FIRST High-School Students and FIRST Graduates: STEM Exposure and Career Choices

Shahaf Rocker Yoel and Yehudit Judy Dori

Abstract*—*Contributions: **The study contributes to the social cognitive career theory (SCCT) by explaining high-school students' career choices and finding possible relations between self-efficacy, interpersonal skills, what inspires them to choose a career, and their actual choices. The practical contribution of this research lies in understanding the impact of the For Inspiration and Recognition of Science and Technology (FIRST) program on its participants and graduates.**

Background: **The FIRST program incorporates project-based learning that fosters the design and production of innovative robotics by teams of students who compete annually.**

Research Questions: **1) Do the FIRST program activities increase STEM exposure and encourage STEM career choices, and if so, how? 2) What are the factors that affect these choices? Are there correlations between those factors? If so, what are they? 3) Is the effect of the FIRST program on FIRST high-school students' exposure and career choices different from that effect on FIRST graduates? If so, what are the differences and does gender play a role in these differences?**

Methodology: **The research participants included 119 FIRST high-school students and 297 FIRST graduates. The research applied a convergent parallel mixed-methods approach, with data collected both qualitatively via interviews and quantitatively via questionnaires.**

Findings: **Analysis of the data showed that the FIRST program increased participants' STEM exposure and career choice in STEM domains. A significant, positive, strong correlation was found between interpersonal skills, STEM exposure, career choice, family and school support, and external motivation.**

***Index Terms*—Career choice, engineering education, For Inspiration and Recognition of Science and Technology (FIRST) program, high-school students, interpersonal skills, problem-based learning, robots, STEM, social cognitive career theory (SCCT), soft skills, STEM education, undergraduate students.**

I. INTRODUCTION

FIRST—For Inspiration and Recognition of Science and Technology—was founded in 1989 in the USA as a nonprofit organization by Dean Kamen, an engineer, inventor, and businessman. The program aims to motivate young children and adolescents, 5–18 years old, to pursue education and career opportunities in STEM domains as they build their knowledge and life skills. The program incorporates project-based learning (PBL) and fosters innovative robotics design and production. The FIRST program includes national-level competitions and an international Olympiad [1]. Evaluations of the FIRST program in the USA showed that it increased participants' interest in STEM, understanding of STEM, and STEM career choice [2], [3]. The vision of FIRST Israel, founded in 2005, is to expose Israeli students to STEM while developing and preserving valuable organizational and social culture [4].

Learning STEM in the 21st century is crucial, as the demand for STEM professionals grows with the increasing global impact of technology. Indeed, there is an ever-increasing need for STEM professionals in the workforce in many countries [5], [6]. Despite the high income that STEM occupations offer [7], there is a decrease in the number of students who pursue these domains [8]. Within STEM, PBL was found to have a positive influence on students' attitudes toward learning and to foster team communication and collaborative behavior [9], [10]. Low-performing students' achievements in mathematics in a STEM PBL learning environment improved to a greater extent than those of students with high and medium achievements [9].

General thinking skills, such as verbal, analogical, quantitative, and analytical–technical capabilities, which are necessary for learning STEM topics, are no longer sufficient in the 21st century; interpersonal skills, such as communication, responsibility, social engagement, creativity, and teamwork, are also important for competing with the increased complexity of today's work environment [11]–[13].

The goal of this research was to examine the effect of the FIRST program in Israel on interpersonal skills and STEM career choices among high-school students participating in the program and graduates of the program. In this article, previous findings regarding graduates of the program [14] are elaborated. Then, the impact of the FIRST program on high-school students participating in the program and the relationships and differences between current participants and graduates, as well as between men and women, are examined. Finally, the intentions and career plans of past high-school students and their adulthood achievements are compared and discussed.

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Shahaf Rocker Yoel is with the Faculty of Education in Science and Technology, Technion—Israel Institute of Technology, Haifa 3200003, Israel (e-mail: shahafr@campus.technion.ac.il).

Yehudit Judy Dori is with the Faculty of Education in Science and Technology and the Samuel Neaman Institute for National Policy, Technion—Israel Institute of Technology, Haifa 3200003, Israel (e-mail: yjdori@technion.ac.il).

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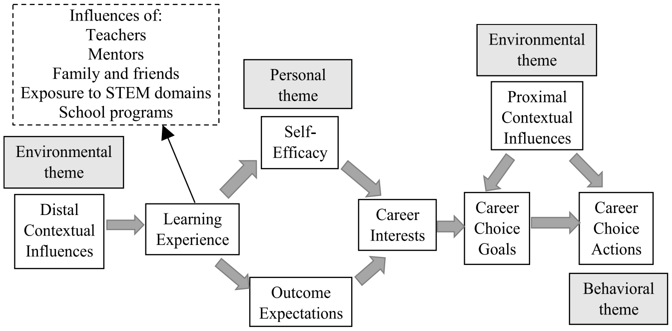

Fig. 1. SCCT model based on Lent *et al.* [16].

II. Literature Review

The theoretical background and literature review presented here cover the theoretical framework of STEM exposure and career choice based on both social cognitive theory (SCT) [15] and social cognitive career theory (SCCT) [16]. The literature review includes also PBL, robotics, interpersonal skills, and relations to SCCT.

A. Social Cognitive Career Theory

The SCT, which was developed by Bandura [15], comprises three themes: 1) personal; 2) environmental; and 3) behavioral. The personal theme includes knowledge, thinking skills, attitudes, expectations, and self-efficacy. The environmental theme refers to family, role models, friends, physical settings, and social norms. The behavioral theme is related to challenges, overcoming obstacles, and the choice of a career.

The SCCT was developed based on SCT and it enumerates the various factors within each theme. As suggested by Lent *et al.* [16], SCCT explores the relationships between the personal, environmental, and behavioral themes to predict the individual interest and career choice [17], as shown in Fig. 1.

SCCT is applied for investigating FIRST high-school students' and FIRST graduates' perceptions of factors that affect their career choices and beliefs [14]. In the international science Olympiad, students indicated that their interests, 21st-century skills, and career aspirations were affected mostly by their teachers, personal interests, and parents. The students believed that their participation in the Olympiad influenced their plan to choose a STEM field of higher education and helped them improve their 21st-century skills [18].

1) STEM Exposure: In view of the global technological growth, STEM has become a crucial topic of interest in the 21st century. In recent years, the need to encourage students to study STEM fields, to meet the demand for STEM professionals in the workforce, has increased. There is evidence that students' interest in majoring in STEM has been declining over the years [5], [6]. To make a change and encourage young adults to choose STEM as a career, exposure must start from kindergarten and continue through high school [18]. Studies of the FIRST USA program show that participation increases students' interest in STEM, understanding of STEM, and pursuit of STEM careers [2], [3]. STEM knowledge continues to grow the longer the student stays in the program [4].

Making science more relevant to everyday life and presenting it in broader contexts may help increase students' interest in science and understanding of the benefits of science, thus fostering their aspirations to pursue science careers [19]. Among students in England, understanding the broader relevance of science to their lives was the only measured teaching approach that consistently and positively correlates with students' interest in and application of science. Consistently, students perceived the utility of science as having the strongest positive association with their STEM career aspirations [20].

Informal K–12 programs that provide positive STEM experiences can contribute to students' future involvement in STEM domains. Differences between genders have been found in several studies [21]–[24]. When participation in the program starts at an early age, it has the potential to reduce gender, racial, and socioeconomic gaps, as well as to motivate students to pursue higher education and careers in STEM domains [25], [26].

Each SCT theme is composed of several factors in the SCCT. For example, the personal theme includes the students' self-efficacy in STEM domains, while the environmental theme includes learning experiences, such as the influence of teachers, school programs or mentors, and exposure to STEM domains (see Fig. 1). Students' self-efficacy and their exposure to STEM domains can lead to choosing a STEM career, which belongs to the behavioral theme [14], [25], [26].

2) Career Choice: Students' perceptions and actions while choosing a STEM major in college are influenced by the three major themes of SCT and SCCT: 1) personal; 2) environmental; and 3) behavioral (Fig. 1) [15], [16]. To examine the factors affecting American high-school students' plans for a college major, a study was done regarding the students' math and science efficacy, and their parents' and teachers' expectations [27]. Students' future career choice was found to be positively correlated with their interests and goals in high school. Factors influencing whether students consider studying STEM in college included whether 1) the students' parents held a degree from a U.S. college; 2) the students attended STEM summer camps and completed more STEM PBL projects; 3) the students had high grades; 4) the students received encouragement from their parents and teachers; 5) the students had high math and science efficacy; and 6) the students were male, as males are more likely to consider STEM majors in college [27].

B. Project-Based Learning

PBL is an active learning strategy described by Kilpatrick [28] and Dewey [29]. Encouraging students to use active learning was suggested as the first principle of the PBL method [30]. PBL exposes students to real-world or authentic problems, offers a set of practical tools, and in STEM topics, it also involves producing an artifact [31]. The PBL approach can be used with young students, high-school students, and university students [30]. The PBL process is long, making the skills that the students acquire effective and long-lasting [32]. PBL focuses on problems and questions that encourage students to learn and find solutions using

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decision-making and problem-solving skills, autonomy, and responsibility [33].

1) PBL and Robotics: Robotics projects have been found to improve creativity, problem solving, and teamwork skills [34], [35], and to increase students' interest and motivation [36]. The students use engineering elements to engage in active learning experiences. The teachers' role is crucial when dealing with problems related to this kind of technology, and they must be able to support their students [37], [38].

A study regarding a robotics course for junior high-school students showed that only a few students could learn a new subject on their own through PBL. The course content must be carefully designed, and students must receive clear instructions, so they can acquire the necessary skills and knowledge before starting to work on a complex project. Robotics is a recommended platform for teaching STEM in underprivileged communities and for girls in particular, as it helps to overcome psychological or cultural obstacles of learning science and technology subjects [1], [39]. High-school girls who attended a robotics camp enjoyed the creative aspect of robotics. Furthermore, allowing women-only teams to compete and collaborate could significantly improve team member interaction [40].

2) FIRST Program: Based on PBL, the FIRST program fosters students to learn new knowledge and skills as they build a prototype such as a robot [30], [32], [33]. FIRST is a robotics program designed to foster the development of STEM skills and interests, as well as leadership and 21st-century skills. The FIRST program challenges teams of students and their mentors to solve a common problem within a given timeframe. The students work on the projects and develop their ability to work in teams [2], [41] who build robots from parts, at different levels of complexity suited to the students' age.

In 2002, Brandeis University evaluated the FIRST Robotics Competition (FRC) in the USA. One of the goals was to evaluate the impact of FRC on the participants in terms of academic and career choices. The findings showed that the FRC successfully promoted academic choices and a continual interest in science and technology. Participants in the FIRST program reported a positive sense of belonging and the acquisition of a variety of practical problem solving, planning, and communications skills. For the majority of the program participants, FIRST was one of the most important influences on their lives in the high-school and post-high-school years [2].

A subsequent study [3] involving FIRST program participants took place over a five-year period. The key findings were that five years after entering FIRST, participants showed consistently higher STEM-related interests and attitudes than students in a comparison group. The impacts on STEM attitudes and interests were greater for girls who participated in FIRST than for boys. Students in college demonstrated continued positive impacts of FIRST.

Another study on the FIRST program in the USA [42] indicated that students produced scientific knowledge as a result of participation in a robotics competition. Students distributed and shared their knowledge and understanding in written and oral materials, as well as through their team's robot. A study of students from 30 countries showed that the goals promoted by the FIRST program can dramatically influence social and academic outcomes [43].

The FIRST program utilizes ideas underlying SCCT by designing the learning environment with SCCT elements that include PBL, mentors, and role models, accounting for influencing factors in the personal theme and career choice in the behavioral theme [14].

C. Interpersonal Skills

PBL is an effective method for the development of 21st-century skills, as it promotes critical thinking, problem solving, interpersonal skills, innovation, and creativity [44] while helping students obtain content knowledge and group work skills [45]. There is no clear definition of interpersonal or soft skills, but educators and researchers agree that these skills are important for competing in the increasingly complex contemporary work environment [11]–[13]. The ABET, an organization that certifies college and university programs in STEM domains with emphasis on the engineering domain, has defined a set of soft skills. Soft skills refer to interpersonal skills, including time management, communication, teamwork, lifelong learning, and professionalism [46].

Interpersonal skills can be improved by training, as described in a study regarding a university course for developing engineering students' interpersonal skills [47]. Students improved their interpersonal skills after participating in such a course, and the improvement continued over time. In the researched course, the students were exposed to several skills, including giving and requesting feedback, reflecting feelings, disagreeing, apologizing, dealing with criticism, talking in public, working in teams, coordinating groups, solving problems, making decisions, mediating conflicts, and making friends [47].

Participation in a science competition has a positive influence on students' interest in STEM and developing their interpersonal skills. In SCCT, these skills refer to the learning experience and self-efficacy factors of the personal and environmental themes [1], [14]. The interpersonal skills in the FIRST program and in this study include leadership, communication, responsibility, flexibility, teamwork, presentation, problem solving, and critical thinking.

Following the literature review, the research questions are: 1) Do the FIRST program activities increase STEM exposure and encourage STEM career choices, and if so, how? 2) What are the factors that affect these choices? Are there correlations between those factors? If so, what are they? 3) Is the effect of the FIRST program on FIRST high-school students' exposure and career choices different from that effect on FIRST graduates? If so, what are the differences and does gender play a role in these differences?

III. Methodology

This section describes the research setting, participants, tools, and data collection, and analysis based on the mixed methods approach, in particular the convergent parallel model. Following the guidelines by Creswell and Plano Clark [48],

TABLE I
PARTICIPANTS BY AGE AND GENDER

Research group	Age	Interviews			Questionnaires		
		N	Male	Female	N	Male	Female
High school students	16-18	4	2	2	119	72	45
Graduates	18-21	3	2	1	197	147	50
	22-25	4	1	3	65	43	22
	26-30	4	3	1	32	27	5

the convergent parallel mixed methods design is best suited for this study, to compare the results of the quantitative and qualitative data that were collected simultaneously. In order to delve into a better understanding of the FIRST effect, this design helps in determining if participants respond when they check quantitative predetermined scales in a way similar to that of when they are asked open-ended qualitative questions [48], [49].

A. Research Setting

The research participants were FIRST high-school students in 11th and 12th grades and graduates of the FIRST program in Israel. Every year, there are global competitions in which robots built by the teams compete in a field game. The theme of the game is updated yearly. Volunteer professional mentors guide the teams. Students are required to develop STEM skills and apply engineering principles while realizing the value of intensive work, innovation, and teamwork. Each season ends with a global FIRST competition. The competitions are held in four leagues according to the level and age of the students. In the current study, the main focus is on FRC, in which a high-school robotics program with strict rules, limited resources, has a six-week time limit. Teams are challenged to raise funds, develop a design, and build a robot, use computer animations, and program industrial-size robots to play against competitors. About 12 000 students in Israel participate in more than 1200 groups. In the FRC league, there are 67 groups with about 2000 high-school students in total, spread all over Israel.

The research was approved by the Technion Ethics Committee, approval number 2019–2020. For high-school students, the approval number of the Chief Scientist Committee of the Ministry of Education is 10687.

B. Participants

Study participants included 119 high-school students aged 17–18, who took part in the FIRST program, and 297 graduates of the FIRST program aged 18–30. All participants filled out questionnaires. Four high-school students and 11 graduates were interviewed. The age and gender of the participants are shown in Table I. The connection with the high-school students and graduates who filled in questionnaires was established through social networks, including Facebook, Instagram, and WhatsApp, management of FIRST Israel, and FIRST mentors.

High-school students who confirmed their consent to be interviewed in the questionnaire were selected. The interviews were conducted shortly after responding to the questionnaires in order for the experience to be authentic and in line with the questionnaire answers. The graduates to be interviewed were selected based on recommendations by FIRST Israel management or mentors in the program, so they represent the participants' diversity in terms of gender, age, and position.

According to Creswell, the number of interviews for qualitative data collection can be lower than that needed for quantitative data collection. This is so because the goal of qualitative data collection is to locate and obtain extensive information from a small sample, whereas in quantitative research, a large sample is required to ensure a representation of the population and conduct meaningful statistical analysis [50].

C. Research Tools and Data Analysis

The research tools included semistructured interviews and online questionnaires. The data collection and analysis applied the convergent parallel model for mixed methods analysis using qualitative and quantitative tools, with equal weight attributed to the qualitative and the quantitative data collected [48], [50], [51].

Two types of questionnaires were administered: 1) for high-school students participating in the program and 2) for FIRST graduates. Most of the questionnaires were sent via the social networks and filled online voluntarily. The questionnaires included both close-ended Likert-type questions and open-ended questions. The quantitative data from the questionnaires were analyzed using descriptive statistics, as well as factor analysis, ANOVA and Pearson correlation tests.

1) Interviews: The questions in the semistructured interviews were designed and modified according to the interviewees' backgrounds and connection to the program. Some of the interviews were done face-to-face and the others in conference calls. Most of the interviews were conducted during 1-h meetings. The interviews were audio-recorded with the participants' permission, and a commitment was made to anonymity and confidentiality. The interviews were transcribed and qualitatively analyzed.

Following are examples of interview questions: 1) How did you start your connection with the FIRST program? 2) Describe your role at FIRST; 3) What are the pros and cons you see in the program? 4) Do you feel there is a difference between boys and girls in terms of the roles they play, their aspirations, and their relation to society? 5) Where do you see yourself in 5–10 years from now? The qualitative data from the interviews were initially analyzed by classifying them into themes, categories, and distribution.

Data analysis of the interviews was done by breaking down the transcription into statements, each focusing on a single idea. Each statement was classified into one of the three main SCT themes and then into the relevant category within the theme. To ensure that the category classification was correct, about 20% of the statements for each category were ranked

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TABLE II
SCCT CATEGORIES BY THEMES INCLUDING THE NEWLY FOUND ONES (IN GRAY)

Theme	Category
Environmental	The influence of educational programs on choosing a STEM career
	Influence of teachers and schools
	Family and school support
	Extrinsic motivation: Rewards, status or prestige
	Perceptions and stigmas regarding STEM
	Influence of mentors, parents, or team leaders
Personal	Self-efficacy: scientific learning (interest, responsibility, enjoyment)
	Self-efficacy: task-oriented
	Self-confidence
	Students' qualities
Behavioral	Exposure
	Opportunities vs. limitations
	Mentor, team leader or volunteer – professional and team guidance

separately by five judges, achieving an interjudge agreement of 91% with Kappa 0.83.

In order to analyze and identify the factors in each of the personal, environmental, and behavioral SCT themes, categories were identified using both a top-down and a bottom-up approach. In the top-down approach, SCCT categories from the literature were used, while in the bottom-up approach, new categories that are applicable to the FIRST program approach were discovered. In the previous stage of the research on FIRST graduates [14], 14 categories were identified. In the current study, for the behavioral theme, two categories that focused on mentors were combined into one—mentor, team leader, or volunteer—professional and team guidance. All the 13 categories are presented in Table II. Of these, four categories were in the personal theme, six in the environmental theme, and three in the behavioral theme. Most categories included positive and negative statements. Gray areas in Table II indicate newly found categories. The percentage of statements was calculated in each category per interviewee and per group.

2) Questionnaires: The questionnaires were composed in parallel to the interviewing process. The close-ended questions are statements on a 1–5 Likert scale, where 1 mean totally disagrees and 5 means strongly agrees. There are two types of questionnaires: one for high-school students participating in the FIRST program and one for FIRST graduates aged 18–30, including students from the Technion and other academic institutions. The questionnaires were designed based on previous studies conducted with FIRST participants in the USA and with Israeli participants in other projects [2], [14], [42], [52], [53].

TABLE III
QUESTIONNAIRE FACTOR ANALYSIS

Theme	Category & *An example*	N items	α Cronbach
Personal	Motivation "*I feel that I understand the process of awarding prizes in FIRST.*"	3	0.587
Environmental	Family and school support "*My parents supported my participation in the program.*"	6	0.553
Environmental	STEM exposure "*Without my participation in the program, I would have had no connection to the technological world.*"	3	0.675
Behavioral	Contribution of FIRST to interpersonal skills "*Participating in the program improved my ability to stand in front of an audience.*"	11	0.886
Behavioral	Impact of FIRST on career choice "*The experience at FIRST influenced my choice of profession for life.*"	8	0.765
Total		31	0.815

The questionnaires were divided into two parts: Part A included demographic and personal data, such as gender, age, high-school major, the geographic area where the FIRST activity takes place, and type of STEM education, if any.

Part B included 31 statements regarding the three SCT themes [14], which were rated on a 1–5 Likert scale. Seven statements were added for graduates who are also mentors, and six statements were added for students who received a Technion scholarship. The questionnaire included also six open-ended questions.

As presented in Table III, there were three statements in the personal theme, nine statements in the environmental theme, and 19 statements in the behavioral theme. The contribution to SCT and SCCT can come from the behavioral theme in the FIRST program. Since the personal and environmental themes were explored in depth [24], [27], [52], [54], [55], the questionnaire's closed items in this study focused on the behavioral theme.

Data from the questionnaires were collected using Google forms. Exploratory factor analysis (EFA) was performed to identify factors from 31 statements that appeared in the graduates' questionnaire [14]. To find the best factors for this study, EFA was conducted for nine, six, and five factors, using principal component analysis with Varimax rotation. Eventually, five factors were identified, with general reliability of $\alpha = 0.0802$ [14]

In the next stage, confirmatory factor analysis (CFA) was conducted to identify the factors in the questionnaires of both the high-school students and the graduates. The factors that were found in the graduates' questionnaire were checked to evaluate their consistency with those found for the high-school students. In addition, the open-ended questions were analyzed, looking for categories that are similar to the ones found in the interviews.

Table III presents the five factors that appeared in both questionnaire types, including theme, a category with an exemplary statement, the number of items, and α Cronbach. The total reliability (α Cronbach) for the five factors is $\alpha = 0.815$, which is robust [56]. In the factors that are related to the personal theme and the behavioral theme, α ranges from 0.553 to 0.675, well within the acceptable range (0.45–0.98). Due to the small number of statements, high α was not expected [56].

The STEM exposure factor is represented by the following statements: 1) "Without my participation in the program, I would have had no connection to the technological world"; 2) "Even without participating in the program, I would have tended toward science and technology"; and 3) "Exposure to the technological world in the FIRST program opened up a new world to me that I had not known before."

Exemplary statements classified as belonging to the factor of impact of FIRST on career choice follow: 1) "The experience of FIRST influenced my choice of profession for life"; 2) "The conversation with my group of graduates encouraged me to choose a future [work or study] that is related to the scientific or technological world"; 3) "The acquaintance with people in the industry made me want to study a scientific and technological profession"; and 4) "I would like my life to be similar to the FIRST competition season."

IV. Results

In this section, the results obtained for each research question are reviewed by analyzing data collected from interviews and questionnaires of FIRST high-school students and FIRST graduates. In Section IV-A, the effect of FIRST activities on fostering STEM exposure and STEM career choice in participants is discussed. Section IV-B presents the factors that affect STEM career choice and the correlations between them.

A. Effect of FIRST Activities on Fostering STEM Exposure and STEM Career Choice in Participants

The impact of FIRST on the STEM domains that the high-school students and the graduates chose as a major in high school was analyzed. The analysis was based on the STEM type (science, technology, and engineering) or non-STEM, and on the combination of two or three STEM domains, such as science and technology.

According to the data, the FIRST activities foster STEM exposure and STEM career choice among its participants. The following examples of statements from the interviews, cited below, demonstrate this effect. "*Being in a technology project for three years and falling in love with this thing, getting to know the industry more, and discovering all kinds of entrepreneurs and ideas and projects, and everything that's happening in the world right now.... the areas it exposed me to; I really cannot think of anything else to do.*" (S01, line 38, female, age 17, high-school student).

"*We had a 10th grade student* [in the FIRST program] *who said he wanted to be a lawyer; and this student completed a bachelor's and master's degree in mechanical engineering (at the Technion). I think he would not have studied that if he hadn't been in FIRST... it opened the door for him to experiences he saw that he enjoyed, such as planning, mechanical fields; in the end he chose to come here [to the Technion].*" (AMV02, line 73, male, age 27, graduate, and volunteer).

TABLE IV
Choice of Major in High School

	High school students	Graduates
Science	41%	37%
Technology	28%	28%
Engineering	23%	28%
Non-STEM	8%	6%

Table IV shows the percentage of choosing each domain by FIRST high-school students and graduates. The mean impact of FIRST on career choice differed by STEM type, $F(7, 82.86) = 2.78$, $p < 0.05$. There was a significant difference in the mean impact of FIRST on career choice between participants who majored in science, technology, and engineering domains ($M = 3.78$, SD $= 0.70$) and those who majored in science only ($M = 3.23$, SD $= 0.74$) or in non-STEM subjects ($M = 2.94$, SD $= 1.16$), $p < 0.05$. These results imply that the impact of choosing a career in STEM is higher on those who chose STEM subjects in high school than on those who chose only science or did not study any STEM subject in high school.

The mean scores for STEM exposure scores were not the same for different STEM types, $F(7, 394) = 2.96$, $p < 0.05$. There was a significant difference between the participants who majored in science and engineering ($M = 2.43$, SD $= 0.90$), those who majored in science and technology ($M = 2.86$, SD $= 0.95$), and those who did not major in any STEM subject ($M = 3.50$, SD $= 1.39$), $p < 0.05$. Moreover, there was a significant difference in the mean STEM exposure between participants who majored in science, technology, and engineering ($M = 2.50$, SD $= 0.82$) and those who did not major in any STEM subject ($M = 3.50$, SD $= 1.39$), $p < 0.05$. This means that the exposure to STEM due to participating in the FIRST program is significantly higher for high-school students who did not major in STEM.

B. Factors That Affect STEM Career Choice and the Correlations Between Them

Correlation analysis using Pearson's correlation coefficient showed several significant positive correlations between the five factors for both high-school students and graduates, as shown in Table V. The contribution of the FIRST program to interpersonal skills has a modest positive and significant correlation with the impact of FIRST on career choice, $r(406) = 0.569$, $p < 0.01$. Other correlations are significant but low. The only negative significant correlation is between STEM exposure and family and school support, $r(402) = -0.111$, $p < 0.02$, indicating that when family and school support is higher, the effect of STEM exposure is lower, but this correlation is very low. These results might imply that for past and present students in the FIRST program, the factors are interdependent.

TABLE V
RESULTS OF PEARSON'S CORRELATION TESTS

Variable	Impact of FIRST on career choice	Family and school support	STEM exposure	External motivation
Contribution of the FIRST program to interpersonal skills	.569**	.240**	.245**	.145**
Impact of FIRST on career choice		.185**	.171**	.271**
Family and school support			-.111*	.165**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

C. General and Gender Effects of FIRST on Participants' STEM Exposure and Career Choice: High-School Students Versus Graduates

Examples of statements from the interviews, cited below, demonstrate the differences among FIRST participants regarding gender.

"*In FIRST we see that as the years go by, there are more girls in this program, but still, FIRST and the engineering world have a majority of boys, and we are trying to put our finger on why that is. Maybe there are not enough females as role-models? Maybe the girls experience something in the group?*" (AMVS01, line 163, female, age 25, graduate, mentor, and volunteer).

"*In my team in high school, there was a decision to make girls feel that it is not just something for boys; that it is open to both genders, and girls are invited to take on roles such as mechanics. I think there are many times that girls join the community and slowly slip into mechanics.*" (AMV02, line 84, male, age 27, graduate, and volunteer).

The differences between FIRST high-school students and graduates are significant and large only in the STEM exposure score for men ($M = 2.49$, SD $= 0.87$) compared to women ($M = 3.24$, SD $= 1.03$), $t(111) = -4.16$, $p < 0.001$, $d = 0.79$. The FIRST program showed different effects on men and women for both high-school students and graduates. There was a significant difference in the mean impact of FIRST on career choice between men ($M = 3.60$, SD $= 0.75$) and women ($M = 3.27$, SD $= 0.845$), $t(199) = 3.73$, $p < 0.001$, $d = 0.41$ (medium effect). In addition, there was a significant difference in the mean STEM exposure between men ($M = 2.47$, SD $= 0.91$) and women ($M = 3.06$, SD $= 0.97$), $t(398) = -5.76$, $p < 0.001$.

Fig. 2 shows differences between women and men in their choices of STEM domains later in their lives. The percentage of women is lower than that of men in all study and career frameworks. The percentage of women compared to men decreases over the years.

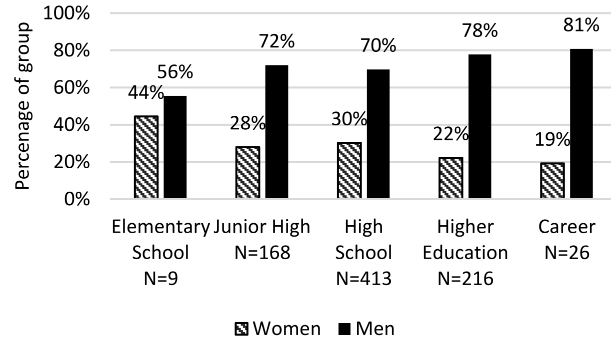

Fig. 2. Women and men majoring in STEM by school level.

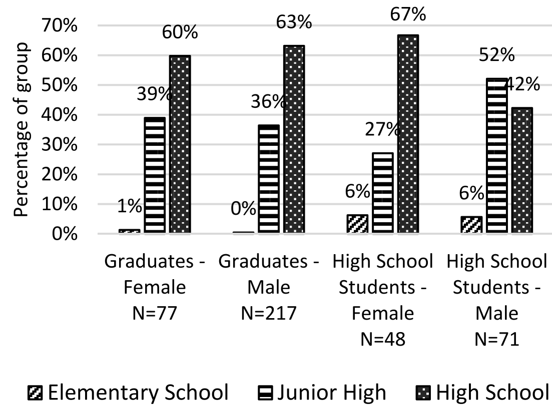

Fig. 3. Beginning of exposure to STEM: high-school students versus graduates.

Fig. 3 shows the differences between high-school students' and graduates' initial exposure to STEM. More high-school students began to participate in FIRST activities in elementary school and junior high than graduates. This is because in the past, there were fewer teams for elementary school students.

V. DISCUSSION

This study is a part of a larger research project regarding the effect of the FIRST robotics program on its participants. Following the first part of this project that described the effect of the program on graduates [14], in this article, the program's effect on high-school students currently participating in the program and on its graduates is examined. The FIRST activities foster STEM exposure and STEM career choice among its participants, starting in elementary school and continuing through high school and adult career choices. Although most of the participants in the FIRST program came with STEM intentions, the previous research [14], demonstrated that the FIRST program directs the participants to a specific STEM domain. While the students who participate in the FIRST program are mostly interested in STEM, not everyone who is interested in STEM in high school goes on to pursue higher education and a career in STEM. As an example, in 2017, 47.6% of the Israeli high-school students chose STEM as a major, but only 22.7% of the university students chose a STEM discipline [14]. The graduates of the FIRST program demonstrate not only choosing a STEM major in high school at an almost maximal rate (98%); they also maintain this high rate of choosing STEM in university education (94%). FIRST activity exposes students to STEM and can direct students who were not interested in STEM to choose STEM in high school, higher education, and as a career choice.

These findings reinforce findings from previous studies that found a strong connection between high-school STEM majors and STEM career choices. The interest in STEM careers at the start of high school was an important predictor of interest at the end of high school [21]–[25]. As part of the statistical analysis, potential intervening factors were considered, including STEM exposure in high school, the influence of the family, and external motivation. These factors were analyzed to examine the possible impact of the FIRST program on STEM exposure and career choice, as well as correlations between these factors.

Results show that the impact of FIRST on high-school students is the same as its impact on graduates, indicating that the program has a lasting effect that extends from 1 to 15 years after participating in it [14]. The five factors that were found to affect the participants' choices coincide with the same factors found in the previous study [14]. This consistency is also in alignment with previous studies [2], [3], which also found an effect of the FIRST program on STEM career choice. The strong positive correlations between those factors indicate that they are synergistic, implying that the effect of FIRST is strong when all the factors are high, and the program has a strong effect on current participants as well as on graduates years later.

For both high-school students and graduates, the impact of STEM exposure is strongest on those who did not choose any STEM major in high school. This implies that the impact is higher for students who are exposed to the program in an early stage and for those who did not have an initial tendency to choose STEM.

The only difference found between high-school students and graduates is that the effect of STEM career choice on graduates is more significant than on high-school students. This finding can be explained by the person's stage in life. The graduates are already at the stage in which they need to choose their careers. Examining the differences between men and women in the program, the effect on STEM career choice is found to be stronger on men than on women, as also found in previous studies [21]–[23]. The influence of STEM exposure is stronger on women than on men, although fewer women participate in the program than men, as presented in other studies [3], [43], [48].

This study presents the contribution of participation in the FIRST program with respect to the factors included in SCCT, presented in Fig. 1. The program has an impact on each of the factors, from proximal contextual influences, through the learning experience, self-efficacy, outcome expectations, career interests, career choice goals, and finally career choice actions. The research has contributed new factors to SCCT: mentors as role models, which is a factor that is added to the proximal contextual influences factor in the environmental theme (see Fig. 1), and mentor guidance in the behavioral theme.

A. Limitations and Future Studies

The limitation of this study is that it reflects the perception of past and present FIRST participants without a control group of subjects who did not participate in FIRST or those who participated in other non-STEM programs. Most of the FIRST participants study STEM in high school, and this characteristic can influence the findings. Expanding the research to include a younger age group of current participants in the program and reporting in real time rather than in retrospect may contribute to understanding how young people who are exposed to STEM ultimately choose careers in STEM domains.

In this study, more men than women participated, reflecting the ratio between men and women in the program. If a future study will have a higher percentage of women, the results should be compared with the results of this study.

Future research can examine the influence of mentors in the FIRST program on students and investigate possible differences between mentors who are FIRST graduates and those who are not. Research [43] has been done on the goals of the FIRST program in 30 countries, and research similar to the current research should be conducted in countries other than the USA to examine whether the effect of gender and career choice is as strong as what has been found in the current research.

B. Contribution

The practical contribution of this study is to demonstrate the positive impact of the FIRST robotic program to stakeholders and to expand the STEM workforce, which is a global necessity. This study contributes to understanding the impact of STEM outreach in high schools and might more broadly affect the engineering education community. On the methodological level, the factor analysis of the validated questionnaires of both high-school students and graduates makes the questionnaires accessible to researchers who might want to use them as a reliable tool in their studies.

The theoretical contribution is to the body of knowledge on the SCT and SCCT, as the research identifies relations between students' career aspirations, interpersonal skills, and actual career choices. While previous studies have shown the connection for narrow or specific age groups, this study has explored the relations among FIRST participants and graduates over different periods of time, ranging from elementary school to middle school, high school, and higher education, all the way to adulthood. Finally, mentors as role models and mentor guidance were discovered as new SCCT factors.

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References

[1] A. Sahin, O. Gulacar, and C. Stuessy, "High school students' perceptions of the effects of international science Olympiad on their STEM career aspirations and twenty-first century skill development," *Res. Sci. Educ.*, vol. 45, no. 6, pp. 785–805, 2015.

[2] A. Melchior, F. Cohen, T. Cutter, and T. Leavitt, *More Than Robots: An Evaluation of the FIRST Robotics Competition Participant and Institutional Impact*, Brandeis Univ. Center Youth Commun., Waltham, MA, USA, 2005. [Online]. Available: https://clear.dol.gov/study/more-robots-evaluation-first-robotics-competition-participant-and-institutional-impacts

[3] A. Melchior, C. Burack, M. Hoover, and Z. Haque, *FIRST Longitudinal Study: Findings at 60 Month Follow-Up*, Brandeis Univ. Center Youth and Commun., Waltham, MA, USA, Oct. 2019. [Online]. Available: https://www.firstinspires.org/sites/default/files/uploads/resource_library/impact/first-longitudinal-study-60-months.pdf

[4] (Jan. 2019). *FIRST Israel*. [Online]. Available: https://www.firstisrael.org.il/

[5] J. Krajcik, S. Codere, C. Dahsah, R. Bayer, and K. Mun, "Planning instruction to meet the intent of the next generation science standards," *J. Sci. Teach. Educ.*, vol. 25, no. 2, pp. 157–175, 2014.

[6] T. J. Moore, K. M. Tank, A. W. Glancy, and J. A. Kersten, "NGSS and the landscape of engineering in K–12 state science standards," *J. Res. Sci. Teach.*, vol. 52, no. 3, pp. 296–318, 2015.

[7] J. S. Eccles and M.-T. Wang, "What motivates females and males to pursue careers in mathematics and science?" *Int. J. Behav. Develop.*, vol. 40, no. 2, pp. 100–106, 2016.

[8] Y. Xie and A. Achen, "Science on the decline? educational outcomes of three cohorts of young Americans," Population Stud. Center Res., Ann Arbor, MI, USA, PSC Research Rep. 9-684, 2009.

[9] H. Sunyoung, R. Capraro, and M. M. Capraro, "How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement," *Int. J. Sci. Math. Educ.*, vol. 13, no. 5, pp. 1089–1113, 2015.

[10] D. Kokotsaki, V. Menzies, and A. Wiggins, "Project-based learning: A review of the literature," *Improving Schools*, vol. 19, no. 3, pp. 267–277, 2016.

[11] T. W. Hissey, "Education and careers 2000. Enhanced skills for engineers," *Proc. IEEE*, vol. 88, no. 8, pp. 1367–1370, Aug. 2000.

[12] M. L. Matteson, L. Anderson, and C. Boyden, "'Soft skills': A phrase in search of meaning," *Portal Libraries Acad.*, vol. 16, no. 1, pp. 71–88, 2016.

[13] S. Anthony and B. Garner, "Teaching soft skills to business students: An analysis of multiple pedagogical methods," *Bus. Prof. Commun. Quart.*, vol. 79, no. 3, pp. 360–370, 2016.

[14] S. R. Yoel, D. S. Asher, M. Schohet, and Y. J. Dori, "The effect of the FIRST Robotics Program on its graduates," *Robotics*, vol. 9, no. 4, p. 84, 2020.

[15] A. Bandura, *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ, USA: Prentice-Hall, 1986.

[16] R. W. Lent, S. D. Brown, and G. Hackett, "Toward a unifying social cognitive theory of career and academic interest, choice, and performance," *J. Vocat. Behav.*, vol. 45, no. 1, pp. 79–122, 1994.

[17] R. W. Lent and S. D. Brown, "On conceptualizing and assessing social cognitive constructs in career research: A measurement guide," *J. Career Assess*, vol. 14, no. 1, pp. 12–35, 2006.

[18] S. Ihsen, W. Schneider, and F. Wallhoff, "Raising interest of pupils in engineering education through problem based learning," *Int. J. Eng. Educ.*, vol. 27, no. 4, pp. 789–794, 2011.

[19] E. Regan and J. DeWitt, "Attitudes, interest and factors influencing STEM enrolment behavior: An overview of relevant literature," in *Understanding Student Participation and Choice in Science and Technology Education*. Dordrecht, The Netherlands: Springer, 2015.

[20] R. Sheldrake, T. Mujtaba, and M. J. Reiss, "Science teaching and students' attitudes and aspirations: The importance of conveying the applications and relevance of science," *Int. J. Educ. Res.*, vol. 85, pp. 167–183, Aug. 2017.

[21] J. G. Gayles and F. D. Ampaw, "Gender matters: An examination of differential effects of the college experience on degree attainment in STEM," *New Directions Inst. Res.*, vol. 152, pp. 19–25, 2011.

[22] C. A. Shapiro and L. J. Sax, "Major selection and persistence for women in STEM," *New Directions Inst. Res.*, vol. 152, pp. 5–18, Dec. 2011.

[23] P. M. Sadler, G. Sonnert, Z. Hazari, and R. Tai, "Stability and volatility of STEM career interest in high school: A gender study," *Sci. Educ.*, vol. 96, no. 3, pp. 411–427, 2012.

[24] I. Sasson, "Becoming a scientist—Career choice characteristics," *Int. J. Sci. Math. Educ.*, vol. 19, pp. 483–497, Feb. 2020.

[25] K. Beddoes and G. Panther, "Gender and teamwork: An analysis of professors' perspectives and practices," *Eur. J. Eng. Educ.*, vol. 43, no. 3, pp. 330–343, 2018.

[26] B. Habig, P. Gupta, B. Levine, and J. Adams, "An informal science education program's impact on STEM major and STEM career outcomes," *Res. Sci. Educ.*, vol. 50, no. 3, pp. 1051–1074, 2020.

[27] A. Sahin, A. Ekmekci, and H. C. Waxman, "Collective effects of individual, behavioral, and contextual factors on high school students' future STEM Career plans," *Int. J. Sci. Math. Educ.*, vol. 16, no. 1, pp. 69–89, 2018.

[28] W. H. Kilpatrick, "The project method," *Teach. Coll. Rec.*, vol. 19, no. 4, pp. 319–335, 1918.

[29] J. Dewey, *Experience and Education*. New York, NY, USA: Macmillan, 1938.

[30] K. D. Beddoes, B. K. Jesiek, and M. Borrego, "Identifying opportunities for collaborations in international engineering education research on problem-and project-based learning," *Interdiscipl. J. Problem Based Learn.*, vol. 4, no. 2, pp. 7–34, 2010.

[31] M. Barak and Y. J. Dori, "Enhancing undergraduate students' chemistry understanding through project-based learning in an IT environment," *Sci. Educ.*, vol. 89, no. 1, pp. 117–139, 2005.

[32] S. Palmer and W. Hall, "An evaluation of a project-based learning initiative in engineering education," *Eur. J. Eng. Educ.*, vol. 36, no. 4, pp. 357–365, 2011.

[33] M. Holm, "Project-based instruction: A review of the literature on effectiveness in prekindergarten," *River Acad. J.*, vol. 7, no. 2, pp. 1–13, 2011.

[34] F. B. V. Benitti, "Exploring the educational potential of robotics in schools: A systematic review," *Comput. Educ.*, vol. 58, no. 3, pp. 978–988, 2012.

[35] D. J. Pack, R. Avanzato, D. J. Ahlgren, and I. M. Verner, "Fire-fighting mobile robotics and interdisciplinary design-comparative perspectives," *IEEE Trans. Educ.*, vol. 47, no. 3, pp. 369–376, Aug. 2004.

[36] S. L. Firebaugh and J. A. Piepmeier, "The RoboCup nanogram league: An opportunity for problem-based undergraduate education in microsystems," *IEEE Trans. Educ.*, vol. 51, no. 3, pp. 394–399, Aug. 2008.

[37] M. Barak and Y. Zadok, "Robotics projects and learning concepts in science, technology and problem solving," *Int. J. Technol. Design Educ.*, vol. 19, no. 3, pp. 289–307, 2009.

[38] T. Karp, R. Gale, L. A. Lowe, V. Medina, and E. Beutlich, "Generation NXT: Building young engineers with LEGOs," *IEEE Trans. Educ.*, vol. 53, no. 1, pp. 80–87, Feb. 2010.

[39] M. Barak and M. Assal, "Robotics and STEM learning: Students' achievements in assignments according to the P3 task taxonomy—Practice, problem solving, and projects," *Int. J. Technol. Design Educ.*, vol. 28, no. 1, pp. 121–144, 2018, doi: 10.1007/s10798-016-9385-9.

[40] D. Keathly and R. Akl, "Attracting and retaining women in computer science and engineering: Evaluating the results," in *Proc. ASEE Annu. Conf.*, 2007, pp. 1–10.

[41] *FIRST Robotics Competition| FIRST. A Global Robotics Community Preparing Young People for the Future*. Accessed: Jan. 5, 2019. [Online]. Available: https://www.firstinspires.org/

[42] G. Verma, A. Puvirajah, and H. Webb, "Enacting acts of authentication in a robotics competition: An interpretivist study," *J. Res. Sci. Teach.*, vol. 52, no. 3, pp. 268–295, 2015.

[43] J. L. Skorinko, J. K. Doyle, and G. Tryggvason, "Do goals matter in engineering education? An exploration of how goals influence outcomes for FIRST robotics participants," *J. Precoll. Eng. Educ. Res.*, vol. 2, no. 2, p. 3, 2012. [Online]. Available: https://doi.org/10.5703/1288284314867

[44] S. K. W. Chu, R. B. Reynolds, N. J. Tavares, M. Notari, and C. W. Y. Lee, *21st Century Skills Development Through Inquiry-Based Learning*. Singapore: Springer, 2017.

[45] R. Lavi, Y. J. Dori, N. Wengrowicz, and D. Dori, "Model-based systems thinking: Assessing engineering student teams," *IEEE Trans. Educ.*, vol. 63, no. 1, pp. 39–47, Feb. 2020.

[46] L. J. Shuman, M. Besterfield-Sacre, and J. McGourty, "The ABET 'professional skills'—Can they be taught? Can they be assessed?" *J. Eng. Educ.*, vol. 94, pp. 41–55, Jan. 2005.

[47] D. C. Lopes, M. C. Gerolamo, Z. A. P. Del Prette, M. A. Musetti, and A. Del Prette, "Social skills: A key factor for engineering students to develop interpersonal skills," *Int. J. Eng. Educ.*, vol. 31, no. 1, pp. 405–413, 2015.

[48] J. W. Creswell and V. L. Plano Clark, *Designing and Conducting Mixed Methods Research*, 3rd ed. Los Angeles, CA, USA: SAGE, 2017.

[49] E. L. Usher, C. J. Ford, C. R. Li, and B. L. Weidner, "Sources of math and science self-efficacy in rural Appalachia: A convergent mixed methods study," *Contemp. Educ. Psychol.*, vol. 57, pp. 32–53, Apr. 2019.
[50] J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, CA, USA: SAGE, 2014.
[51] J. W. Creswell, "Choosing a mixed methods design," in *Methods Design*. California, USA: Clark VLP Sage, 2006, Ch. 4, pp. 58–89.
[52] S. Avargil, Z. Kohen, and Y. J. Dori, "Trends and perceptions of choosing chemistry as a major and a career," *Chem. Educ. Res. Pract.*, vol. 21, pp. 668–684, Feb. 2020.
[53] H. R. Mishkin, N. Wengrowicz, D. Dori, and Y. J. Dori, "Career choice of undergraduate engineering students," *Procedia Soc. Behav. Sci.*, vol. 226, pp. 222–228, Jul. 2016.
[54] G. Shwartz, O. Shav-Artza, and Y. J. Dori, "Choosing chemistry at different education and career stages: Chemists, chemical engineers, and teachers," *J. Sci. Educ. Technol.*, pp. 1–14, Mar. 2021, doi: 10.1007/s10956-021-09912-5.
[55] S. Reinhold, D. Holzberger, and T. Seidel, "Encouraging a career in science: A research review of secondary schools' effects on students' STEM orientation," *Stud. Sci. Educ.*, vol. 54, no. 1, pp. 69–103, 2018.
[56] K. S. Taber, "The use of Cronbach's alpha when developing and reporting research instruments in science education," *Res. Sci. Educ.*, vol. 48, no. 6, pp. 1273–1296, 2018.

Shahaf Rocker Yoel received a Software Engineering Certificate from the Technion—Israel Institute of Technology, Haifa, Israel, in 2001, and the B.Tech. degree (Hons.) in industrial engineering and management and textile engineering from the Shenkar College of Engineering and Design, Ramat Gan, Israel, in 2000. She is currently pursuing the Ph.D. degree with the Faculty of Education in Science and Technology, Technion—Israel Institute of Technology.

She held several roles from 2000 to 2015 as a program manager, planning manager, and quality manager, in electronics, medical, and textile companies. Her research interests include robotics education, self-efficacy, and STEM career choices.

Yehudit Judy Dori received the Ph.D. degree in science education from the Weizmann Institute of Science, Rehovot, Israel, in 1988.

She is a Professor and was the Dean of the Faculty of Education in Science and Technology, Technion—Israel Institute of Technology, Haifa, Israel, till February 2020, where she is also a Senior Research Fellow with the Samuel Neaman Institute for National Policy Research. Since 2000, she has intermittently been a Visiting Professor or a Visiting Scholar with the Massachusetts Institute of Technology, Cambridge, MA, USA. Her research interests include learning in technology-rich environments, educational assessment, scientific visualizations, 21st-century skills, and metacognition at high school and university levels.

Prof. Dori received the NARST 2020 Distinguished Contribution to Science Education Research Award—DCRA.