What can the "Start-Up Nation" do to enhance diversity in physics?

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Abstract

Israel is among the world's leading nations in terms of achievements in technological development, earning it the nickname the "start-up nation". Science studies in general, and physics specifically, are among the foundations of this technological growth in Israel. As part of efforts to advance the field of physics, looking towards the future, we conducted an unprecedented study of undergraduate and M.Sc. degree students of physics in Israel, as a collaboration between the Weizmann Institute of Science and the Israeli Physical Society.

The study's findings reveal that both B.Sc. and M.Sc. students are a homogeneous group, characterized by an over-representation of students of high socioeconomic background and an under-representation of several population segments, including: women, Arabs, ultra-Orthodox Jews, and students from the socio-geographic periphery. In light of these findings we ask what can be done to increase diversity among physics students in Israel.

This article proposes enacting a change that centers on two interconnected steps, aimed at removing the structural barriers that hinder the entrance of students from underprivileged groups into the academic field of physics. The first move is related to high school-level studies; in essence, it entails strengthening physics studies in the peripheries and making them more accessible to students from underrepresented groups by establishing centers for science education (such as the Schwartz/Reisman Science Education Centers) and distance learning using the "Virtual High School" model. The second step relates to the entry into higher education, and has to do with encouraging students from underrepresented groups who did not study physics in high school to enroll in pre-academic programs at the

universities (using economic incentives). These two steps combined will increase accessibility to this field, remove structural barriers to equality for groups in the social-geographic periphery, and enrich the field of physics with talented youth from a variety of backgrounds.

Introduction

The present article is based on an unprecedented study conducted in Israel through a collaboration between the Weizmann Institute of Science and the Israeli Physical Society. The study examined the background characteristics and attitudes of undergraduate and master's degree physics students in all of Israel's research universities. It's two main objectives were: first, to identify characteristics of Israeli physics students and their attitudes towards the academic physics study track. Second, to create a knowledge base through which it will be possible to examine the characteristics and attitudes of physics students over time, as a basis for strategic forward thinking about advancing the field in Israel.

This study supports similar studies from around the world about physics students, conducted by professional physics associations (such as the American Institute of Physics, which includes a center for statistical studies that carries out research as well as collects and analyzes data about education, careers, and diversity in physics and astronomy).

Methodology

The study population includes all B.Sc. and M.Sc. physics students in Israel's six research universities: Technion, Tel Aviv University, Bar-Ilan University, the Hebrew University of Jerusalem, Ben-Gurion University of the Negev, and the Weizmann Institute of Science (M.Sc. students only).

Research tools: two self-administered online questionnaires, one completed by B.Sc. students and one completed by M.Sc. students. The questionnaire for B.Sc. students contained 38 questions, including six open-ended questions. The questionnaire for master's degree students contained 40 questions, including four open-ended questions. The following topics were examined: the students' socio-demographic characteristics, personal and family background, academic background (high school and undergraduate studies), attitudes towards the academic physics track, perceptions and image of the physics field, future academic plans, and perceptions about their future employment.

The questionnaires were administered between May and July 2018, with a total of 712 undergraduate respondents, comprising 49% of the population of undergraduate physics students, and 211 M.Sc. students, comprising 59% of that population. These high response rates reflect the concerted efforts of the research team, which entailed several steps aimed at raising the response rates (individual appeals to the students through university deans, multiple reminders, and a lottery among respondents). The high response rates enhance the reliability and validity of the data and significantly reduce the sampling error.

The sampling error for the entire population is 2.7% for the B.Sc. student survey and 4.4% for the M.Sc. student survey.

Main Findings

Socio-demographic characteristics of physics students

The table below presents the main findings regarding socio-demographic characteristics of B.Sc. and M.Sc. physics students. The data reveals that students at both degree levels comprise a homogeneous group lacking in socio-demographic diversity.

Table 1: B.Sc. and M.Sc. students in physics, socio-demographic characteristics

Variable	**B.Sc. Students**	**M.Sc. Students**
Gender: male	74%	84%
Age: 16-25	75%	22%
26-30	23%	62%
Family status: single	86%	56%
Sector: Secular Jewish	84%	84%

Birth place: Israel	90%	88%
Military service: Yes	84%	93%

As the data shows, most physics students are male and are young (most B.Sc. students are under 25, and M.Sc. students tend to be in their mid-twenties), Israeli-born, have completed military service, and were educated in the secular state education system.

A comparison of the students' data with the characteristics of the Israeli general population (Central Bureau of Statistics, Society in Israel Report 2018) reveals an underrepresentation of several population groups among physics students: women, Arabs, ultra-Orthodox, and those of low socioeconomic status from the socio-geographical peripheries.

Table 2: Underrepresented social groups among B.Sc. and M.Sc. physics students

Variable	B.Sc. Students	M.Sc. Students
Gender: Female	25%	16%
Sector: Ultra-Orthodox Jewish	0%	0%
Sector: Arab	2%	2%

The first group that is severely underrepresented is women. Women comprise about a quarter of B.Sc. students and only 16% of M.Sc. students (while comprising 51% of the overall population). A study of the women who could potentially choose to enter this field reveals that women comprise 36.7% of those who took the highest-level (5 units) physics matriculation exams in 2016, meaning that the potential proportion of women physics students, given current admission standards, is greater (Mani-Iken, Rozen & Bashan 2017)

Another group that is conspicuously underrepresented is students from the Arab sector of society. Arab high school graduates comprise just 2% of both B.Sc. and M.Sc. physics students, while Arabs account for about 20% of the overall population. This figure is particularly remarkable considering that 18% of those who took the highest level (5 units) physics matriculation exams in high school were Arabs. In other words, the barrier to university studies in this field for Arab students is not related to their academic credentials (as of 2016, see: Mani-Iken, Rosen & Bashan 2017).

Yet another group that is underrepresented consists of Jewish students educated in the ultra-Orthodox education system. These students comprise 14% of Israel's Jewish student population (Central Bureau of Statistics 2018), yet lack any representation in the field of physics. Israel's ultra-Orthodox population is a unique case, given that their cultural background has led thus far to their absence from the sphere of higher education in Israel. Only in the last decade has this population begun integrating into the academic world, albeit in small numbers and in selected fields. In contrast to the ultra-Orthodox, students from the religious national education system (excluding the ultra-Orthodox) are represented among physics students in similar proportions to their overall representation among the general population (they comprise about 10% of B.Sc. and M.Sc. physics students, while accounting for about 12% of the overall population in Israel, according to data from the Central Bureau of Statistics).

The final group identified in the study as underrepresented in the field of physics are those from the country's geographic periphery and of low socioeconomic status. This variable is more difficult to quantify, nonetheless, it was derived by cross-analyzing a number of data: the educational institutions from which they graduated, the financial support provided by the students' families during their studies, and their parents' level of education, which in Israel correlates closely with economic status.

Examining the educational institutions physics students graduated from reveals an overrepresentation of prestigious schools located in Israel's main cities (high schools regarded as strong in Central Israel and in the Tel-Aviv, Haifa, and Jerusalem districts).

Data on parents' background reinforces this image, by revealing that physics students (at both the B.Sc. and M.Sc. levels) hail from a highly educated segment of the population. About 70% of these parents (mothers and fathers) have an academic degree, and a considerable number of them have doctoral degrees (about 12% of B.Sc. students and 16% of M.Sc. students have at least one parent with a Ph.D.).

The socioeconomic background of the students is revealed by the level of financial support they receive from their parents. The study reveals that an overwhelming majority of B.Sc. students are supported by their parents during their studies. The students report that undergraduate studies in physics are extremely demanding and require much memorization and independent study; most described their courses as very interesting, but also very difficult and demanding. Correspondingly, most physics B.Sc. students do not work during their studies (55% did not work at all, and an additional 30% worked in student positions that were very limited in scope). These students thus need financial support to cover their tuition and living expenses, which is provided by their parents. The study found that 61% of the students received significant financial assistance from their parents during the course of their studies.

Table 3: Financial support from parents during undergraduate studies for B.Sc. students

Financial support	**B.Sc. Students**
Substantial support	**61%**
Minimal support	**23%**
No support	**16%**

These findings as a whole indicate a structural (economic) mechanism that may serve as a barrier to entry into physics (undergraduate) studies for students whose families cannot afford to fund tuition as well as living expenses during their B.Sc. studies.

Academic background of physics students

The scholastic background of these students reveals that nearly all began their B.Sc. studies after graduating from science tracks in high school and successfully completing advanced level (5 units) mathematics and physics (some of the respondents in this study who did not take 5 units had graduated from high schools abroad).

Table 4: Science studies at high school for B.Sc. and M.Sc. physics students

Variable	B.Sc. Students	M.Sc. Students
5 units mathematics	86%	**88%**
5 units physics	87%	**100%**

This data reveals that the Israeli higher education system is missing out on a great number of students who did not take advanced (5-unit) mathematics and physics in high school. While advanced mathematics is a vital foundation for the academic study of physics, even 5-unit physics studies in high school are basic, and those who did not take advanced physics matriculation exams can make up the gap in pre-academic programs (offered in several universities).

The difference between physics and mathematics studies in high school is that, while advanced 5-unit mathematics are offered at nearly every high school in Israel (the Ministry of Education is recently making a concerted deliberate effort to increase the number of students taking 5 units of mathematics, with proven success), physics studies at the high school level suffer from a severe shortage of teachers and resources necessary for establishing teaching labs. This is particularly true in the country's peripheries. Recent data from the Ministry of Education indicates a severe shortage of physics teachers: in 2019, Israel had 430 thousand high school students and only 1,240 physics teachers. That year, just seven new physics teachers joined their ranks and thus, in 2019, there were 347 students per teacher (Dettel 2019). This shortage of teachers and resources means that many schools do not offer physics tracks at all, thereby creating a structural inequality. The situation is particularly severe in the Bedouin sector, where 70% of the schools do not have a physics track, and the rate of matriculation in physics is a mere 2%.

These conditions, namely a chronic shortage of teachers and resources for high school physics studies while 5-unit matriculation in physics is a prerequisite for acceptance into physics B.Sc. programs, create the present situation, wherein students who did not take a physics track in high school are precluded from entering the academic world of physics.

The solution offered today, as noted, is enrolment in a pre-academic course, offered by most Israeli universities so as to allow potential students without physics matriculation exams to enter the field. Yet, this solution is challenging, since pre-academic courses are difficult, last several months, and are costly. These conditions create additional barriers preventing students from underrepresented groups from entering the field.

How can diversity among physics students be increased?

Sociological research has the power to expose social structures that have been, up until now, hidden. This was the experience of the research team and of policy makers in the realm of higher education upon first discovering the results of this study and learning the extent of inequality in academia in the field of physics.

A strategic view of the physics field and its future led us to the understanding that well-thought out initiatives are necessary in order to bring to fruition our commitment to create equal opportunities in higher education generally, and in the field of physics specifically. In order to strengthen physics studies in Israel, and with the understanding that this discipline is a major engine for growth in the Israeli economy, we must find ways to increase diversity among physics students in Israel. This is crucial for the "start-up nation" (Senor and Singer 2009), a leading country in economic accomplishments and technological developments in the West.

Based on the considerable research data collected on the effects of diversity in STEM fields, we believe that increasing diversity has a dual purpose: to create better science and to promote a better society. Therefore, we propose taking action to effect change, focusing on two interconnected moves; the objective is to remove existing structural barriers that hinder students from underrepresented groups from entering the academic field of physics as well as to increase diversity.

The first move is related to high school studies of physics and focuses on strengthening these studies in the periphery, making physics accessible to wider segments of the student population that are at present underrepresented.

Several excellent programs, which are focused on making physics more accessible to high school students in the country's center and periphery, already exist in Israel. We recommend evaluating the possibility of expanding a number of programs that we perceive as promoting this goal: centers for science education and distance learning using the Ministry of Education’s Virtual High School model.

At present, the Schwartz/Reisman Science Education Centers operate in three municipalities in Israel’s center. The Schwartz/Reisman Center in Rehovot (in collaboration with the Weizmann Institute of Science) serves students from the cities of Rehovot and Ness Ziona, and as of this year, it also has a class of students from the Arab sector in the neighboring city of Ramla. The Schwartz/Reisman Center in Rishon LeZion and the Center for Science and Technology Education in Tel Aviv serve the student populations of their respective cities. The primary purpose of these centers is enrichment and reinforcement of science studies (physics, chemistry, and other subjects), combining a high-quality team of teachers with the most advanced scientific-education equipment, including state-of-the-art, well-equipped labs and advanced teaching tools. The concentration of the best means of education in a single institution provides students the opportunity to study at the highest level: this focus enables them to be provided with the best knowledge, resources, and capabilities for teaching the subject and providing access to a large number of high schools in a given geographic area. A study of the last six years reveals that the number of high school graduates matriculating with 5 units in physics has doubled in Rehovot and tripled in Ness Ziona. Furthermore, physics dropout rates have decreased dramatically. Another initiative working to strengthen physics studies among students in the periphery is run by the Tamar Center Negev, aimed at the Bedouin population. This initiative provides an after-school framework that assists students in obtaining matriculation diplomas in sciences (though the scope of its operations is limited).

The model of the Schwartz/Reisman Science Education Centers, which has proved successful in the country’s center, has yet to be expanded to the periphery. Thus the current situation in fact exacerbates the gaps between students from the country’s center and those in the geographic periphery. Establishing similar centers in additional cities across Israel, and especially in the periphery, will help bridge these gaps and make the field of physics accessible to a greater number of students, including those currently underrepresented.

Another project that can be applied to the effort to make physics education more accessible in the peripheries is teaching physics using the Virtual High School (established in 2012 and run by the Center for Education Technology). This program allows interested students to study physics (as well as mathematics and civics) at the advanced 5-unit level through distance learning. Each classroom is composed of students from different schools across the country, who are instructed by a teacher located in the center. At present, the Virtual High School serves about 1,000 students from 130 schools across the country every year, and draws students from all population sectors: Jewish and Arab, in both the religious and secular education systems.

Expanding and strengthening these initiatives – the centers for science education and the Virtual High School – will help make physics more inclusive and accessible to a larger population, including in the periphery, and will increase the pool of potential students studying for advanced degrees in physics.

The second step is concerned with enrollment in physics B.Sc. tracks and focuses on encouraging students without a background in physics to enroll in a pre-academic program using financial incentives.

Currently, the potential pool of physics students is relatively limited and consists primarily of students who graduated from physics tracks in high school. This pool amounts to between 8,000 and 9,000 students per year over the past decade (Mani-Iken, Rosen & Bashan 2017). At present, in order to enable those who did not complete a physics track in high school to enter the field, most universities in Israel offer pre-academic programs, which make it possible to catch up (usually by taking a summer semester course costing NIS 1,000-3,000). This requirement to enroll in pre-academic studies and their high cost could be construed as a barrier to students from lower socio-economic background.

The move we are proposing is to encourage students from underrepresented groups to enroll in pre-academic program using an economic incentive: by giving an exemption from tuition for the program, and even a financial reward, to those who complete it successfully, in addition to scholarships for B.Sc. studies for students from the target population.

The combination of these two proposed steps will, in our estimation, expand the potential pool of physics students among population groups that are presently underrepresented, thereby contribution to enhancing equal opportunities and diversity in the study of physics.

The potential impact of these moves extends beyond undergraduate education and can in the long run also increase diversity among physics faculty in Israel (where today there is an evident lack of diversity in gender, religion, and socio-economic status).

Expansion of the student pool in a way that will draw from underrepresented groups, will enable us to increase the number of students with potential to become excellent physicists. **Increasing diversity will create a richer learning environment, increase creativity in developing and implementing new ideas and, ultimately, will benefit the advancement of science**. **We hope that this plan will contribute to the formation of a better society, one that provides equal opportunities regardless of ethnicity, class, religion, gender, or race** (strategic action along these lines is being promoted in many other countries: see for example the statement made by the American Educational Council in 2012).

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