Consultant Report
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STEM: Country Comparisons

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STEM in Israel: The Educational Foundation of 'Start-Up Nation'

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Table of contents

List of Figures

List of Tables

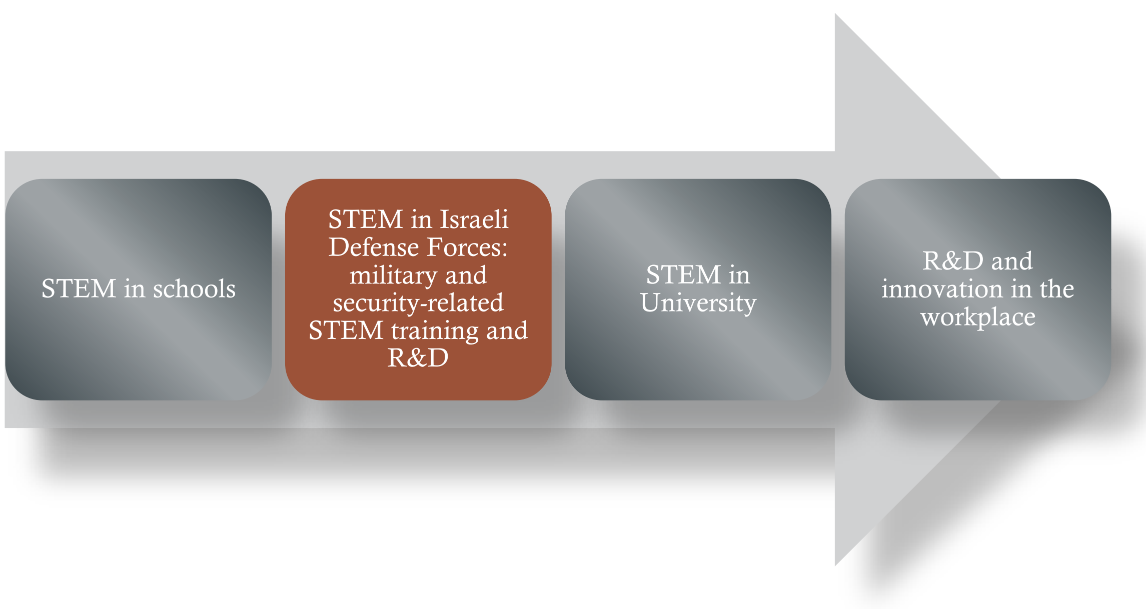
1. Executive summary

Israel enjoys the reputation as ‘Start-Up Nation’, celebrating the success of its innovation-driven high-tech economy. Much of the credit for today’s thriving knowledge economy is given to Israel’s education system, particularly to Israeli universities and research institutes. This report examines science, technology, mathematics, and engineering (STEM) education, from primary schools to tertiary education institutions, and considers its impact on STEM-related workforce in Israel.

Israeli STEM is unique in three ways.

- Like the United States, Israel’s STEM pipeline has the odd feature of weak input and particularly strong output: STEM education in schools is compromised due to weak infrastructure, high student-to-teacher ratios, and small budgets yet Israel is among the leading countries in academic research, industrial and military R&D, and high-tech innovation.
- Israel’s STEM potential is compromised by the fact that an estimated 15-17% (and rapidly growing) of Israel’s population is Ultra-Orthodox and therefore does not participate in STEM education and workforce.
- Departing from the typical STEM pipeline of schooling into the workplace, Israel’s STEM track is ‘interjected’ with compulsory military service for 18-year-olds. This requirement of a *minimum* of 2 (women) or 3 (men) years of service delays the start of tertiary education, yet also builds skills and work culture that translate into innovation and entrepreneurial capabilities.

Israeli STEM ‘pipeline’



Additional findings

- The Israeli public takes great pride in Israeli science, technology, and innovation and is confident in their importance for national security, prosperity, and quality of life.
- Israeli schools require a minimum of math and science classes until 10^{th} grade and offer elective, expanded curriculum in math, physics, chemistry, and biology, including high-level matriculation in STEM. Israeli high-school students can also continue with 13^{th} and 14^{th} years, in STEM professions.
- Compared with other OECD-member countries, Israel ranks 6^{th} for ages 7-8, 13^{th} for ages 9-12, and 19^{th} for ages 13-15 on share of hours devoted to STEM.
- Between 2007 and 2011 TIMSS rounds, Israel's scores dramatically improved, with ranking climbing by 17 in math and by 12 in science.
- Israel's eight universities, which account for 78.2% of the total higher education budget, register more patents than firms, military labs, and private labs combined.
- Israeli Defense Forces (IDF) serves three functions in Israel's STEM pipeline: by training recruits in many technical fields, by providing work habits and team building skills that translate nicely into the work culture of start-ups, and by being a large client for local R&D.
- Israel's 'Silicon Wadi' is a magnet to foreign innovation-intensive firms: in 2012, over 240 foreign firms located R&D centers in Israel. Vibrancy of local high-tech is also drawing Israeli scientists and engineers, thus taming brain drain.

1. Introduction

Senor and Singer's 2009 book, 'Start-Up Nation', quickly hit the best-sellers list of the Wall Street Journal and the New York Times and was translated into some twenty languages. The book peaked the world's fascination with Israeli innovation by answering 'the trillion dollar question': 'How is it that Israel – a country of 7.1 million, only 60 years old, surrounded by enemies, in a constant state of war since its founding, with no natural resources – produces more start-up companies than large, peaceful, and stable nations'? And, 'how is it that Israel has, per person, attracted over twice as much venture capital investment as the US and thirty times more than Europe?' The Israeli 'miracle' stands as a code to be cracked, or as an exemplar for countries and regions worldwide that are seeking innovation-based development. The buzz around this book builds on the recognition of innovation as the critical component for success in the global knowledge economy: the basis for an innovative and entrepreneurial economy that is integrated into the global knowledge economy comes from the foundations in education, particularly in the fields of science, technology, engineering and mathematics (STEM).

Israel's base in science education is anchored in institutional development prior to the founding of the State of Israel in 1948. As early as 1924-1925, two prime institutions were founded, modeled after the German higher education: the Technion (Israel Institute of Technology) and in The Hebrew University of Jerusalem. These institutions offered classes and degrees in a range of STEM fields and, carried forward the ethos of Zionism as continuing on the legacy of the 'people of the book', education and science received broad support. In this spirit, among the first acts of the emerging State were a series of education-related policies and laws. But pre-state sectoriality carried into statehood and education was soon partitioned into three separate systems: national secular, national religious, and independent system that is overwhelmingly Ultra-Orthodox. With the Ultra-Orthodox sector shunning science education and the national-religious sector giving it low priority, Israel's STEM 'pipeline', conceived as the kindergarten-to-lab pathway, is fed almost exclusively through the nation-secular system. This adds to an already weakened human capital foundation: Israel's class size is among the highest in OECD countries, only 47% of high school students reach the level required for admissions to tertiary education institutions, and while national education expenditure is higher than the OECD average, expenditure per capita is dramatically lower in comparison and expenditure on STEM is lower yet. Here lies the riddle of Israel's economic success: with a weaker-than-average base in STEM education and decade-long cuts in higher education and R&D, what are the human capital foundations for Israel's most successful innovation-driven and technology-laden economy?

2. Attitudes towards STEM

The Israeli public, Israeli institutions and the international business and finance community express much confidence in Israel's science, technology and innovation and, by implication, in Israel's STEM education and its labor market impact. Israel's high-tech boom and the strength of Israel's economy through the 2008 recession are attributed to the match of Israel's STI base with conditions of the global knowledge economy.

2.1 Public support

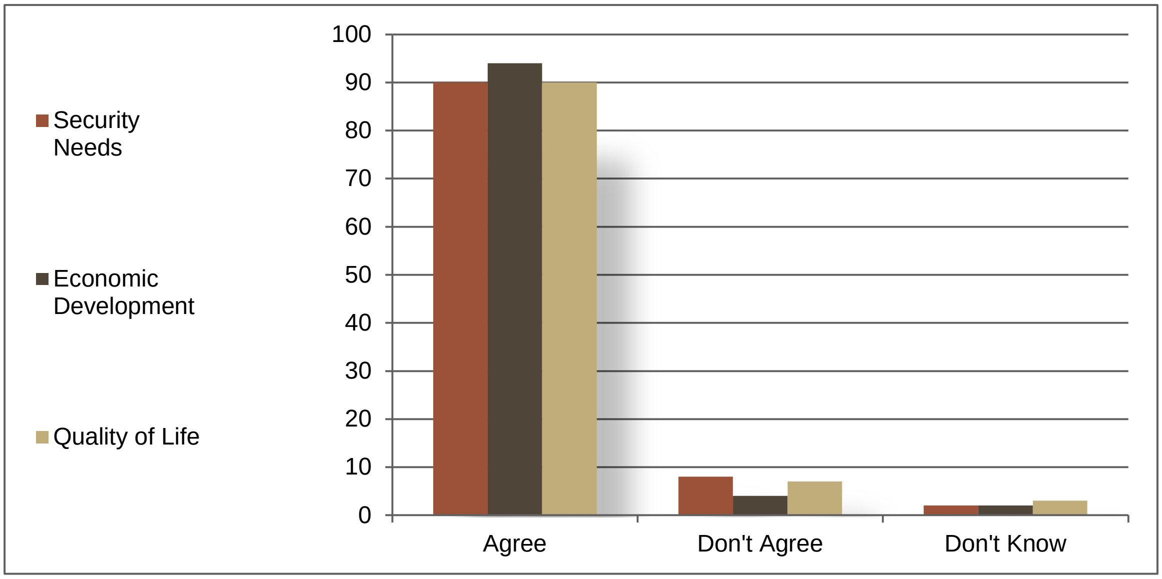
Israel prides itself on its 'brain power'. In a 2006 public opinion survey, Israelis listed science and technology as the top source of national pride (78% of Israelis) and the category of academia and higher education was ranked 3rd (74%; Yaar 2006:8). Israelis also consider science and technology as essential for Israel's future: 90% of Israelis agree that science is essential for Israel's security[1], 94% note it as essential for Israel's economic success, and 89% - as essential for wellbeing (see Figure 1). Only the Ultra-Orthodox sector departs from this overwhelming confidence in science, even if also among this rather isolated community in which STEM subjects are not at all taught, 67-75% argue for the importance of science for security, economic success and well-being (Yaar 2006:5).

Israeli academia specifically wins the confidence of the Israeli public: second only to the Israeli Defense Forces (IDF) and in advance of Israel's High Court of Justice, the news media and elected officials, 71% of Israelis proclaim utmost confidence in the Israeli higher education system and academics (Yaar 2006:8). Related to this, Israeli parents rank engineer, doctor, and scientist as the top three professions they wish for their kids (2006:12). Israeli children too describe science as a desired profession:

[1] With a gap between Jewish and Arab Israelis: 91% of Israeli Jews and 83% of Israeli Arabs regard science as important for Israel's security (Yaar 2006:3).

34% of Hebrew-speaking school children and 45% of Arabic-speaking school children say that they want to become a scientist (Koren and Bar 2009:2499).

Figure 1. Israeli Public Confidence in the Utility of Science



2.2 STEM literacy

With the aspiration of 'aiming not just at superstars but rather at the whole population,'[2] as early as 1968 the Witzmann Institute of Science founded the Department of Science Teaching. The Department, which has since evolved into the Davidson Center for Science Teaching, remains dedicated to writing instructional material, developing pedagogies, setting curricula, and training STEM teachers. Out of these plans came numerous pioneering education strategies and experimental teaching strategies. For example, Rachel Mamlok-Naaman and Avi Hofstein (Abd-El-Khalick 2004: 404-406) report of Israeli experimentation with inquiry-type laboratories for teaching chemistry, which found to reduce teachers' anxiety about hands-on teaching methods and to increase students' excitement about learning and their independent thinking, were later deemed too expensive for system-wide implementation.

These pedagogical efforts to create STEM literacy are nevertheless met with student complaints: Hofstein, Eilks and Bybee (2011) report of school children complaining that science studies are not interesting and, as reported in Section 2.1, many school children take only the minimal requirement in STEM studies in order to graduate high school. Gaps in STEM literacy among school children in Israel are also evident by gender (Barak and Asad 2012) and by Hebrew-language proficiency (Zuzuvsky 2010).

To expand initiatives beyond schooling, STEM literacy is also advanced through Israel's 7 science museums. The largest among them are the Technion-affiliated

[2] Phrase attributed to Prof. Haim Harari, later President of Weitzmann Institute (see, Weitzmann Institute, 2012: 5).

MadaTech in Haifa and The Hebrew University-affiliated Bloomfield Science Museum in Jerusalem. MadaTech, which was founded in 1986 and resides in the 1920s historic home of the Technion, draws some 450,000 visitors annually and holds special programs for school visits, for grades K-12. The Bloomfield Museum, which developed out of kids-friendly workshops held on The Hebrew University's campus, has operated since 1992 and moved into its current attractive residence in 2001.

In spite of these efforts to introduce STEM literacy, Israelis hold a rather stereotyped perception of science and of scientists. Rubin, Bar and Cohen (2003) report that soon-to-be teachers did not differentiate between a scientist and an inventor and described a scientist as a male (with not even a single female scientist named among their top-20 scientists; with Arab-speaking Israelis noting an Arab man and Hebrew-speaking Israelis describing a scientist as a Western man), wearing glasses (57%) and with un-styled hair (44%). These students in teachers' colleges also exhibited a most limited familiarity with general science: for example, while over 90% of all students recognized the name of Albert Einstein, over 50% also regarded Christopher Columbus as a leading scientist. Follow up studies reveal a similar pattern (see, Koren and Bar 2009). These perceptions of science have implications for the raising of future STEM in Israel. Rubin, Bar and Cohen conclude that '[t]he existence of these gaps in the consciousness of trainee teachers and, presumably, of practicing teachers is likely to result in their pupils receiving an inadequate picture of the role of the scientist in society, his character, his equipment and the location of his work' (2003: 841).

2.3 Investments in STEM

Investment in STEM-related activities and institutions is an expression of confidence in Israel's STI capacity. In addition to proclamations and legislation in support of science and technology, Israel leads the world in investment in civilian R&D, with 4.4% of GDP in 2010[3] (compared with 4.5% in 2009 and 4.8% in 2008). And while little information is made public about military- and security-related R&D, it is estimated that in the 1980s (prior to the springing of high-tech industry in Israel) 65% of national expenditure on R&D were defense related and only 13% were directed at civilian industries (Peled 2001: 5). Since then the Israeli venture capital sector emerged, grew rapidly, and became the largest worldwide; this too is regarded as a vote-of-confidence in the prominence and productivity of Israel's science and technology. With similar sentiments, official government policy supports each and all of the related fields, without reservation: science, technology, education, R&D, and innovation (see Section 5.1).

On-going cuts in Israel's investment in education, universities and science and technology has been met with a public outcry. Leading Israeli scientists are most vocal in expressing their concern that the 'lost decade' (2000-2010), of massive reduction in public funding for education and R&D, will derail a system that has been noted for excellence and world leadership. These concerns too are expressions of the sweeping belief in the importance of science and technology – shared by

[3] Equaling 36 billion NIS.

parents, policy-makers, investors, and voiced over ethnic and religious barriers. This widely held belief is driving STEM education.

2.4 Confidence in STEM: Summary

Although Israelis express strong confidence in the role that science and technology play in securing Israel's future and while foreigners too express such confidence by investing heavily in Israel's new economy sectors and in Israeli academic research, tendencies towards superstition and religiosity are possibly eroding the otherwise-overwhelming confidence in science and technology. Yaar (2006: 38) shows a dramatic change in this direction in the short 7 years that between 1999 and 2006: more Israelis believe in the supra-natural abilities of rabbis (rise from 72% in 1999 to 76% of Israeli Jews in 2006), in the power of 'evil eye' (47% to 57%), in the existence of heaven and hell (45% to 53%), and in the coming of the messiah (52% to 63%). Moreover, Yaar reports a decline in the share of Israelis who agree with the statement 'people today have too much confidence in science and too little faith in feelings and beliefs': a decline from 57% in 1999 to 49% in 2006 (2006: 23). This seemingly contradictory attitude, between a sweeping confidence in STEM and a growing belief in supra-natural powers, is apparently commonplace among Western countries.[4]

3. STEM education: Provision and participation

Israel has a rather large share of young population, with 28% of total population under the age of 15 and ranking 4th among OECD countries (average 18.5%). This, along with a growing share of religious population, has put a strain on Israel's already-starved education system. Therefore, while investment in education accounts for 7.2% of Israeli GDP (compared with 6.2% OECD average), the investment per capita rate in Israel is far lower, ranging between 65% of OECD per capita investment for elementary schools to 85% for high schools. This resource strain attenuates the link between belief in the importance of STEM and its actual social impact.

[4] Eurobarometer report 'Europeans, Science and Technology' 2005 (http://ec.europa.eu/public_opinion/archives/ebs/ebs_224_report_en.pdf, accessed 31 January 2013) and NSF Science and Technology report 2004, 'Chapter 7: Public Attitudes and Understanding' (http://www.nsf.gov/statistics/seind04/c7/c7h.htm, accessed 31 January 2013).

3.1 STEM in primary and secondary schools

Science and technology are listed among the core subjects, as specified by Israel's Ministry of Education.[5] After a series of general science classes offered during elementary school (grades 1-6, ages 6-12), a wide range of STEM subjects are offered in secondary schools (7-12 grades). Israeli secondary, or high, schools offer: biology, chemistry and physics within the science cluster; computer science within the technology cluster; computer science, information technology, industrial chemistry, biotechnology, computerized manufacturing systems, and energy within the technology cluster; mechanical and electrical engineering within the engineering cluster; and, the mathematics cluster includes a range of traditional math fields (algebra, geometry, trigonometry, calculus). Science subjects are a part of the theoretical track, engineering and technology clusters are a part of the vocational track, and math is a system-wide requirement. Therefore, of STEM subjects, only mathematics is a required part of Matriculation testing[6], with a minimum of 3 units (of a minimum of 21 units) required in mathematics. Science education (biology, chemistry, or environment studies), on the other hand, is required until 10th grade and in grades 11 and 12 is an elective (4 or 5 units). Engineering and technical studies are offered as high school electives.

3.1.1. Enrolment

General science and math are required curricular items in primary schools in the national, religious-national, and Arab education systems.[7] In this sense, STEM enrolment in primary schools is mandatory, with the exception of Ultra-Orthodox schools. Ultra-Orthodox schools, which enrol an estimated 30% of schoolchildren in Israel in 2012 (and are estimated to grow to 44% of the Israel school-age population by 2017), offer very little of the core curriculum as specified by the Ministry of Education. Only 87% of these schools report that they offer any math studies in primary schools and no science classes are offered (Dattel 2012). Wherever there are Junior High Schools, mediating between primary and secondary education, the situation gets slightly worse, with even fewer STEM studies offered.

High school is the site for STEM differentiation – among STEM subjects and by level of concentration. While the minimal standard of math (3 units) is a requirement for high school graduation and for the Matriculation certificate, this requirement does not apply to the Ultra-Orthodox high school system. Students in the Ultra-Orthodox school system do not matriculate and thus get no exposure to STEM curricula; only

5 The list of 'core subjects' for high school includes: math, Hebrew, English, history, geography, civics, Israeli heritage, science and technology, road safety and life skills. Arab schools are teaching Arabic, with Hebrew being taught as a second language (and they deemphasize Hebrew and Jewish curricular items: 44% of them teach Hebrew grammar, 46% teach Hebrew literature, and 5.2% teach Bible studies). National-religious schools require Bible and Talmud studies.

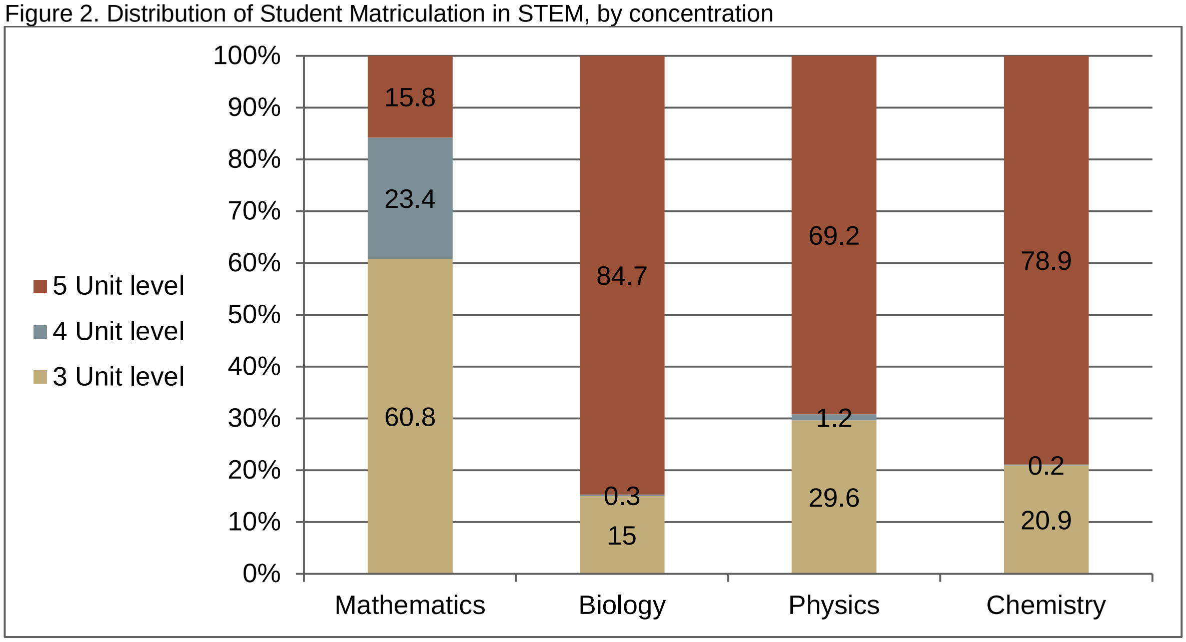
6 Matriculation testing is the culmination of 12 years of education and a requirement for university admissions. It is comparable to International Baccalaureate certification. Israeli Matriculation requires a minimum of 21 units, combining required subjects and electives. 1-3 unit courses, followed by and culminating with 1-3 level matriculation tests, are required core curricular subjects, topics; 4 or 5 unit courses are defined as concentrations or advanced placement tracks and culminate in advanced 4- or 5-level matriculation tests.

7 Law partitions Israel's school system partitioned between 4 sub-sectors: 'national' system (state education designed primarily to non-religious (Jewish and Arab) sector), 'religious-national' (state education for religious, Jewish, non-Orthodox public), 'Arab national' (…), and the Ultra-Orthodox religious system (which operates as a private sector, is neither supervised nor funded by the Ministry of Education, and is focused exclusively on religious studies).

41% of Ultra-Orthodox schools offer any math education, concentrating mostly on arithmetic (Dattel 2011). As noted in Section 4.2, this has important implications for Israel's labor market, with the inability of the Ultra-Orthodox Jewish population to integrate into the workforce – let alone into Israel's high-tech industries – is currently defined as a national problem, if not a crisis.

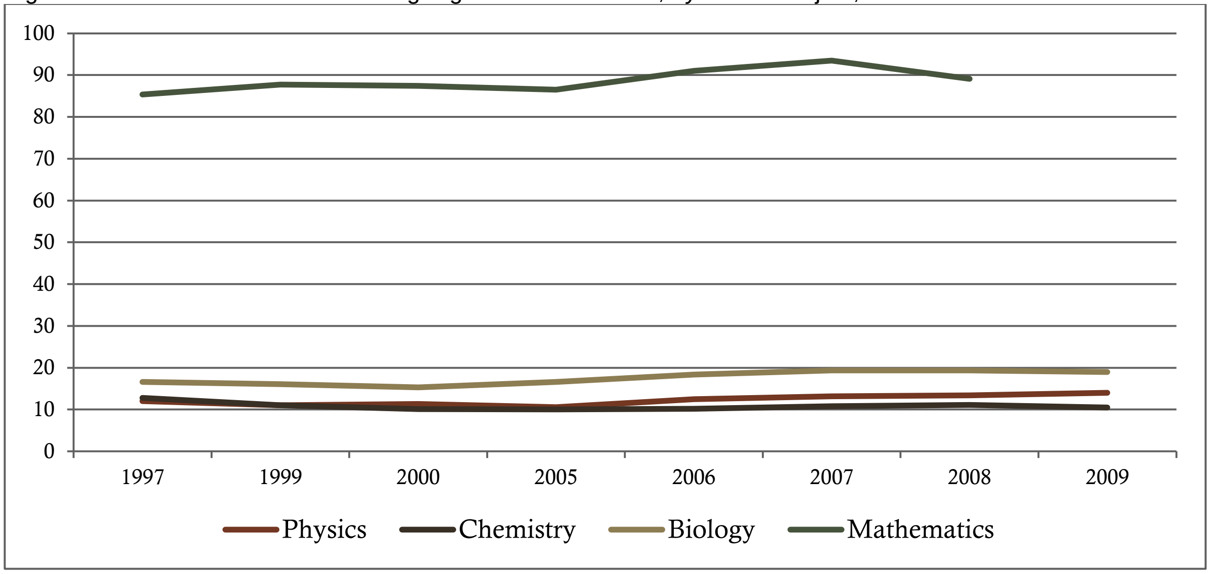
The split requirement – between minimal math Matriculation (3 units) required of all Matriculating high school students, while advanced studies in STEM is optional – is evident in enrolment rates. Indeed, in 2009 10.5% of high school students tested for matriculation in chemistry, 14% in physics, 19% in biology, and, due to the requirement, 90% of students took the matriculation test in math. Yet, while most students matriculating take only a 3-unit, thus basic proficiency test, students matriculating in science subjects tend to enrol in comprehensive and advanced matriculation (4 and 5 units; see Figure 2).

Figure 2. Distribution of Student Matriculation in STEM, by concentration



In correspondence with the rise in the number of matriculating high school students, the total number of matriculating high school students in the various STEM subjects is also on the rise since 1997. Due to the requirement for minimal (3-unit) math, the share of matriculation in math is consistently above 85%, with a rise to about 90% by 2008. Other STEM subjects show a more dramatic rise: from 12% of total matriculating high school students in 1997 to 14% in 2009 for physics and from 16.6% to 19.0% for biology, with chemistry showing a decline from 12.8% in 1997 to 10.5% in 2009 (see Figure 3).

Figure 3. Share of Matriculation among High School Students, by STEM subject, 1997-2009



Overall, over a third of Israeli high school students complete study tracks in sciences and technology, most of whom also enrol in the advanced and comprehensive (4-5 units) Matriculation courses in physics, biology or chemistry. The share of high school graduates in the tracks of sciences, engineering or technology rose between 2001 and 2003 from 36% to 37.1%.

Post-matriculation, graduates of these advanced and comprehensive courses may continue into 13th and 14th years of schooling. These 13th and 14th year studies, which are offered in 2-year college programs, conclude with certification as technician or practical engineer. These studies must be approved by military authorizes, since they require deferment of military service, and most graduates of these programs are then recruited into technical professions.

3.1.2 Expenditure

Table 1. Hours of STEM Instruction, by grade

Subject	Grade and Level of Study		Annual Number of Hours
Mathematics	Elementary (required)		125
	Middle School (required)		120
	Upper secondary	3 Units (Minimal Requirement)	360-270
		4 Units	450-360
		5 Units	540-450
Science And Technology	Elementary (required)	Grade 1-2	120-90
		Grade 3-4	150-120
		Grade 5-6	180-150
	Middle School (required)	Grade 7	120
		Grade 8-9	150
	Upper secondary	Grade 10 (required)	270 per 90) (topic
		Grades 11 and 12 (elective, 4-5 Units)	360

Investment varies across STEM subjects. In terms of teaching hours, the Ministry of Educations sets a minimum number of instruction hours per subject, by grade (see Table 1[8]). Over the decade since 2000 there has been an increase of 41% in teaching hours devoted to math and 3% increase in biology, but 25% decrease in hours devoted to computer science, 18% in chemistry, 6% in technology studies, and 5% decrease in physics. Overall, though, the hours of STEM teaching are fewer with an increase in school grade. In comparative terms, Israel ranks 6th for ages 7-8,

[8] Official guidelines regarding STEM instruction time are set in different ways (by instruction hours, annually and per week; by teacher hours, annually and per week). This is our best effort to calibrate across these measures.

13th for ages 9-12, and 19th for ages 13-15 on share of hours devoted to STEM in comparison to other OECD countries. While such hourly investment is rarely translated into monetary terms, it is clear that Israel's education expenditure is unbalanced: total national education expenditure is higher than the OECD average (7.2% of GDP in 2012, compared with an average of 6.2% for remaining OECD countries, thus ranking 6th of 37), yet expenditure per capita is dramatically lower in comparison: Expenditure per capita in secondary schools (middle and upper schools, grades 7-12) is 5,842 (constant USD), compared with OECD average of 9,312, thus Israel ranks 27th among 37 OECD-monitored countries (OECD, 2012).

3.1.3 Achievement

As an output function, the performance of Israeli students in comparative tests in STEM subjects reveals inconsistent patterns (see Tables 2 and 3). TIMSS results show an increase in both science and math scores and in ranking in performance in science and math.[9] The recent phenomenal improvement in TIMSS scores in math and science, with a jump of 17 and 12 ranks respectively, was met with much irony and stirred a political debate. On the other hand, PISA results show the Israeli students score far below average is science and math and thus Israel repeatedly ranks within the 3rd quarter of countries. Compounding these differences are the gaps between Jewish and Arab communities within Israel: differences in socioeconomic capital explain the consistently lower scores of Israeli-Arab school children in TIMSS, PISA and Mitzav[10] tests and language proficiency explain why the gap is scores is smaller in science and even more so in math than it is in reading (Zuzuvsky 2010).

Table 2. Achievements of Israeli students TIMSS, 1999-2011

Year	[11]1999		2003		2007		2011	
Number of countries are reviewed	38		45		49		42	
Subject of Study	Math	Science	Math	Science	Math	Science	Math	Science
Average score, all countries	487	488	467	474	451	466	467	477
Score, Israeli students	466	468	496	488	463	468	516	516
Rank	28	26	19	23	24	25	7	13
Change: **Score** **Rank**	-	-	+30 _9	+22 _3	_33 +5	_20 +2	+28 +17	+23 +12

9 With a dip in 2007 testing results, which is explained by the lengthy teacher strikes which resulted in a shortened school year.

10 Standardized tests administered by Israel's Authority for Education Measurement and Assessment (supervised by the Ministry of Education) since 2002. The tests are given in 4 core subjects: native language (Hebrew or Arabic), math, English, and science and technology.

11 Test included Arab and Ultra-Orthodox students, who were not tested otherwise.

Seeing matriculation rates as another indicator for STEM achievement, we see a rise in matriculation in STEM subjects (Figure 3) that there is a slight rise in Matriculation rates. Among high school students who take advanced courses (4-5 units) in chemistry and biology, some 80% of students take the respective Matriculation exam (84.7% in physics in 2008, up from 80.6% in 1997; 78.9% in chemistry in 2008, up from 78.2% in 1997). In Physics there is a decline in numbers: only 69.2% of high school students who enrol in advanced physics courses take the physics Matriculation exam, down from 86.6% in 1997. These matriculation rates are consequential for entry into university. And while the 1996-2010 share of high school matriculated students who pass the threshold of university admittance is 46.6%, 70.7% of students in STEM tracks in these years are eligible for university entry.

Table 3. Achievements of Israel students in PISA, 2002-2009 [12]

Year	**2000**[13]		2006		2009	
Number of countries are reviewed	41		57		64	
Subject of Study	Math	Science	Math	Science	Math	Science
Average score, all countries	500	500	500	500	496	501
Score, Israeli students	433	434	442	454	447	455
Rank	31	33	40	39	41	41
Change: Score Rank	-	-	+9- +9	+20 +6	+5 +1	+1 +2

[12] Israel did not participate in the 2003 due to the proximity to the previous sampling in 2002.

[13] Benchmarked with PISA 2000 test results.

3.2 STEM teaching

In response to the growing demand for STEM schooling, teacher colleges credential some 11% as science and technology teachers, 2/3 of them becoming high school teachers (grades 10-12). There are between 2,500 to 3,500 science and technology teachers (range accounting for different years between 1996-2010) and some 17,000 math teachers. Half of the math teachers teach in elementary school (grades 1-6), less than a fifth teach in junior high (grades 7-9) and about one quarter teach in high schools (grades 9-12).

In addition to acquiring teaching credentials, most STEM teachers also completed university studies: among teachers of mathematics, some 80% have university degrees and some 25% were awarded MA or PhD. Still, the problem of recruitment of teachers in general and of STEM teachers in particular is casting a shadow on prospects for deepening STEM education in Israel. Of the university graduates in mathematics, only 6-7% choose teaching as their profession and only 3% teach math in high school level.

Support for STEM teaching comes also from Israel's participation in such European Union initiatives as PARSEL[14], which concluded in 2009. As an exemplar program, PARSEL aimed at creating a network of support for STEM teachers by establishing forums for curricula developers, STEM school supervisors, STEM matriculation examiners, and of course teachers of each STEM subject. This cooperative plan, it was argued, facilitates the diffusion of effective STEM pedagogies, evens out STEM teaching across the whole Israeli school system, and better integrates STEM with the teaching of all other subjects. Additional such programs continued into the Seventh Framework Program (FP-7), such as CORDIS, in which Israel is a very active participant.

In spite of Israel's reputation as a leader in STEM education, STEM teaching in Israel is met with much grievance from students. Without making a strong case for the relevance of STEM education to daily life, students are not motivated to make the necessary effort in these studies and many complain that STEM studies are simply not interesting (Hofstein, Eilks, and Bybee 2011). This builds a shaky foundation for future transition into knowledge-economy occupations.

3.3 STEM in tertiary education

Because of compulsory military service, service in the Israeli Defense Forces (IDF) is the section of the STEM 'pipeline' that follows high school education and leads to tertiary education. In this way, Israeli students in tertiary institutions are older than students in most other countries[15] and some gain special training in STEM subjects. As described in Section 4.1, IDF service serves an important role in human capital preparations in general, as well as in STEM fields.

[14] Popularity and Relevance of Science Education for Scientific Literacy, PF-6 (Sixth Framework Programme, Science and Society Priority).

[15] Median age of Bachelor students in Israel is 25.1 years, for Masters is 30.7 and for doctoral degree the median age is 33.7 years.

Israel has a very large system of tertiary education. Institution-wise, in 2012 Israel has 8 universities, 27 academic colleges, 25 academic teachers' colleges, and 70 academies for advanced technical education.[16] Most of these academic institutions are publically funded. The total number of students in tertiary education institutions in 2010/11 was 189,240. This means that 46% of Israel's adult population holds a tertiary education degree, thus placing Israel in 3rd rank of 41 countries tracked by OECD. Of a 2012 budget allowance of close to 1.8 billion USD in 2012, 78.2% was allotted to the universities, 48% of which were targeted for research and additional 48% for teaching. Of the budget allotted to colleges, 95% of funding was targeted at teaching. This is expressed in STEM teaching: teaching budgets for STEM in colleges are larger than they are in universities, for both Bachelors and Masters degrees. Yet, since it is universities that are defined as research institutions, the bulk of research funding goes from universities.

3.3.1 History

From their inception, Israel's academic institutions were oriented towards STEM. Indeed, the Technion (Israel Institute of Technology), which is Israel's first academic institution and opened its doors in 1924, was designed as a university of science and technology in the German tradition. During their first year of operation, the Technion had two faculties (civil engineering and architecture) and The Hebrew University of Jerusalem (started teaching in 1925) had three institutes (biology, chemistry and Judaic studies). And, following in this tradition of emphasis on STEM in academia, the Weizmann Institute was the third of Israel's academic institutions to be founded: Dr. Haim Weizmann, a world-renowned chemist who was a Zionist leader and then Israel's first President, was behind the founding of the Daniel Sieff Research Institute in 1934, which in 1949 was expanded and renamed in honor of Weizmann. These three founding academic institutions imprinted Israeli academia as a whole with STEM as priority fields.

3.3.2 Expenditure

STEM disciplines receive the lion share of the funding directed at Israel's tertiary education institutions. Of the funding for universities, which is parceled among 28 disciplinary categories, the six highest allotments are for dentistry (6.77% of teaching allotment to universities), physical sciences (6.23%), biology and environmental studies (5.74%), engineering (4.99%), chemical, material and medical engineering (4.99%), clinical medicine (4.81%), and computer and electronics engineering (4.35%), with architecture (4.12%; ranked 7th), math and computer science (3.77%; ranked 9th), management engineering (3.93%; ranked 10th) and agriculture (3.77%10th 11th).[17] A similar emphasis on STEM teaching is repeated in Israel's colleges, even if medicine is totally absent from their curricular mandate. Therefore, among the 21 disciplinary categories in Israel's colleges, the categories allotted more than 6% of the total teaching expenditure in colleges are: physical sciences (7.39%), biology and environmental studies (7.39%), engineering (6%),

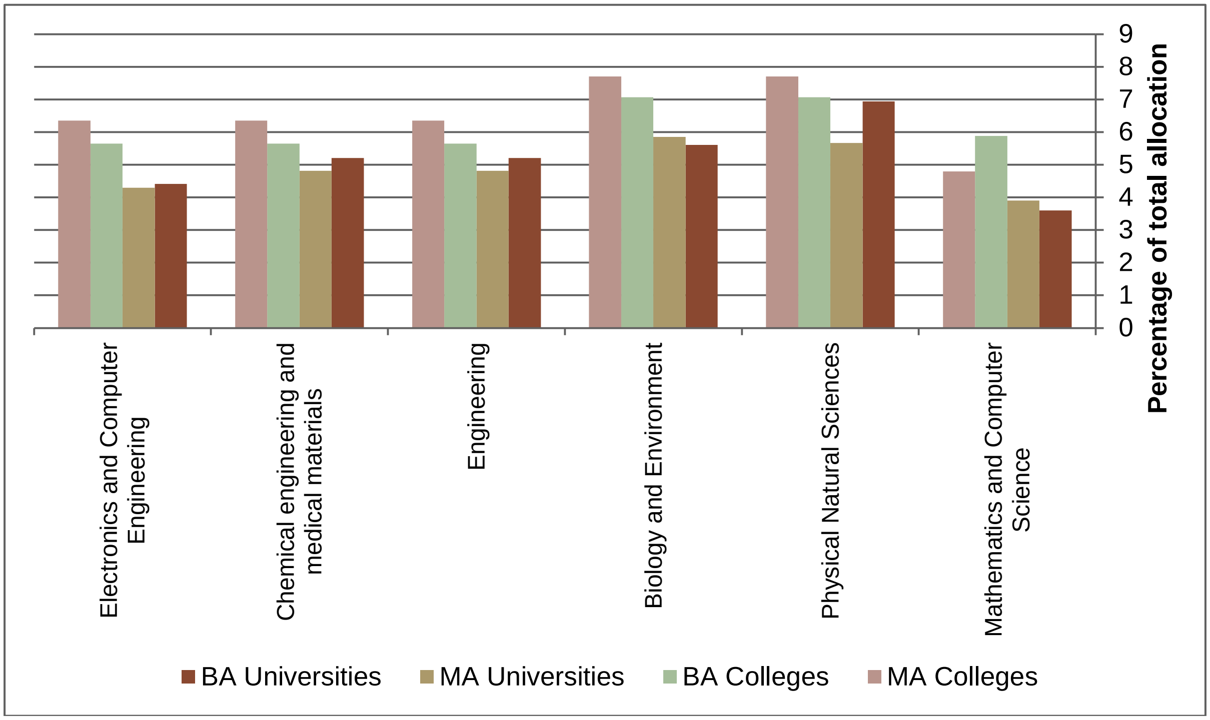
16 These numbers include only institutions that are accredited by Israel's Council for Higher Education, thus excluding all religious (non academic) institutions.

17 2012 data; Source: Israel Central Bureau of Statistics.

chemical, material and medical engineering (6%), and computer and electronics engineering (6%), even if the 1st ranked disciplinary category is music (7.64%) and the third is art and design (6.76%). Figure 4 displays the share of the total teaching expenditure devoted to STEM disciplines, by academic degree (Bachelors and Masters) and by type of academic institution (universities and colleges).

In nominal terms and because of the emphasis on research, STEM teaching is more expensive in universities. Also, with only minor exceptions[18], these patterns remain also in translation to monetary terms per student. With that, teaching expenditure does not correspond with enrolment.

Figure 4. Share of STEM Teaching Expenditure, by academic degree and by institution type



3.3.3 Enrolment

Student enrolment in STEM disciplines in higher education institutions varies greatly across disciplines (see Figures 5). For Bachelors and Maters degrees, there is a reduction in the relative size of enrolments in sciences[19], while engineering[20] shows a slight growth. For doctoral studies, mathematics and natural sciences show an expansion, while others are slow to grow. This change in relative size, across degrees, shows the shift in balance from emphasis on human-capital building and thus teaching to innovation and research: Israel is not only encouraging college

[18] Whereas in general STEM teaching expenditure in universities is higher than in colleges and higher in Masters than in Bachelors, only in the case of math and natural sciences teaching expenditure is similar in universities as in colleges and expenditure on Masters is smaller than on Bachelors.

[19] Category includes: biology and environmental sciences, physical and natural sciences, mathematics and computer sciences.

[20] Category includes: engineering, chemical and medical engineering, electronics and computer engineering, industrial engineering and management.

education for the whole population (general human capital strategy), but also encouraging university students to immerse themselves in research with the intension of building cadre for cutting-edge research and innovation.

Figure 5. Ratio of Student Enrolment By Discipline, by degree, until 2012
Figure 5.1. Bachelors

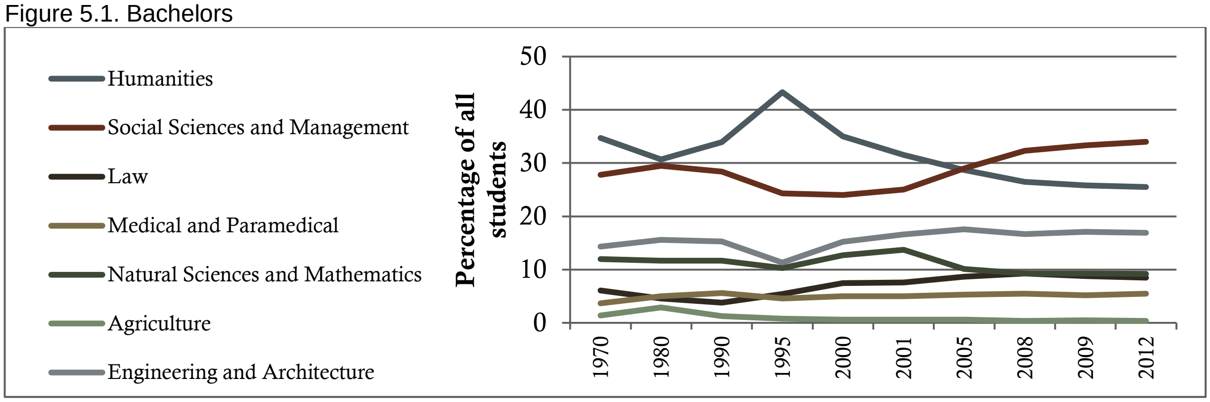


Figure 5.2. Masters

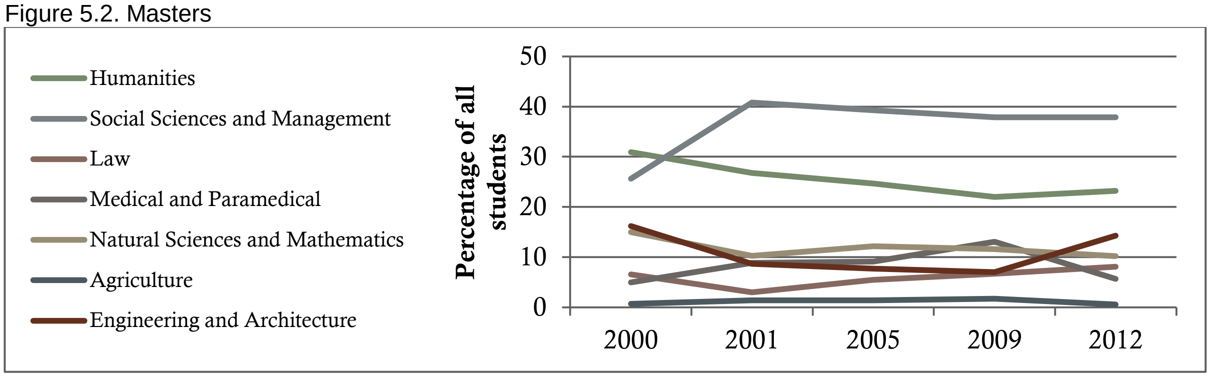
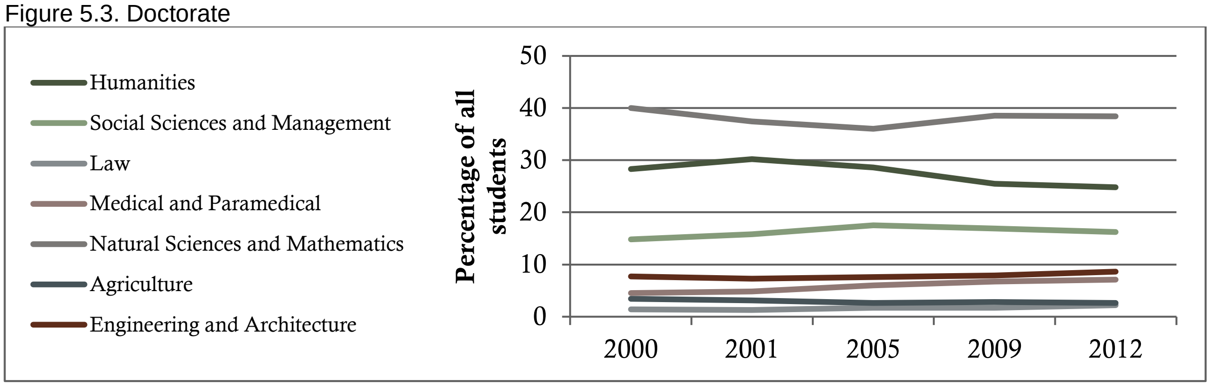


Figure 5.3. Doctorate



Under conditions of a growing system of tertiary education, these relative patterns translate to growth in the absolute number of STEM students in tertiary education. For example, the number of mathematics graduates grew between 1995-2009 from 855 to 1811 for Bachelors, 158 to 430 for Masters, and 42 to 112 for PhD. Growth in numbers of students is equally impressive in engineering and architecture, biological sciences and physical sciences. And these numbers do not include Israeli students earning their academic degrees abroad: it is common for Israeli students to earn doctoral degrees abroad, especially in STEM professions.[21]

In addition to these academic programs, there are some 70 vocational colleges awarding technician degrees, in 48 study tracks, to some 22,000 students annually. Over a half of these students are earning technical credentials and the share of this group rose by 600% in the past 4 decades: from 4,793 students in 1971 to 32,889 in 2011. This sector, which is supervised by the National Institute for Training in Technology and Science within the Ministry of Industry, Trade, and Labor, is heavily subsidized by special Government funds.

3.3.4 Achievement

In addition to providing a highly skilled labor force and being recognized for research (see Section 5), Israeli tertiary education has been rewarded for educational achievement. For the sake of such differentiation between the various achievements of Israeli academia, this section is devoted solely to research and teaching matters and will describe the state of academic research and teaching in terms of its products: grants, awards and publications.

Six Israeli scientists won Nobel prizes for scientific achievements: 4 in chemistry and 2 in economics. Israel ranks 8th in terms of the total number of ERC grants awarded to scientists in its institutions, thus out-performing with more ERC grants than investments in its academic research. Israeli academia is also prolific in academic publications: Israel ranks 3rd worldwide in academic publications per capita.[22] 27% of Israeli publications in these years are in clinical medicine, 14% in physics, and about 10% in chemistry and in all these categories the share is greater than the world average (Getz et al. 2005: 50). The field of Israeli research most cited in 1999-2003 is molecular biology. On the whole, citations of Israeli science and technology publications receive, on average, 66% more citations than the world average in the relevant STEM field.

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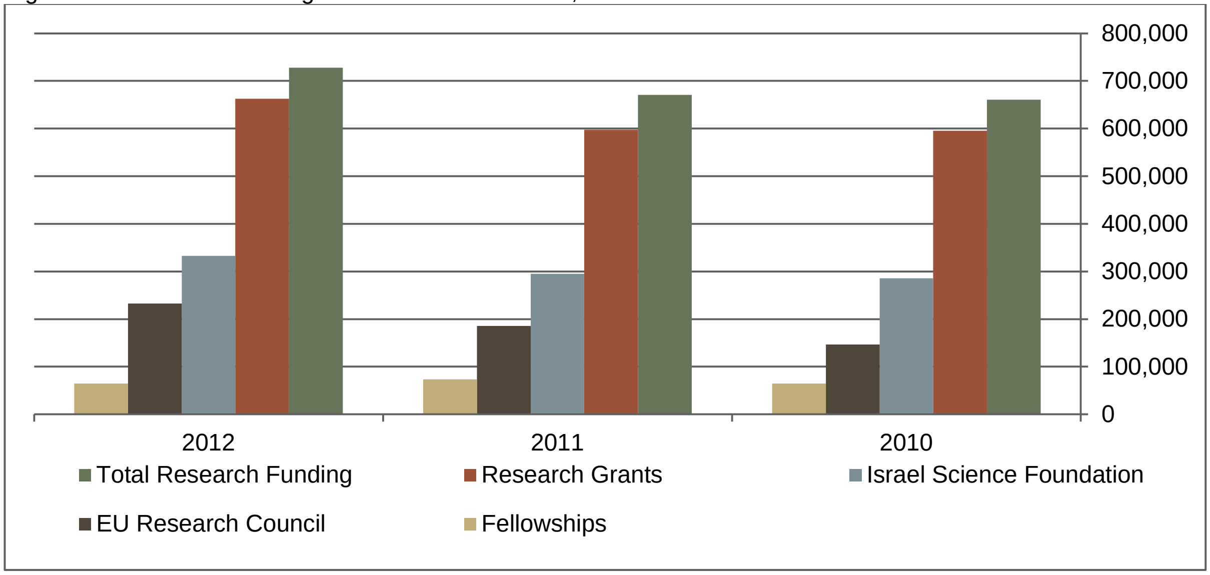
21 While data are not available for Israeli students abroad, it is estimated that in 2011 14% of total Israeli PhDs and 20% of Israelis math PhDs live abroad for over 3 years.

22 1999-2003 data: Israel 1,549 articles per million people, following Switzerland (1,932) and Sweden (1,706); source: Getz et al 2005.

Figure 6. Sources of Funding for Academic Research, 2010-2012



Still, in spite of the remarkable success of Israeli STEM in academia, Israel is hardly a destination for international students. Setting aside concerns about security, the main reason is the language of instruction: only the Weitzmann Institute of Science offers full curriculum in English.

3.4 STEM education: A summary

With education engraved into the Israeli ethos of a modern society, STEM education in particular is considered the foundation for Israel's science excellence, technology leadership, and high-tech success. Israeli government and the general public are equally concerned with Israel's standing as a world leader in these fields and, with that, concerned with STEM education. The split of Israel's primary and secondary schooling into 4 separate systems creates chaos in the governance of education in Israel. 'What looks on paper to be a highly centralized system is in fact a sprawling network of parallel systems that all report to a single minister' (Cramer 2011). Repeated attempts at system-wide reform are met with opposition from teachers' unions or parents' groups and are also underfunded (Reichman and Artzi 2012).

Two factors, relating to the structure of Israel's education system, make Israel's STEM education most unique. First, the mandated partitioning of Israel's school system into multiple and separate education systems results in uneven exposure to STEM education. Most extreme in this regard is the absence of any STEM education in Ultra-Orthodox schools, which results in some 20% of Israeli children studying in a school that offers no STEM education. Second, due to the demand for compulsory military service, Israeli 18-year-olds do not transition from high school into college or university.

4. STEM, beyond education

4.1 Military service

By legal demand, all Israeli citizens must enlist for a minimum of 2 (women) or 3 (men) years of military service and some 75% of Israeli 18-years-olds enlist upon graduation from high school.[23] This required military service disrupts the traditional flow yet builds added STEM-related capacity (see Figure 4). In addition, the military service impacts the 'STEM pipeline' in direct and indirect ways.

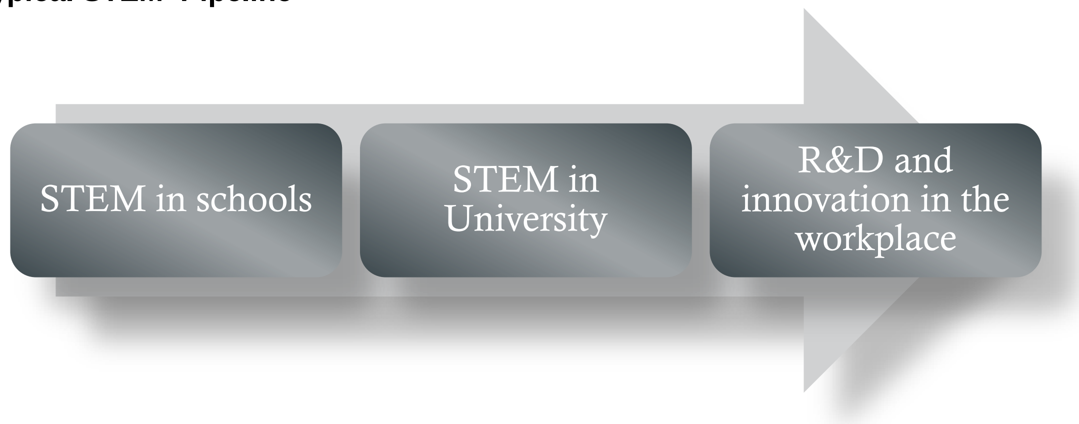
The direct impact is through the STEM-related educational opportunities that service in IDF offers. For example, IDF invites high school graduates to enrol in a special program, titled Atuda (academic reserve), which allows for college education in several disciplines upon high school graduation in exchange for added years of military service. In this way, Atula alumni enter the workforce having already gained much experience working in their profession. The major direct impact comes from military training in STEM-related topics, with military units teaching specialized skills required for military STEM-related tasks. Depending on professional track, such training may last as long as a year. And while some such training may require additional service time, any veteran of these specialized military units is quickly recruited into industry. Last, IDF is most innovative in its military STEM-related training by creating training programs that are both integrative and secret. The most known of these programs is the elite Talpiot, which enlists brilliant recruits into academic studies of basic science while integrating them into R&D defense projects. To manage Israel's defense-related R&D needs, the IDF and Israel's Ministry of Defense share the responsibility over the Directorate of Defense R&D.

IDF also affects the STEM pipeline in an indirect manner by equipping veterans with skills that benefit the nature of the global knowledge economy. The informal culture of IDF (where officers rise from among the ranks, ingenuity is praised and rewarded, and rapid response is encouraged) and the coaching in teamwork carry into civilian workplace: veterans bring these skills, which so perfectly match the work habits of start-ups, into their post-service jobs. In addition, military acquaintances built future business partnerships, with many high-tech start-ups being founded on such friendship ties and also on spin-off technology from military projects. Several of Israel's most prominent new firms, such as NICE Systems and CheckPoint, have this legacy of being founded by army buddies.

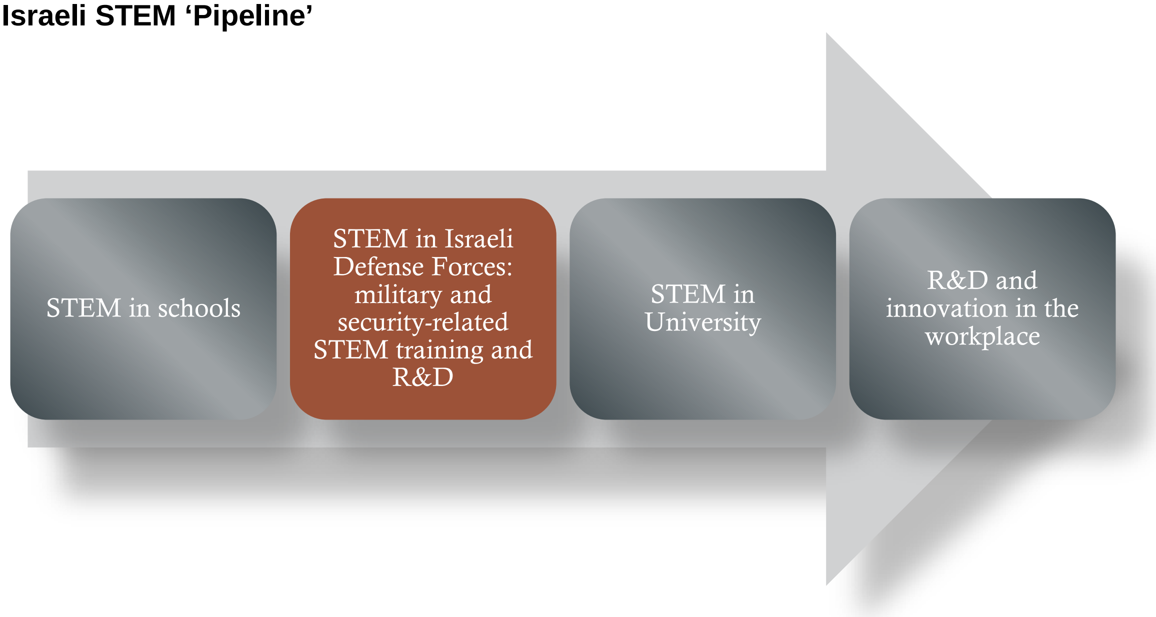
[23] The law absolves Orthodox Jews and Arabs from such service and, with the demographic growth in these segments of the population, the share of each cohort that enlists for IDF service shrinks from year to year.

Figure 7. Adapting the 'Pipeline Model' to the Israeli STEM Context

Typical STEM 'Pipeline'



Israeli STEM 'Pipeline'



In summary, military service in IDF adds a segment to the STEM pipeline. It formally adds to the skill-set of STEM-trained Israelis and informally builds social ties and work culture that supports the nature of work in knowledge-intensive industries of the 21st century.

4.2 Labor force

STEM education, acquired in schools and universities and as a part of military service, greatly impacts Israel's workforce: it fueled the transition of Israeli economy from an agriculture and traditional industry into a high-tech hub now known as 'Silicon Wadi.'[24] Israeli STEM professionals are sought after, by Israeli and foreign companies, for work in Israel and abroad. Regardless of changes in overall

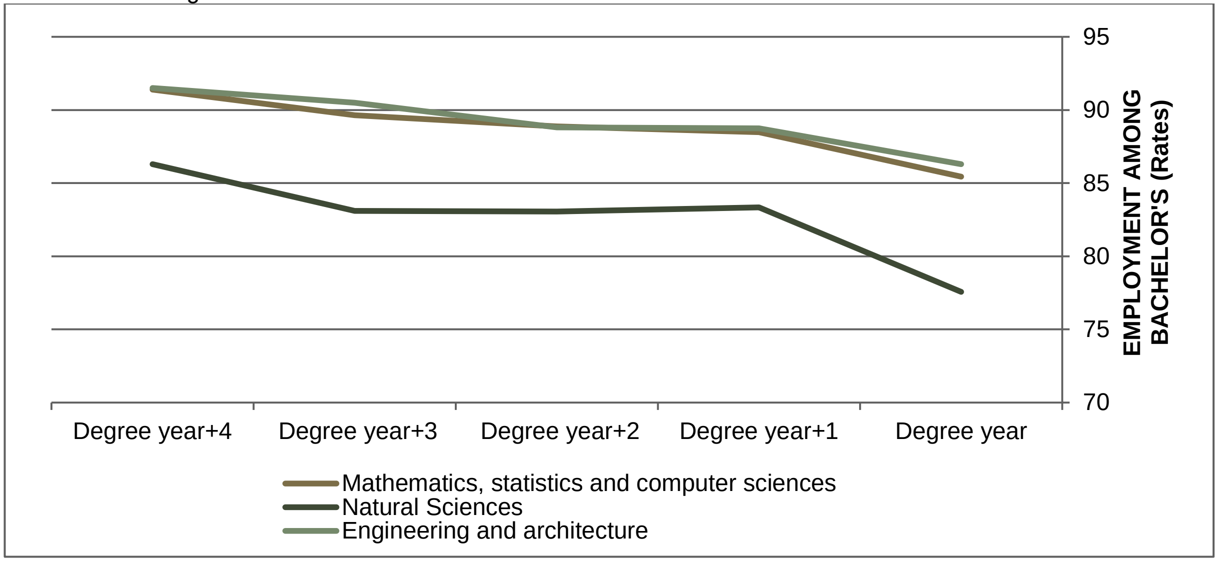
[24] 'Wadi' is the colloquial word in Israeli Hebrew (originating from the Arab language) for 'valley.'

unemployment rates, Israeli professionals are quickly absorbed into the workplace after completion of their university studies: 77% of graduates in natural science disciplines, 85% of graduates of math, statistics and computer science, and 76% of graduates of engineering and architecture find employment immediately upon graduation, and within a year of their graduation the employment rates jump to 86.5%, 92% and 92%, respectively (see, Figure 8). This employment pattern confirms the characterization of Israel's high-tech sector, which is second only to Silicon Valley in innovativeness and investments, as oriented primarily to information and communications technologies (ICT) and as heavily export-oriented. The globally competitive nature of these sectors demanded further STEM training in order for Israeli firms to stay ahead. Indeed, we see that Israeli professionals in the knowledge-intensive sectors of ICT, medical and pharmaceutical industries and cleantech are rapidly expanding their STEM advanced education: the share of professionals in these sectors with 16 or more years of education has risen from 32% in 1995 to 44% in 2007.

Israel's noted standing in STEM education and productivity quickly lured high-tech multinationals to invest in Israel, with Motorola being the first U.S. firm to set an Israeli arm in 1964. Notably, the main activity of multinational technology-intensive companies in Israel is R&D: Microsoft and Cisco Systems built their first R&D center outside of the US in Israel; Motorola set its largest R&D center in Israel; Intel, which started operating in Israel in 1974 and has 2 manufacturing facilities, has 4 R&D centers in Israel and Google holds 2 R&D centers in Israel. In total, in 2012 over 240 foreign companies established R&D centers in Israel. And R&D-related products comprise more then half of the total industrial exports (excluding diamonds). With that, Israel ranked 11th worldwide in company R&D spending[25] and is leading among OECD countries, in particular in knowledge-intensive industries.

[25] Israel's score 4.7 (on scale of 6); Global Competitiveness Report 2010-11.

Figure 8. Ratio of STEM Bachelors Graduates Entering Labor Force, by duration since graduation, 2000-2004 average



This entry of foreign technology firms into Israel slowed, but has not ceased, 'brain drain' from Israel. Many graduates of Israeli universities, especially in the sciences and engineering, continue their studies abroad, mostly in American universities. And many of them remain in the United States following their graduation: 14% of Israelis who were awarded doctoral degrees in science or engineering in the United States remained abroad for more than 3 years after their graduation, compared with 11% in other professions (Figure 9). This trend has been tamed after 2000, most likely because of the growth in high-tech opportunities back at home. Indeed, the number of high tech professionals in Israel is quickly rising (Figure 10) and, as a result, the share of high-tech in total national employment in Israel far exceeds the share in any other OECD country (see, Figure 11). And, Israeli high-tech professionals are increasingly more educated, gaining added formal training and academic degrees over time (Figure 12). Overall, with Israel's economy transitioning from manufacturing high-tech industry to service high-tech industry, there is a greater need for highly educated workers.

Figure 9. Ratio of Israeli STEM Graduates Remaining Abroad For 3+ years After Graduation, 1985-2005

Figure 10. Ratio of High-Tech Employees, 1995-2011

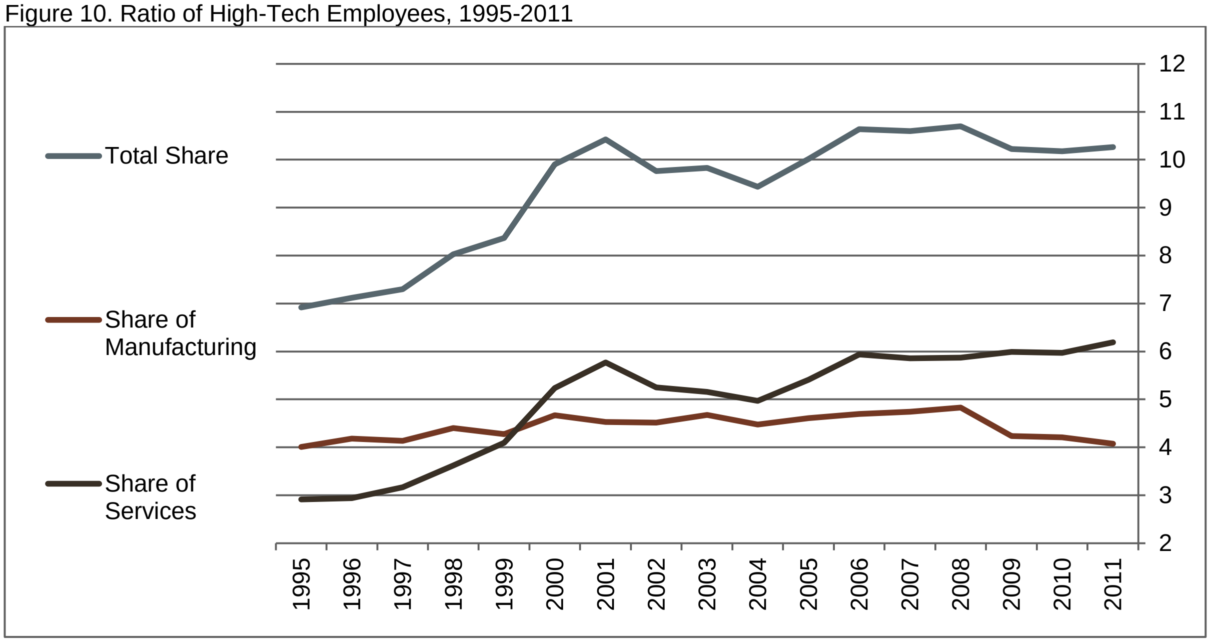


Figure 11. Cross-National Comparison of Employment in High Tech, by sector, 2007

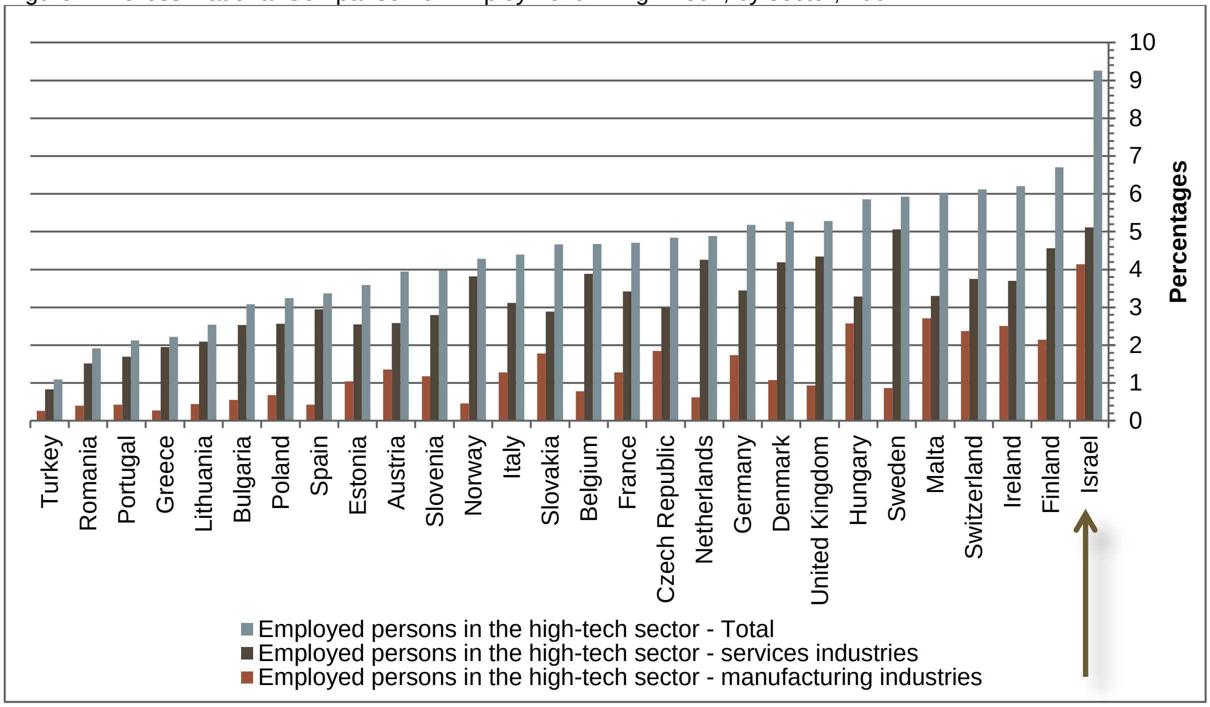
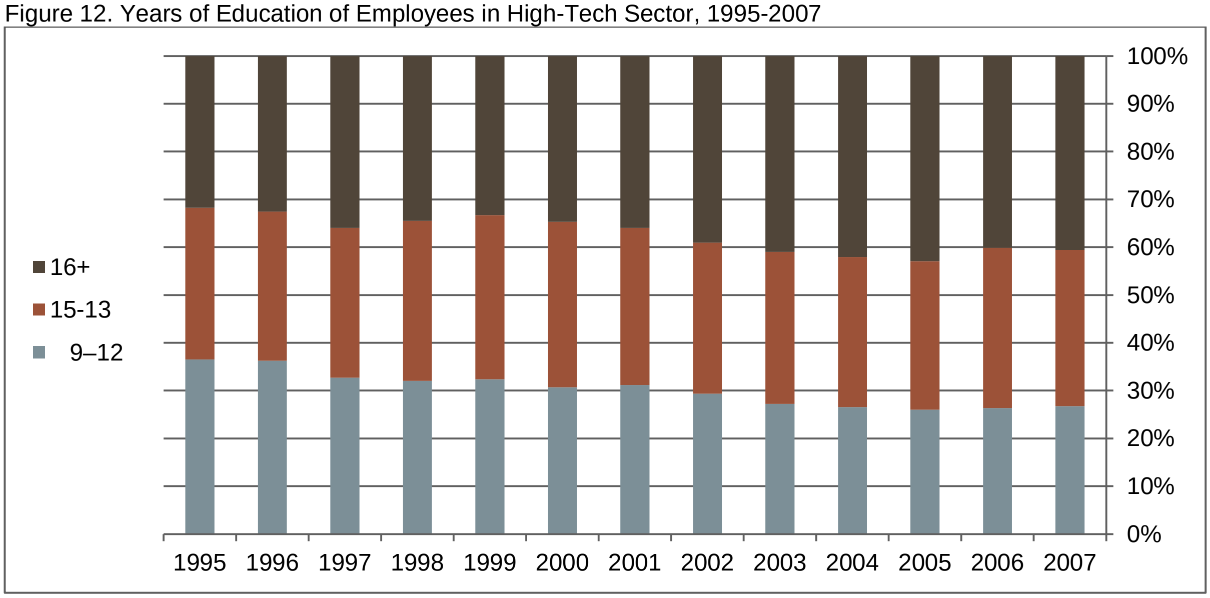
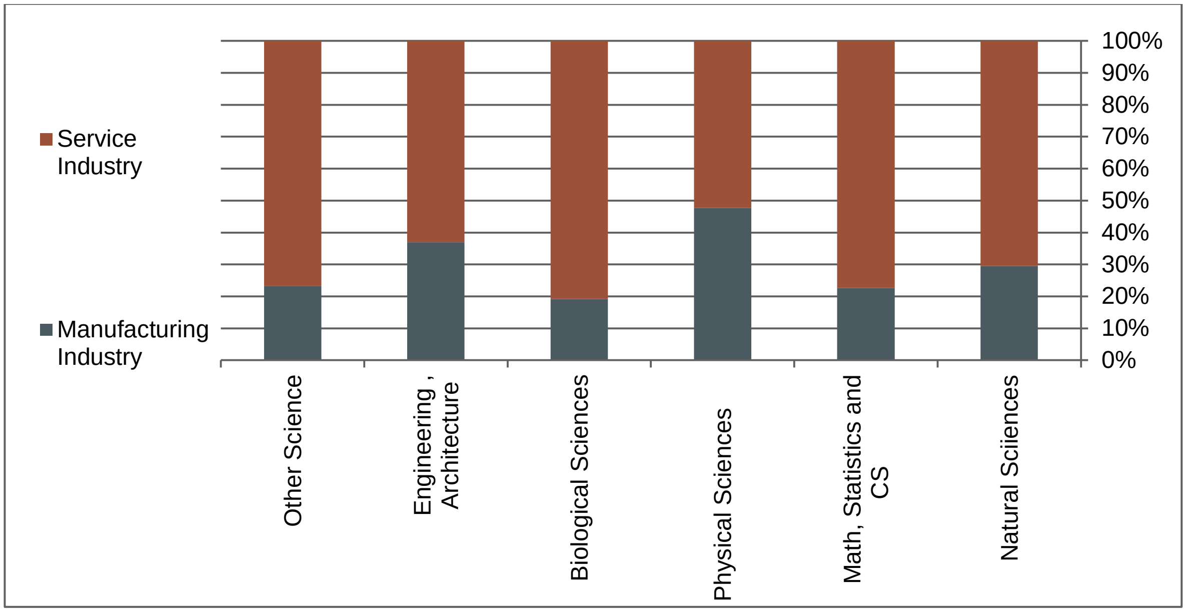


Figure 12. Years of Education of Employees in High-Tech Sector, 1995-2007



This change to the Israeli economy is drawing graduates of all STEM professions into Israeli high-tech industry and more than ever into service industries (IT, communications, and R&D). Indeed, most STEM graduates find employment in the service high-tech sector: Figure 13 shows the pattern for STEM graduates holding Bachelor's degree.

Figure 13. Share of STEM Bachelors Graduates in Service or Manufacturing High-Tech, 2000-2002



Israel's military- and security needs fuel investments in defense industries and spur the innovativeness of these defense industries, for which little if any information is public. Their size and success make the defense industries attractive for scientists and engineers; and certain projects are reserved for Israelis with special security clearance, thus also securing these jobs for Israeli citizens and specifically for veterans. In this way, IDF plays an additional role as a client of knowledge- and technology-intensive industries.

Last, Israeli academia becomes a home for many of Israel's scientists and engineers. Most academic staff are graduates of Israeli universities. This is most dramatic in agriculture[26], medicine[27], and in math, statistics and CS[28]. The distinction of STEM professionals among Israeli academics is doubled: first, the size of the academic faculty in mathematics, statistics and computer science, physics, biology, engineering and architecture is far larger than the faculty size in other disciplines and faculty in these STEM disciplines is also more senior in rank than in other faculties. These patterns are a double-edged sword: they reflect the prominence of faculty members in these disciplines and their worldwide recognition, while also hinting at a dearth of positions available for junior faculty members.

[26] In agriculture, 100% of lecturers, 100% of senior lecturers, 75.9% of associate professors and 93.6% of full professors earned their PhDs in Israel.

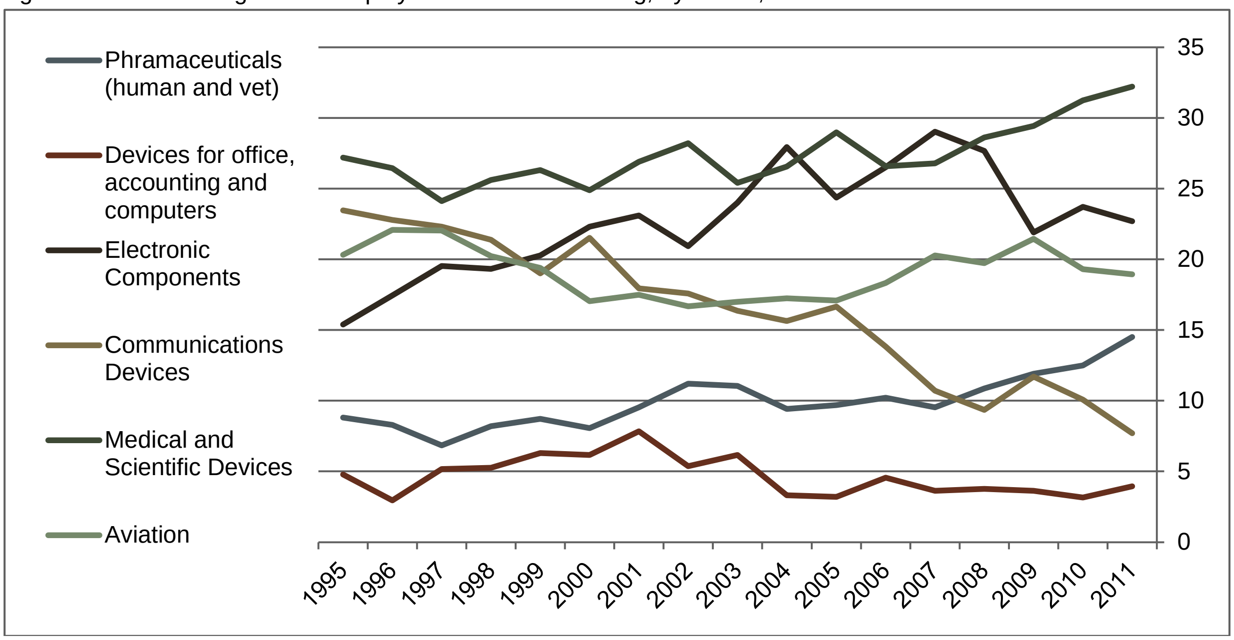
[27] In medicine, 84.9% of lecturers, 79.1% of senior lecturers, 79.1% of associate professors and 83.9% of full professors earned their PhDs in Israel.

[28] In math, statistics and computer science, 100% of lecturers, 84.9% of senior lecturers, 64.6% of associate professors and 67.4% of full professors earned their PhDs in Israel.

4.3 STEM productivity

Israel's economy is a knowledge economy, with high R&D investment and a high yield in intellectual property and academic output. With 2010 gross domestic expenditure of R&D (GERD) standing at 4.4% of GDP (excluding defense) and an average annual growth of 4.1% in 2005-10, Israel stands as an OCED leader in R&D-related expenditure. The strength and potential of Israel's knowledge-intensive industries is widely recognized: 52% of GERD in 2008 came from private sector funding and in 2012 over 240 foreign companies established R&D centers in Israel. And, R&D-related products comprise more then half of Israel's total industrial exports (excluding diamonds). Already at 2000 Israel's Silicon Wadi cluster was recognized as equal in strength to Boston, Helsinki, London, and Kista (Sweden), second only to Silicon Valley. Such leadership is also evident in Israel's leadership in patenting in specific fields, most notably IT: The 2011 Global Competitive Report ranks Israel 4th worldwide in patent production ratio.

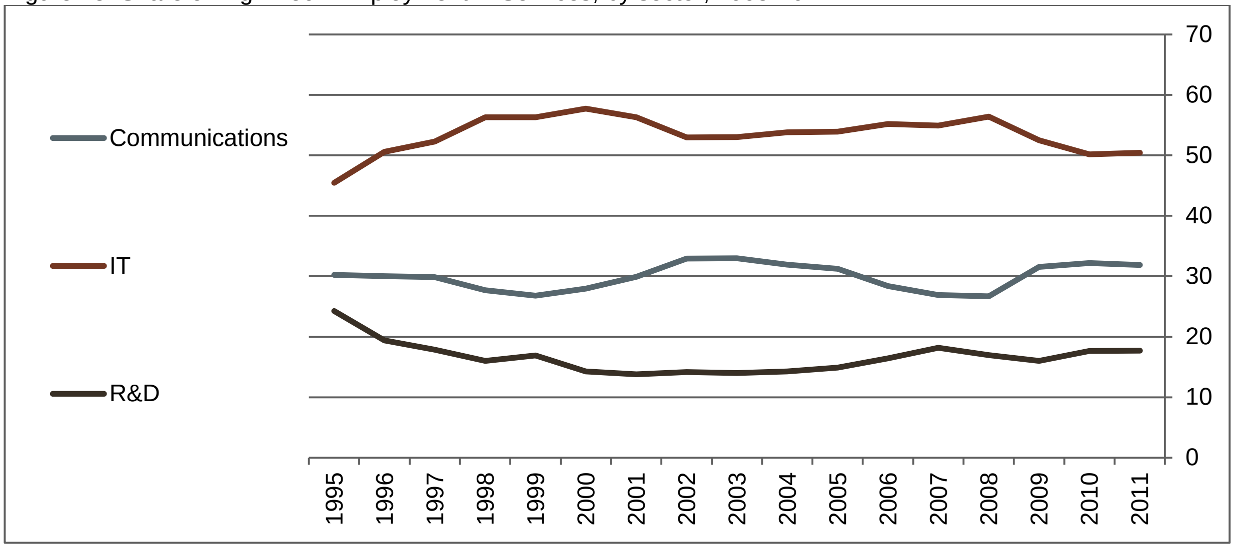
Figure 14. Share of High-Tech Employment in Manufacturing, by sector, 1995-2011



Employment in Israel's high-tech manufacturing industry is oriented towards device industries (Figure 14) while employment in the high-tech service sector is concentrated mainly in IT and communications, together accounting for over 80% of total high-tech employment in the service industry (Figure 15). Among high-tech manufacturing, there is a dramatic contraction in the manufacturing of communications devices.

These emphases are also reflected in the patenting patterns of Israeli scientists. In 2011, 31.5% of all patents assigned to Israelis were in electrical engineering, 27.1% in instruments, 25.1% in chemistry and 12.6% in mechanical engineering. Overall, Israel ranks 16th in the world in the number of PCT patents registered in 2010 and 3rd in the number of US patents per capita. Some of these Israeli patents are for items that are commonplace worldwide: the USB, the first anti-virus software, cherry tomatoes, camera chips for phones, and SMS messaging.

Figure 15. Share of High-Tech Employment in Services, by sector, 1995-2011



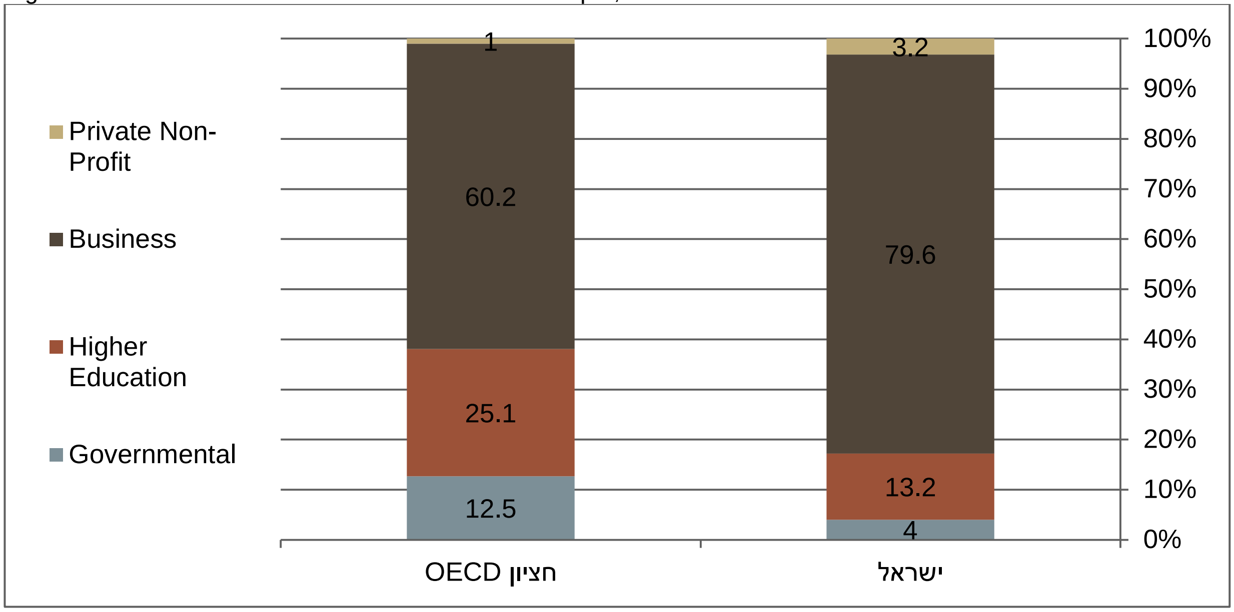
Israel's academia ranks high too, with a high rate of scientific publication, high ranking of universities, international awards for Israeli science, and patent productivity of universities – all of which contribute to Israel's repeated ranking as #1 worldwide in quality of scientific research institutions. The leadership of Israeli universities is noted in particular in computer science, mathematics, economics, and chemistry[29] and national plans set several specific scientific fields as national priorities. Finally, all seven of Israel's research universities have a technology transfer arm, with Weitzmann Institute's YEDA founded in 1959, much earlier than noted TTOs elsewhere in the world.

4.4 STEM at work: A summary

The change of the Israeli economy into a major player in the global knowledge-economy has been a major draw for STEM professionals into Israeli knowledge- and technology-intensive industries. Israeli industry and academia appeal to Israeli – and foreign – scientists and engineers. With that, Israel is home to the third most educated workforce worldwide, with 12% holding academic degrees.

[29] According to the Shanghai ranking of universities 2001: in computer science Weitzmann Institute ranks 11th worldwide; Technion 15th, Hebrew University 26th and Tel Aviv University 28; in Mathematics, Hebrew University 22nd, Tel Aviv University 32 and Technion in group 51-75; in Economics both Hebrew University and Tel Aviv University in group 51-75.

Figure 16. Relative Share of Sectors in Total R&D Output, 2009



While workplace integration has been substantively similar across the various high tech industries, productivity has been uneven. Israeli industry and also the workforce is heavily tilted towards ICT: in comparison with cleantech and bio- and nano-tech, ICT is the least integrated with other knowledge-intensive sectors, and thus there are fewer multilateral partnerships with academic- and public labs. Only 8.7% of ICT patenting in 2007-2009 occurred in university or public research labs, compared with 14.5% in environment-related technologies and 35.8% of patenting in bio- and nano-tech. The strength of Israel's high-tech firms is evident in NASDAQ listing: in 2011 there were more Israeli firms traded on NASDAQ than all firms originating in Europe, India and China combined.

Generalizing about R&D output in Israel, Figure 16 exhibits the sectoral share of R&D output in 2009, comparing between Israel and other OECD-member countries. This pattern confirms the importance of government partnership, support, and active involvement, not only in schools and education but also throughout the STEM 'pipeline' into patenting and other industrial processes.

5. Strategies, policies and programs to enhance STEM

Israel's history as a centrally planned economy until the wave of privatization and liberalization in the early 1980s imprinted the institutional map of STEM-related initiatives. Therefore, while private industry and knowledge- and technology sectors increased rapidly is size and vibrancy, Israeli government policies and sponsorship, as well as legislation, remain the dominant force behind STEM.

5.1 Government initiatives

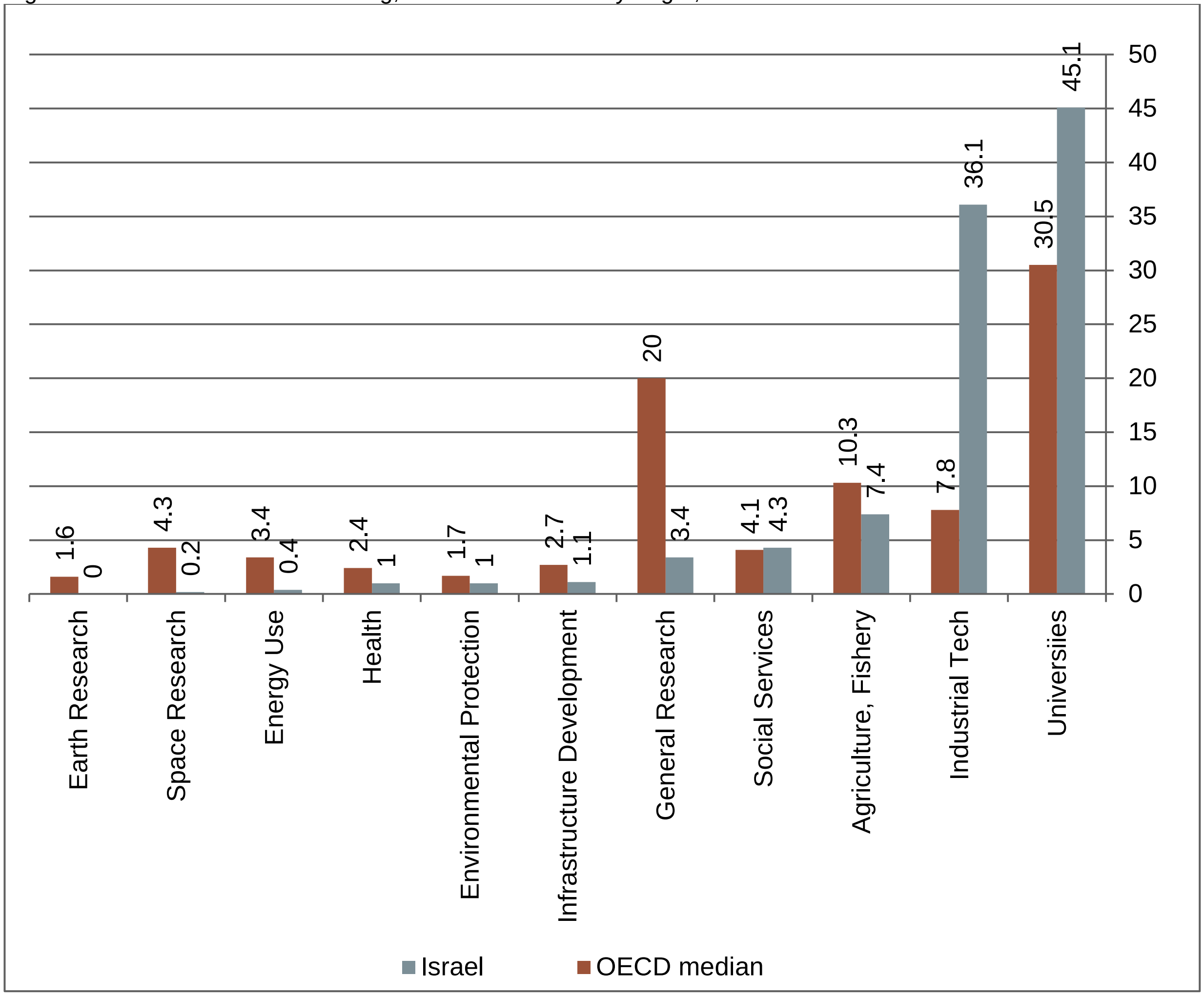
Israel's science, technology and innovation (STI) policy regrettably spans the jurisdictions of several ministries: Ministry of Industry, Trade and Labor, Ministry of Science and Technology, and Ministry of Education. The Ministry of Education, naturally, supervises STEM education, STEM in industry and work is supervised by the Ministry of Industry, Trade and Labor, and the Ministry of Science and Technology is charged with highlighting these fields across governmental administration. For science alone, Israel's governmental science policy is determined in coordination of the National Council for Research and Development[30], the Ministry of Science, and the Forum of Chief Scientists[31]. Yet, while the Chief Science Office is a part of most of Israel's ministries, there is no comprehensive national STI plan or strategy.[32] The path of Israel's STI policy is, therefore, unique in comparison to other emerging economies: Israel's successful IT industry is built upon already present R&D and educational capacity and was then spurred by a 'market-failure-focused, industry-neutral S&T policy' (Breznitz, 2007). Still, as noted by OECD reports, in comparison to other OECD-member countries, Israel's innovation policy is lagging (see Figure 5). The absence of cohesive governmental leadership on STEM matters, while creating redundancies and loose coupling, results in a plethora of government initiatives to enhance STEM and to secure Israel's global leadership in knowledge- and technology-intensive industry.

[30] A 15-member council, operating as an independent government agency under the auspices of the Ministry of Science and charged with civilian R&D.

[31] A coordinating body among the chief scientists of the various government ministries. Posts of Chief Scientist are a part of the following Ministries: Agriculture and Rural Development; Communications; Construction and Housing; Defense; Education; Energy and water Resources; Environment; Health; Immigration Absorption; Industry, Trade, and Labor; Public Security; Science; and Ministry of Transport.

[32] For comprehensive review of policy, updated to 2007, see Getz and Segal (2008).

Figure 17. Government R&D Funding, share of allocation by target, 2010



The following sections detail initiatives taken by Israeli governments in the past 3 decades, categorized by the sector targeted.

5.1.1 School-oriented government initiatives

- Creating coordinating agencies regarding STEM education: Founding of the Science and Technology Administration as an agency with the Ministry of Education that is dedicated to 'ensur[ing] that graduates of the education system respond to the current needs of industry and the military'. The Agency sets STEM education goals, crafts STEM curricula and related pedagogies, supports the introduction of ICT into classrooms, monitors student achievements in STEM subjects, and leads Israeli initiative of 'Adapting the Education System to the 21st Century'.[33]

[33] For more information, see http://cms.education.gov.il/EducationCMS/UNITS/MadaTech or contact Dr. Ofer Rimon, head of CMS (oferri@education.gov.il)

- Drawing excelling students into STEM: Israel's Ministry of Education founded an honors program for excelling students, which offers a 6-year track in STEM subjects. Students are identified by teachers during grades 5 or 6 and then enrol in a 7-12 grade program in STEM. Graduates of this STEM honors program receive special consideration for recruitment into certain military units and for admissions to the Technion.
- Disseminating STEM curricula and pedagogical tools equally across population groups: Matar (science and technology on-line) is a Ministry of Education-sponsored program that is operated by Tel Aviv University. The program offers an on-line portal for STEM studies: from podcast lessons for students, to classroom aids for teachers, to books and other information sources for school-level research.

5.1.2 Academia-oriented government initiatives

- Spurring research excellence: The Higher Education Plan 2011-15 doubled the funding for the Israel Science Foundation (from 75 million USD in 2011 to 139 million USD by 2015) and created an I-CORE (Israeli centers of research excellence) project with an added budget of 362 million USD.

5.1.3 Workforce-oriented government initiatives

- Integrating adults from marginalized groups into the STEM-related workforce: with governmental support, several colleges offer training programs for special populations, such as Ultra-Orthodox Jews. Such programs, targeting adults only, offer a combined curriculum that includes preparatory courses in STEM and professional training in STEM-related occupations. Several such programs are working these days to add an academic component, with BA and BSc credentialing.
- Absorbing skilled immigrants into STEM-related professions: the 1991-1998 incubators program was founded to alleviate stress of large and highly educated immigration from the former Soviet Union. It later spun some 500 graduating companies with 50% success rate (Trajtenberg 2000). These days there are private, non-profit versions of this incubator program; the Israeli NGO Gvahim (heights, in Hebrew) runs TheHive, which is a 6-month high-tech incubator residency that is offered to new Israelis.

5.1.4 Industry-oriented government initiatives

Seeing the dependence of Israeli knowledge- and technology-intensive sectors on foreign financing and global trade, Israeli policy has had a dual purpose. On the one hand, government initiatives work to invite additional foreign firms to set foot in Israel, while, on the other hand, government initiatives work to build local capacity.

Specifically, to encourage foreign technology-intensive firms to settle in Israel, Israeli government has been:

- Supporting breakthrough innovation into commercial and industrial use: the MAGNET program was established in 1994 and is managed by the Office of the

Chief Scientist of the Ministry of Industry, Trade & Labor, with a budget of 57 million USD in 2011. MAGNET has several tracks, each aimed at supporting technology initiatives at different stages of development.

- Bridging the distance between Israel and world markets: MATIMOP, the executive agency of the Office of the Chief Scientist of the Ministry of Industry, Trade and Labor of Israel, is dedicated to generating and implementing international cooperative industrial R&D programs between Israeli and foreign enterprises.

In addition, in order to build national capacity, with local technology-intensive industry, the Israeli government has supported:

- Incubating start-ups: 28 technology incubators were created between 1991-1993, partly as an absorption strategy for skilled immigrants, mostly from the former Soviet Union. These incubators were to offer support for inventors at the fragile initial stage of technological development and carry them into maturity of exit or commercialization. While the incubators program added to the vibrancy of the Israeli high tech sector at its early stage, the direct results of the program were rather disappointing, with few exits or M&As for tenant companies. Still, the total exit valuation of companies incubated by 2007 is estimated at 1.2B USD.

5.1.5 Government initiatives that target supporting institutions

Several government STEM-related initiatives offered an indirect support for STEM by building the eco-system in which STEM operates. Such initiatives built financial capacity, industrial and technological infrastructure, and business training. For example:

- Identifying sources of funding: the 2010 Ministry of Finance initiative titled ‘relative advantage’ is aimed at locating financing sources for Israeli start-up companies. While Israel is rich with venture capital funding, Israeli high tech sectors are not maturing into large ICT companies. The program sets to correct the preference for a quick exit strategy and seeks to build an ‘Israeli Nokia.’
- Building VC capacity: the Yozma (‘initiative’ in Hebrew) program used government investment of 100M USD to leverage 150M USD from private investors, to build 10 VC funds in which government is a stakeholder. This spurred the emergence of the VC sector in Israel and contributed to the start-up boom.

5.2 Regulatory framework

Many of these government initiatives and programs are anchored in national legislation. Numerous laws guide Israeli policy regarding STEM and STI, revealing the policy emphasis on education and particularly on R&D.

Several laws target STEM and STI directly. For example, the Encouragement of Industrial Research and Development Law 5744-1984 (amended as late as 2006) created a solid administrative basis for subsequent R&D-related initiatives during the critical years of Israel's high tech growth. Israel also has 20 different laws regarding intellectual property, all of which secure the rights of inventors and with that encourage local STEM-related innovation. And, of course, the series of laws that guarantee the right for education, offering free public education starting at age 3 and heavily subsidized public university education, have set the foundation for Israel's education system.

Other laws impact STEM and STI indirectly: for example, the Law for the Encouragement of Capital Investment, 5719-1959 (amended as late as 2011) enables the creation of Israel's now flourishing VC sector. Similarly, several laws for preferential treatment of R&D investments in the Negev and Galilee served to lure foreign companies to build R&D centers and plants in these peripheral regions. For this reason, Intel's largest fab plant in Israel is located in the city of Kiryat Gat.

It is also through regulatory means that most government agencies charged with STEM are created. For example, the National Council for Research and Development, which is a governmental agency supervised by the Ministry of Science, was founded through the National Council for Civilian R&D Law of 2002. While such laws declare the governance structure and the scope of tasks for such agencies, there is an obvious overlap among the policy domains of STEM-related agencies.

5.3 Corporate initiatives

Realizing their dependence on a continuous input of STEM-skilled and innovative employees, corporations are moving to support STEM education and thus supplement government investments.

- Intel Teach: the worldwide Intel initiative is very active in Israel, offering teacher-training programs for use of ICT to aid teaching and learning in schools, reached some 12,000 Israeli teachers
- Mind the Gap!: started in 2008 by a group of women at Google Israel, the program tackles the problem of gender disparity in STEM. With the aim of introducing girls to the world of STEM-related study and work, the program hosts girls of high school age at Google offices and sponsors their visits at R&D labs, university classrooms, and conferences. The program prides itself that some 40 percent of the girls who participated in the 2011 conference later chose computer science as a high school major.

5.4 Civil society initiatives

Israel's burgeoning civil society sector too is rallying in support of STEM education and STEM-related industrial growth. Many are the private, non-profit and independent agencies whose mission pertains to STEM, directly or indirectly.

- The Ilan Ramon Youth Physics Center: inaugurated in January 2007 and named after the Israeli astronaut on the Columbia space mission, the Physics Center offers high-quality physics instruction for excelling teenagers on the campus of Ben-Gurion University of the Negev. It also runs hands-on learning activities in schools in 15 cities across Israel's southern region, reaching some 8,000 children.
- Israel Technology Transfer Network (ITTN): an umbrella organization for the technology transfer agencies of universities, medical centers and public health agencies, and regional incubators. ITTN acts as a lobby, advocating the facilitation of links between research and its industrial and commercial use.

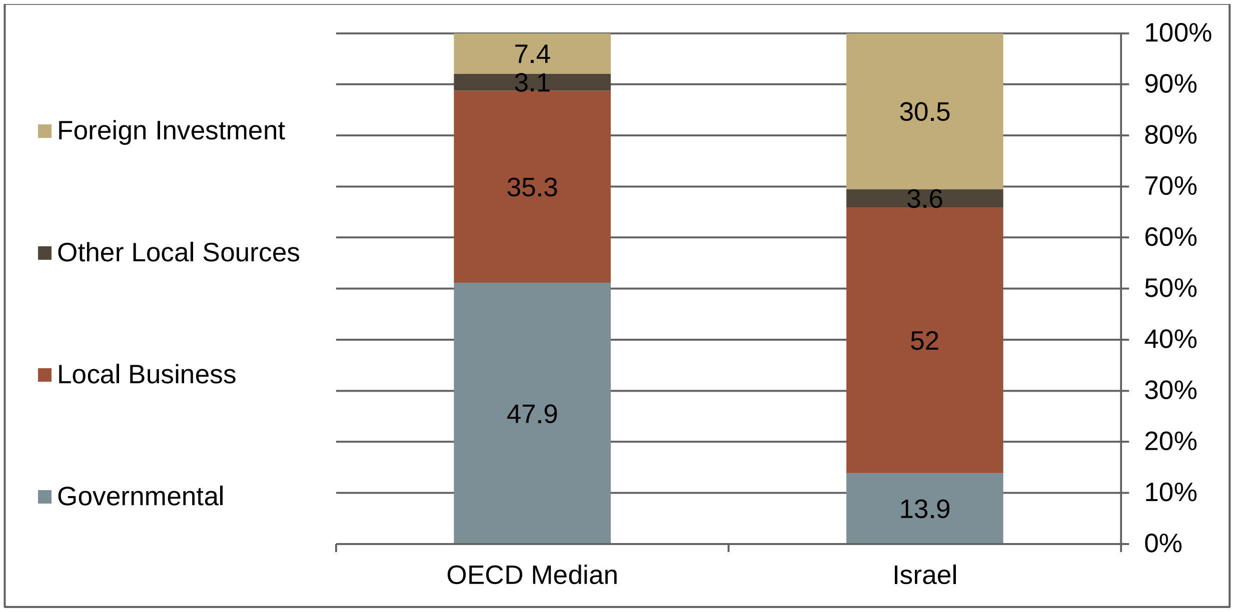
5.5 Academia's initiatives

- Hemda, an innovative regional program for science teaching: initiated by the Weizmann Institute of Science in 1991 in Tel Aviv and since expanded to a Rehovot campus, Hemda creates a learning center for high school students from several nearby schools who wish to matriculate in advanced (4-5 units) STEM. Hemda offers STEM education (fully-equipped labs, superb teachers, and tutorial services) that are otherwise beyond the capacity of each individual high school in the region. Plans for the future are to create Hemda centers also in Israel's peripheral regions, where STEM education is particularly lacking.
- The Hebrew University of Jerusalem and the Technion were instrumental in the sprouting of Israel's 2 leading science museums, Bloomfield Science Museum and MadaTech. On each such initiative the academic institution worked with several partners to bring the project to fruition. For example, Bloomfield Science Museum in Jerusalem grew out of the cooperation of the Hebrew University, the Jerusalem Fund, and the Bloomfield family and with the leadership of Jerusalem's most charismatic mayor at the time, Mr. Teddy Kollek.

5.6 Initiatives to support STEM: A summary

The commitment to support STEM – from schools to universities to R&D centers – is evident in the funding commitments of various sectors. While the nature of the Israeli polity is such that many public initiatives in Israel are brought forward by government, in regards to STEM the share of government in total R&D investment in Israel in 2009 is far smaller than the OCED average (Figure 18). This is, to a large extent, the result of the huge Israel venture capital sector (classified herein in the category of 'local business'). This for-profit vote-of-confidence in Israel's STEM is also evident in the large share of foreign investment in Israel's total national R&D, which is also far larger than the OECD average. Yet, while such figures flatten the notion of commitment, the range of programs listed in Section 5 reveals the diversity and ingenuity of STEM initiatives in Israel.

Figure 18. Sources of Nation R&D Expenditure, 2009



6. Concluding comments

While the quality of science education in Israel, from elementary- through high schools, is in the lower-middle range among other OECD-member countries, the success of Israeli academia and of Israeli civil- and military R&D branded Israel as 'start-up nation'. Israeli STEM is most unique in three ways. First, like the United States, Israel's STEM pipeline has the odd feature of presumably weak input and particularly strong output. Second, departing from the typical STEM pipeline of schooling into the workplace, Israel's STEM track is 'interjected' with compulsory military service for 18-years-olds. Last, Israel's STEM potential is compromised by the fact that an estimated 15-17% (and rapidly growing percentage) of Israel's population is Ultra-Orthodox and therefore does not participate in STEM education and workforce. Nevertheless, Israel stands as a particularly strong partner to the global knowledge economy. Israeli academia, knowledge- and technology intensive industries, and venture capital sector are most dynamic and productive, with high rates of success and yield.

STEM-driven changes impacted the nature of Israeli society. High labor mobility in knowledge-intensive sectors, in and out of Israel, made Israeli high-tech companies into multicultural spaces: they adopted English as the language of work and recruit from various nations, even if the pace of their work remains Israeli in character (for example, the work schedule coincides with the Israeli calendar, where Jewish holidays are observed and Sunday is a workday). In addition, the success of Israeli firms brought great wealth to their Israeli founders, partners and employees, thus introducing a culture of world-class consumerism that was alien to Israeli society until the 1980s. Israel is now more cosmopolitan than ever before, further tying Israel with the global economy and culture, while all the while Israel remains in a frail and temporary quiet in terms of its security and political standing. STEM has therefore brought much prosperity to Israel but has not eased Israel's precarious position among its Arab neighbors and has not offered any breakthrough in the troubled relations between Israel and Palestine.

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