Digital World."

69. Eckstein, Lifschitz, Sagie and Trilenik, "Technological and Vocational Higher Education," 8-9.

70. Madhala-Brik, "Analog in a Digital World."

71. Madhala-Brik, "Analog in a Digital World."

in particular new immigrants from the CIS who have integrated well in industry, retire<sup>72</sup>. The current vocational training system is a residual system that finds it difficult to reach employees in the labor market. Vocational trainings that rely on training centers deployed around the country are dwindling. Most of the interventions are carried out within the factories or through business courses offered in the private sector. The dramatic change in the standing of vocational training in Israel has been witnessed in the massive budget cuts at the Vocational Training Division. The training budget for adults decreased from NIS 159.4 million in 2000 to NIS 45 million in 2012. In 2015, for example, 4,800 people were trained out of the Ministry of Economy budget, of which 1,000 took computer courses and 412 took electricity and electronics courses. Additionally, out of 1,502 vocational training vouchers, 137 were issued to industry and 233 to technology<sup>73</sup>.

Finally, another factor affecting the success of the system is the institution of clear accreditation rules. Those rules facilitate transitioning between technological training and academic studies – and the other way around - which augment and streamline the studies. They also enable the labor market to assess the skills of the graduates and the different levels of knowledge they have acquired. The accreditation system frames the worker's career path, facilitates professional advancement by granting credit to previous studies, and provides employers with a transparent system for assessing which professional level the worker is at<sup>74</sup>. In 2015, only 5,858 students were accredited as practical engineers or technicians, as opposed to 50,000 students at academic institutions who completed their degrees. According to data collected by the Economy and Research Administration at the Ministry of Economy, in 2008-2009 only half of the people who completed their studies at technological colleges found employment in the field they majored in after graduating.

For many years, traditional industries were a major economic and employment foundation in the Israeli economy, making a special contribution to different regions in the periphery. The fading of traditional industries has created an economic and social problem. Restoring those industries to their appropriate place will necessitate a national approach based on innovative tools and financial tools. To achieve that end, it will be necessary, among other things, to train skilled manpower. The renewed growth of traditional industries means training thousands of new workers. However, the challenge is not limited to the shortage of skilled manpower. To train people who will be able to meet the requirements of industry and future occupations, the curriculum, training programs and the way they are delivered need to be updated to ensure they incorporate skills development and hands-on professional experience.

To meet market requirements, the government has to set a target that once again determines that around 50% of all workers participate in vocational study programs<sup>75</sup>.

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72. Eckstein, Lifschitz, Sagie and Trilenik, "Technological and Vocational Higher Education," 3-4.

73. Lotan, "What is the Connection," 10-12.

74. Eckstein, Lifschitz, Sagie and Trilenik, "Technological and Vocational Higher Education," 22.

75. "The Science, Technology, and Scientific-Technology", 44

## IV. Untapped populations: Gender, Minority and the Periphery

### Key Points

1. The Ultra-Orthodox, women, and the geographic periphery are populations that present a particular challenge; numerous national and private initiatives seek to narrow the existing gaps.
2. The gaps are well known, and there is broad-based consensus that they must be confronted in order to secure the national objectives. Nevertheless, the gaps are numerous and extensive.
3. While 15% of Israel's academic high schools do not offer any of the technology or science courses at the 5 unit matriculation level, and 35% do not offer chemistry, efforts are underway to redress the situation prevalent primarily on the geographical and socioeconomic periphery.

## A. Sectorial deficits

### Overview

Sectorial deficits are very often due to a combination of education, culture, opportunities, and budget allocation. In order to increase the quantity and quality of STEM students and workers, national efforts are being made to tap into the potential of population that lag behind in general, and in STEM education in particular: Women, periphery, Arabs, and Ultra-Orthodox Jews.

There are different programs that tackle the sectorial deficit and advance equal opportunities for all population. Programs involve cross-sector partners and interministerial work, and are being adapted to each sector in order to answer some particular characteristics. For example, the gender gap's main objective is to establish an organizational climate that stimulates equal opportunities in Science and Technology learning. It seeks to encourage student girls to choose disciplines from the scientific area: Physics, Chemistry, Biology, and the Engineering Technological disciplines in secondary education in view of the IDF and future career development.<sup>76</sup>

The main efforts to integrate the Arab population in the high-tech industry focus on three avenues: 1. Budget allocation from the Planning and Budgeting Committee to encourage Arab students to learn STEM studies; 2. Integration of graduates in the industry; 3. Orientation towards technological studies.

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76. Kearny, "National Response: Israel," 52

There is a strong national will and policies to tap into the potential Haredi population and beside national-level initiatives, some private-sector initiatives exist to integrate the Haredi population in the IDF and high-tech industries.

Most programs, including national programs, put a strong emphasis on developing the STEM potential in the periphery. The National Program To advance Math Excellence, includes the recruitment of Mathematic teachers among hi tech professionals; the establishment of smaller classes; support for Virtual Classrooms for students whose schools do not offer a 5 units program in Mathematics (mainly schools in periphery regions unable to recruit adequate teachers; The Ministry of Sciences, Technology, and Space's Support for RTD Regional Centers in Peripheral Regions' (mentioned above)<sup>77</sup>, and the Ministry for the Development of the Galilee and the Negev, developed strategies and programs – that are aligned with national development plans of those areas – to open academic and research centers, some of them in the STEM field, such as the Faculty of Medicine in the Galilee, or cooperation programs with industries that support STEM students during their studies through grants and training positions, as well as a position for a year after graduating.

## Women

The number of women in R&D positions in the private sector is 25%.<sup>78</sup> Of the women studying STEM fields, 47% choose 5 units in mathematics; 27% of IDF soldiers serving in programming positions are women. Among those who defer IDF service to first acquire a profession that meets anticipated needs, to serve in the reserve corps noted above 20% are women, but only 16% of them are in engineering; and 7% serve in technical or technological positions.<sup>79</sup> In 2013/14, engineering was the field of study for 27% of the undergraduates, 29% studied mathematics and computer science, 37% studied physics and 64% studied biology.<sup>80</sup>

## Gaps in high school:

Matriculation exam data in the Sciences and Technology and PISA test scores in Math, the Sciences and Problem Solving, which is administered to students at the age of 15, indicate large disparities between different high school-aged groups in the population.

## Gender gap: female students - male students

Based on matriculation exam data, one can see gender gaps in some of the subjects:

- In 5 study units in Math, the percentage of male and female students is identical and no significant gap exists.
- In Physics and Engineering, the percentage of female students who take matriculation exams in those subjects is lower than the percentage of male students.
- In Biology and Chemistry, the percentage of female students is higher than that of the male students.

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77. The purpose is to establish a local knowledge basis as ground for the social and economic development in peripheral regions; stimulate cooperation between researchers in established institutions with researchers based in the periphery; to expose Science to the community through the RTD Centers; cooperate with the educational system in advancing study of STEM disciplines. Kearny, "National Response: Israel," 24

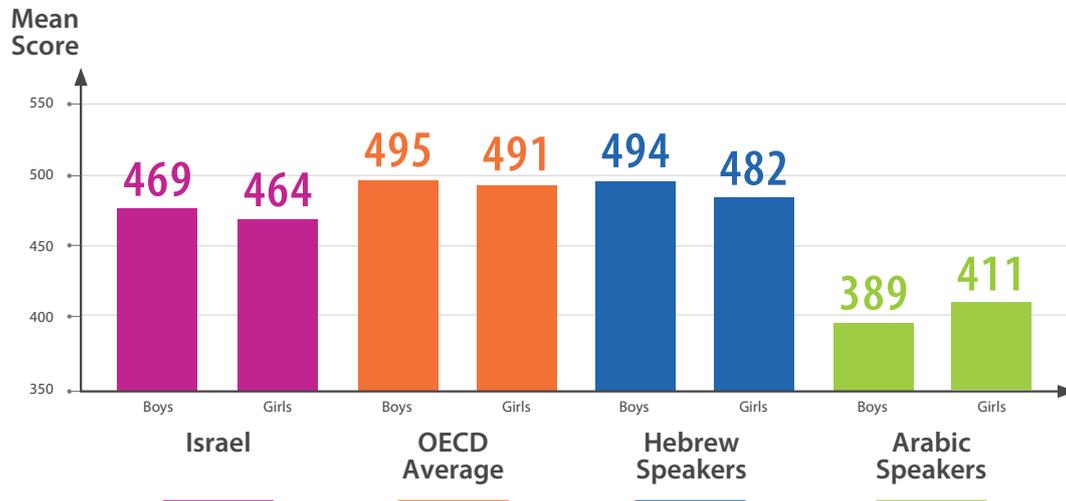
78. Manny and Rosen, "Teaching Sciences in Israel," 12.

79. Hazan (sup.), "The Scientific and Technological Education," 35-36.

80. "The Higher Education in Israel, 2015," 44.

## PISA Math and Science test data (2015):

Overall, PISA Math and Science test data (2015) indicate that there are no significant differences between the achievements of male and female students. In the Arab sector, the female students have higher scores on the tests than those of the male students. (PISA test data in the Sciences are presented below. The Math data suggest similar trends).



## Gender gaps in higher education

The Science and Technology subjects that are taught at institutions of higher learning include: Math, Statistics, Computer Science, Biological Sciences, Physical Sciences, Engineering and Architecture.

The following data pertain to the percentage of women who take STEM courses at universities and colleges in selected years (Source: The Higher Education System, 2014, The Council for Higher Education, Planning and Budgeting Committee)

	Math, Statistics & Computer Science	Physical Sciences	Biological Sciences	Architecture & Engineering
2009	29%	36%	64%	28%
2013	29%	37%	64%	27%

### The data show that:

- In Math, Statistics and Computer Science, and also in the Physical Sciences, the percentage of women is lower than their share of the population. Furthermore, over the years, there is a downward trend in the percentage of women who study those subjects.
- In the Biological Sciences, the percentage of women is higher than their share of the population.
- In Engineering and Architecture, the percentage of women is lower than their share of the population. However, over the years, there has been an increase in the percentage of women who study for a BSc in these subjects.

## Arabs

20% of the Arab population who have graduated from academic institutions and have earned degrees in science and technology work in the hi-tech industry. They face barriers that include: geography, language, lack of professional experience compared to the Jewish population which gains experience in the course of its military service, security limitations, etc.

The Arab Israeli population has limited access to postsecondary education, including vocational programs. Although 40% of the student population in upper secondary VET programs (those under the Ministry of Economy and Industry) are Arabs, they represent only 7% of students in practical engineering and technician programs (2013).<sup>81</sup>

In 2012, there were 1,638 Arab students studying for engineering and computer science degrees, or 7.5% of all students, but only 3% are employed in hi-tech, among whom 1-1.5% are engineers.

### Sector gaps in high school: the Jewish sector & the Arab, Druze and Bedouin sector

Matriculation exam data indicate that compared to the Jewish sector, only a very low percentage of students from the Arab, Druze and Bedouin sector study Math, Sciences and Engineering.

	Math (5 units)	Physics	Chemistry	Computer Science
Jewish Sector	84% 	78% 	58% 	88% 
Arab Sector	12% 	18% 	33% 	10% 
Druze Sector	2% 	3% 	5% 	2% 
Bedouin Sector	1% 	1% 	4% 	1% 

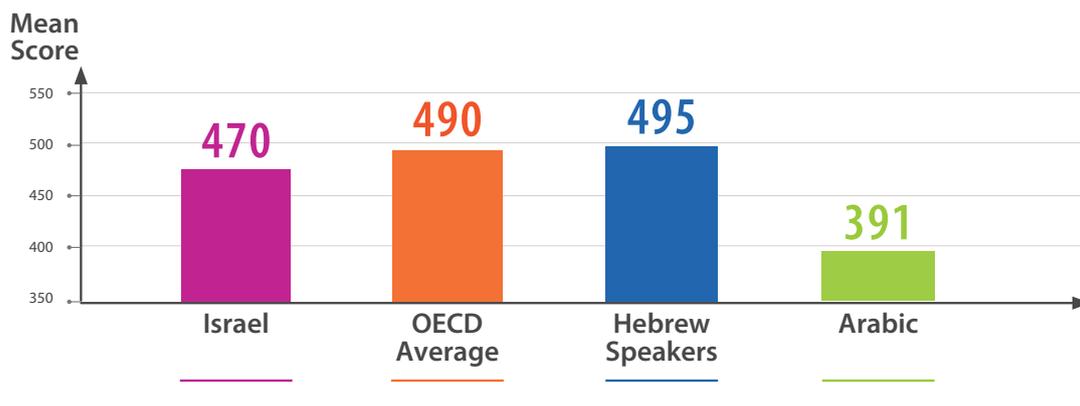
Year of Graduation: 2014

Data source: Ministry of Education

81. Musset, Kuczera and Field, "A Skills beyond School," 33.

## PISA test scores in Math

- PISA test scores in Math indicate that a large gap exists between the scores of Arabic speakers and Hebrew speakers. The scores of the Hebrew speakers were 104 points higher than those of the Arabic speakers.
- The gap between the OECD average and the average of the Hebrew speakers is only 5 points, whereas the gap between the OECD average and the Arabic speakers is 106 points.



Source: Rama, The National Authority for Measurement and Evaluation, the Ministry of Education

## Haredi – the ultra-Orthodox population

Haredi, ultra-Orthodox students face a different challenge, but with similar consequences. There are 600,000-900,000 Haredi citizens, 8%-10% of whom get a higher education. Of them 13% chose science and engineering tracks. Every year, 0.5% choose 5 units in mathematics, 2,500 women graduate as practical software engineers, and 2% are employed in hi-tech.

Haredi schools offer far fewer technological courses than other schools (5% of the state-religious schools were in vocational or technological tracks in 2010). Even though there are no specific data about their participation in postsecondary VET programs, anecdotal evidence seems to show that their participation is very limited.<sup>82</sup>

## B. Periphery

### In numbers

The gaps in national and international aptitude achievement tests in STEM subjects between pupils from well-established towns and pupils in the periphery are extremely wide, the highest among the leading 25 OECD members<sup>83</sup>.

The more distant a town is from the center of the country, the lower the chances that the high school offers its students STEM courses for matriculation. The figures improve somewhat if ultra-Orthodox educational institutions which choose not to offer science classes are not factored in, and if facilities for dropouts and at-risk youth are also disregarded. However, even then, a full 15% of Israel's academic high schools do not offer any of the technology or science courses at maximum 5 unit matriculation level, and 35% do not offer chemistry at all.<sup>84</sup>

82. Musset, Kuczera and Field, "A Skills beyond School," 33.

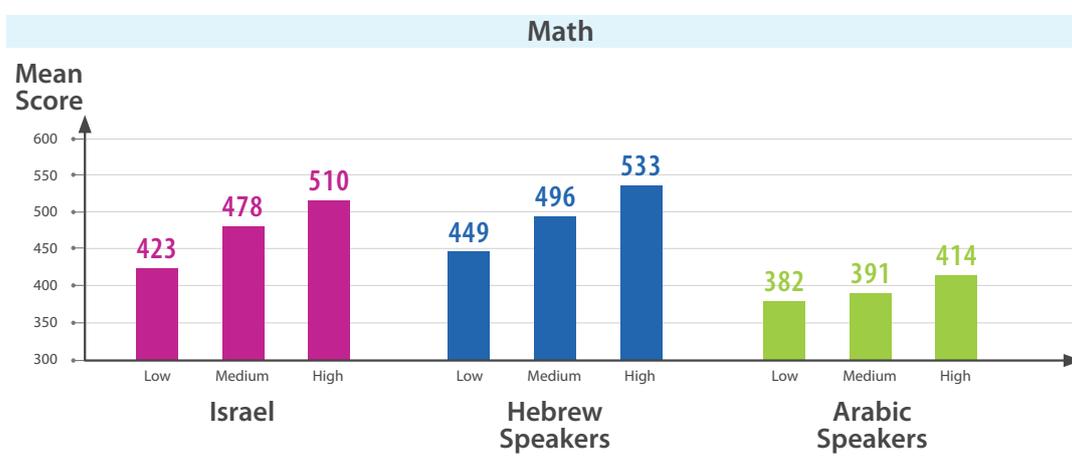
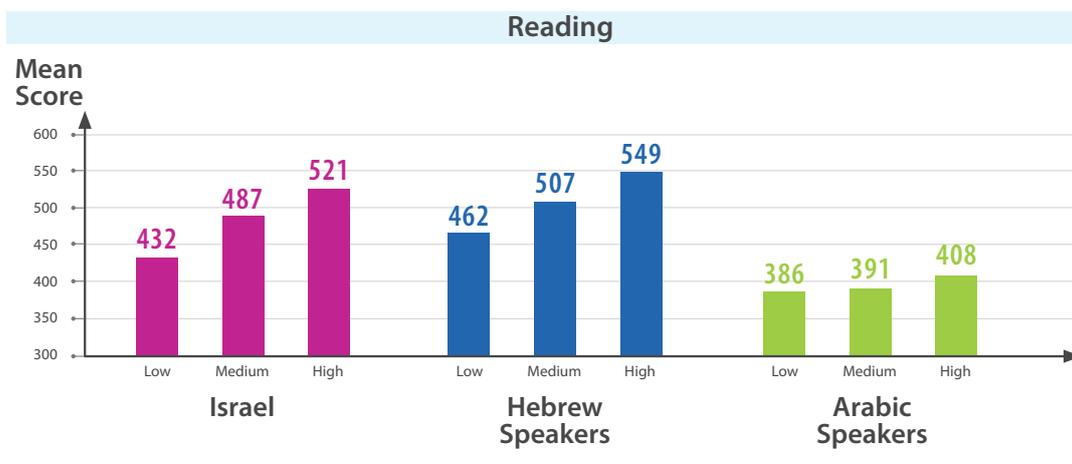
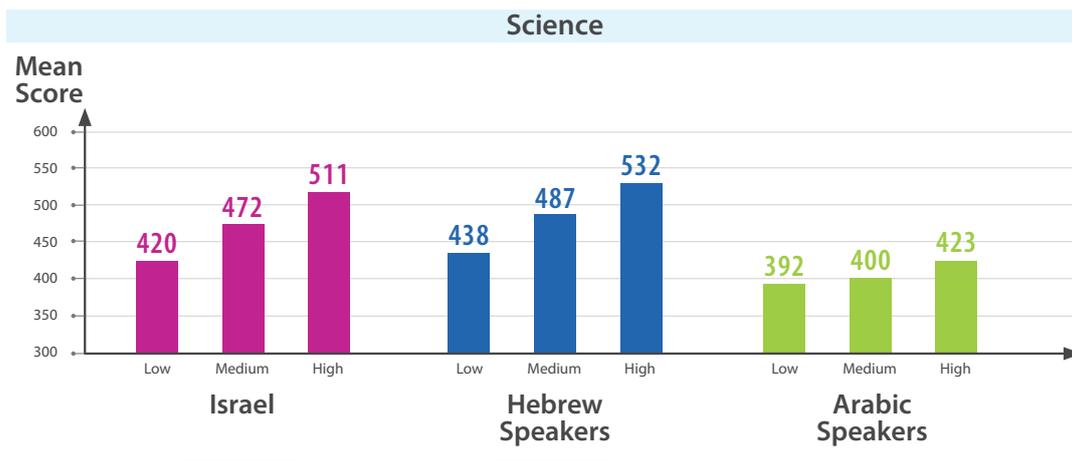
83. Levy, "Status of STEM Teaching," 9.

84. Dattel, "Fewer Science Classes Offered."

As a result, the opportunity for students to graduate high school with a focus on either science or technology is largely a function of how close they live to the center and their community's standard of living.

### PISA test scores (2015)

PISA test scores in Math indicate that, on average, students who come from a high socioeconomic status have higher test scores. That holds true both for Hebrew speaking students and Arabic speaking students.



## Strategy for change

Most programs – national, local, formal and informal - put a strong emphasis on developing the STEM potential in the periphery: The National Program To Advance Math Excellence, includes the establishment of smaller classes and support for virtual classrooms for students whose schools do not offer a 5 unit program in mathematics (mainly schools in peripheral regions unable to recruit adequate teachers); RTD Regional Centers in Peripheral Regions' (mentioned above), with the support of The Ministry of Sciences, Technology, and Space, aim at establishing a local knowledge basis; stimulating cooperation between researchers in established institutions with researchers based in the periphery; exposing science to the community; and cooperating with the educational system in advancing study of STEM disciplines and HOTAM – engaging excellent STEM graduates for teaching (including English and civic studies). They are deployed at periphery towns and in cities quarters in which there is a need for educational and social strengthening.<sup>85</sup>

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85. Kearney, "National Response: Israel," 48.

## V. Conclusions:

# Gaps and opportunities for action

The main goal of mapping the STEM pipeline was to highlight the current state of STEM education from kindergarten to employment in Israel. Implications of the mapping then provide a frame of reference within which plans of action for the future can be considered. At almost any given crossroad, numbers and analyses show that although there is a real understanding and action on the national level of the need to improve scientific and technological literacy and excellence, gaps remain.

All the short and medium term programs are estimated to result in an additional 500-600 engineers per year. The long term programs can be divided into two categories: 1. programs aimed at ensuring the market's future reserve; 2. exposure of children and adolescents to science and technology amidst positive experiences, which cultivate positive attitudes, and role models. It is difficult to estimate the quantitative impact of those programs, including those which are IDF-related. Nevertheless, stimulating the STEM pipeline at its major stations is likely to increase the necessary skilled workforce to sustain industry growth and needs<sup>86</sup>

Nonetheless, the gaps are not only measured in numbers. There are also major gaps in content, which is often obsolete, and gaps in the way of teaching and learning, skills, methodology, and ICT literacy need to be integrated along the STEM continuum.

This chapter will attempt to highlight the main gaps and main opportunities for further action:

### 1. Continuum, synchronization and coordination

Currently, the continuum along and across the STEM pipeline is fragmented and lack continuity. Along the pipeline, the different stakeholders in each phase are not accountable and responsible, but to achieve their own goals, with no general overview of the entire pipeline. For example, Junior high school and high school have been identified as a critical phase. All stakeholders in that phase need to look back in order to create a strong continuum between kindergarten and high school. On the other hand, they need to look and assess future needs – IDF, higher education, employment - in terms of content and skills, in order to create a second strong continuum from high school to employment through IDF and higher education.

Across the pipeline, there is a lack of synchronization and cooperation between the formal and informal education. Excellence, but also literacy, require the mobilization of concurrent circles: school, family and community. Hence, the necessity to strengthen the coordination and common activities between the education system and the diverse education NGOs, science

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86. "Increasing the supply," 48-49.

museums, educational networks, universities, research centers that operate complementary, and sometime parallel, programs.

## **2. Untapped populations - Providing solutions for women, Arab, Haredi, and the periphery**

Sectorial deficits are very often due to a combination of education, culture, opportunities, and budget allocation. In order to increase the quantity and quality of STEM students and workers, national efforts are being made to tap into the potential population that lag behind in general, and in STEM education in particular: Women, periphery, Arabs, and Ultra-Orthodox Jews.

Although targeted programs exist on the national and local levels, the gaps between sectors and geographical lines are still so distinct and will not disappear without external intervention, that the need to further address these gaps and be proactive through affirmative action programs is an imperative.

Additionally, there are not enough efforts of coordination and synchronization between the Ministry of Education, the local municipalities and academia to increase the participation of these populations and address motivation and incentives for education and technological training.

## **3. Quality Skilled teachers**

The shortage in quality skilled teachers is the most strategic issue across the pipeline, and one of the main avenues for change and action, since teachers have a tremendous influence over their students' educational and professional choices. Efforts are being pursued on a national level to train quality teachers, and provide incentives for career changes for industry personnel. This needs to be addressed through quality training preservice for teachers, through the teachers' training colleges, and not just in service, after being enrolled as a teacher. New training methodologies and content need to be introduced, as well as tighten the entrance criteria for STEM teachers. The Trump Foundation is a major player in cultivating high school teachers focusing mainly on 5-unit math and physics teachers in high schools. Investment in all other teachers in STEM and STEM-related fields along the pipeline from junior high school to higher education is limited. The problem becomes exacerbated in technological tracks and colleges where there is sometimes a tradeoff between pedagogy and experience, as a result of which the graduates of these programs are shortchanged and less prepared than they could be for entering the labor force in STEM fields.

## **4. Kindergarten and elementary school**

The Ministry of Education has changed curricula in a manner reflecting their recognition of the need to start STEM education at an early age. However, informal educational organizations, industry and philanthropists, have yet

to become engaged in this arena. Most of the attention remains focused on junior high school, and even more on high school, where results are already evident. The relevant entities, from all sectors, should be made aware of the real need and potential that can begin to be tapped from kindergarten as a catalyst for long term improvement in the results at the end of the pipeline.

## 5. Technological education

A number of issues interfere with gaining the most effective results from the technological education pipeline:

- The duplication between the Ministries of Education and Economy and Industry, has created a political decision-making rather than a collaborative environment in terms of knowledge, skills and attitudes.
- The degree of government funding is lower for teachers in the technological tracks than in academia. The budget for technological colleges is a 1/3 of the academic college's budget, per student per year. This is also the case for teachers, labs, etc.
- The technological education has a bad reputation and a positioning problem. In the current state of affairs, the biases, stereotypes, and negative attitudes towards the technological tracks will continue, unless the public sees and believes the field is taken seriously. High profile campaigns similar to the Math efforts, defined as high priority and backed by dedicated additional budgets, should be a possible model to duplicate.
- Insufficient commitment and involvement on the part of the private sector with respect to different methods of training - employment, mentorship, apprenticeship, etc., from the early stages of technological education – leaves unaddressed needs. Encouraging a growing role for the private sector in STEM education should prove beneficial for students, teachers and employers.

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## 6. Higher education

The past decade has seen an increase in the number of graduates in fields that do not reflect the market needs. Clearly higher education has been unable to respond to the demands of the industry.

In order to address the need to train students in the STEM professions, particularly computers and engineering, the Ministry of Finance and the

Budget and Programs Committee amended the budget and created incentive packages for universities that manage to increase the number of students. Universities have also developed virtual courses and learning platforms.

However, some substantial gaps remain. First, the university's acceptance criteria in science and technology should reflect the importance of skills and knowledge, and include such criteria as project work, critical thinking, innovation and creative thinking etc.

Second, the universities entrance bonuses do not reflect the necessity to encourage STEM studies. They give a 35% bonus for students with 5 points matriculation in mathematics , 25% for students with 5 points matriculation in sciences and only 20% for other 5 points ,articulation for all other disciplines including technology and engineering studies. This difference gives those studying math and sciences a real advantage compared to those studying technology. Hence, students have less incentives to study technology. Changing the bonus difference sends a clear message that technology is as important as science in STEM education.

In some of the OECD countries it has been reported that there is a mismatch between the graduates of the academia and the requested work force in the labor market. More effort and investments are required to integrate industrial practice in the engineering curricula.

Finally, Practical engineers who would like to peruse their engineering studies in Israeli universities should be accredited with more academia credits, which will enable them to complete an engineering degree 2-2.5 years as it is in American or European universities.

## **7. Employment and Workforce Development**

Whereas every year, an additional 7,000 new jobs are added to the hi-tech sector, the number of high school graduates with satisfactory math skills is 6,600 pupils a year, and the number of graduates in computer disciplines from universities and colleges is only 4,500 a year. The indicators of the shortage are the numerous available positions with high salaries, the insufficient high school graduate flow and industry reports of difficulties in recruiting personnel.

In parallel, the hi-tech and practic-tech industries lack thousands of technicians and practical engineers. The Ministry of Economy and Industry is very much aware that employers need to be more engaged and the Israeli background report itself assesses employer's involvement in funding, curriculum development and work-based learning as weak.

Compared to developed countries, graduates of non-academic postsecondary studies in Israel do not receive the tools needed for integrating in quality positions in the job market. Additionally, the higher education system does not manage to fully address the needs of the economy, articulated in a shortage of engineers in the hi-tech industry.

Finally, jobs of the future will add additional stress on the system, because they will require new knowledge and skills if industries want to lead economic and technologic developments. Israel has to choose the market structure and labor relations that are conducive to addressing 21st century challenges.

## **8. Final Remarks**

The goal of mapping the STEM pipeline was first to highlight the current state of STEM education from kindergarten to employment in Israel. Although there is at almost any given crossroad a real understanding and action on the national level of the need to improve scientific and technological literacy and excellence, gaps remain. Implications of the mapping then provide a frame of reference within which plans of action for the future can be considered:

Despite the gaps, we are witnessing some positive trends in STEM education which are indicative of a real momentum for change. This is evident in the increasing number of students taking the 5-unit math and quality matriculation, as a direct result of the national plan implemented by the Ministry of Education and the recent policy changes. Math, however, is a necessary but not sufficient to close all the gaps, and are only the first step, followed by a stronger integration between science and technology, whether literacy, skills, or excellence.

The STEM issues can only be tackled by moving from an ego-system approach, in which each stakeholder looks at the pipeline from his perspective and agenda, to an eco-system that includes all STEM stakeholders along and across the pipeline, so as to create a real, comprehensive continuum, where the strategy takes into account each phase. A concerted effort, will attract more quality women and men along the pipeline. In order to cope with the challenges of the 21st century – new skills, new jobs, new technologies - an integrative, inter- and multi-disciplinary approach is required from stakeholders.

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