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Trends and perceptions of choosing chemistry as a major and a career†

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In many countries, the choice of a STEM career, especially in chemistry, is decreasing. A shortage of appropriately skilled workers can become a threat to any country's future achievements. Our research strives to understand behavioral trends and career choice factors related to personal and environmental themes. Building on the foundations of the Social Cognitive Career Theory, the research sheds light on prospective trends and retrospective perceptions of chemistry-related professionals in choosing chemistry in high school, as a career, and as a STEM occupation. To analyze the prospective trends in choosing chemistry, we used data curated by the Israel Central Bureau of Statistics on 545 778 high school graduates. For the retrospective perceptions of choosing a chemistry career, we investigated three research groups (N = 190): chemists and chemical engineers, chemistry teachers, and third year undergraduate chemistry students. We found that choosing chemistry as a major and profession decreases from high school to higher education. Women tend to choose chemistry more than men at high school and university levels, and minorities tend to choose it more in high school but less in higher education compared to non-minorities. Task-oriented self-efficacy was the factor which contributed the most to chemistry career choice in all three research groups. The theoretical contribution is the unique SCCT application through the integration of both the prospective views on the behavioral theme and the retrospective views on the personal and environmental themes. Furthermore, we present new chemistry-related factors within the personal theme of this theoretical framework that can extend the SCCT framework.

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Introduction

Studies conducted in various countries have shown that there is an acute shortage of science, technology, engineering, and mathematics (STEM) college graduates. This shortage is translated into an ongoing shortage in scientifically qualified people in the STEM workforce (Salta *et al.*, 2012; Affeldt *et al.*, 2017; Smith and White, 2018; Moore and Burrus, 2019). For more than 20 years, researchers and organizations have been calling for increasing the qualified workforce in STEM and STEM education, with an emphasis on underrepresented population groups in these fields (Baker and Leary, 1995; Blickenstaff, 2005; Lent *et al.*, 2008; Smith and White, 2018). The shortage of scientifically qualified people in the workforce and the shortage of qualified science teachers have led to a crisis in science education. The need for STEM professionals calls for a greater understanding of how STEM career paths evolve and develop (Tytler, 2007; Nugent *et al.*, 2015).

Various researchers claim that chemistry is not a popular career choice and that the field is deficient at all levels of education, academia and industry (Solano *et al.*, 2011; Ogunde *et al.*, 2017; Salonen *et al.*, 2018).

According to different studies high school students tend not to choose chemistry as a subject of study, and fewer students choose to pursue chemistry in higher education (Salta *et al.*, 2012; Ardura and Pérez-Bitrián, 2018). Chemistry is a fundamental disciplinary science that relates to a variety of occupations in industry and academia (Solano *et al.*, 2011) such as producing new materials, medical chemistry, green and environmental chemistry, forensic chemistry, engineering and materials chemistry, and nanotechnology (Phoenix, 2007; Solano *et al.*, 2011; Dangur *et al.*, 2014). Therefore, it is essential for the development of technological and scientific innovations that constitute any country's future achievements.

Our research analyzed the *prospective* trends of the behavioral choice using data obtained from the Central Bureau of Statistics (CBS) in Israel. Additionally, the research focused on the *retrospective* perceptions of chemists, chemical engineers, chemistry teachers, and third year undergraduate chemistry students.‡ The perceptions relate to *Personal* and *Environmental* themes

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‡ Also known as post-secondary students who study toward bachelor's degrees.

that affect career choice in the chemical industry or chemical education.

Theoretical framework

In his Social Cognitive Theory (SCT), Bandura (1978, 1989, 1991) suggested the triadic-reciprocal model which is related to three aspects (themes) associated with human behavior and decision making: (a) cognitive and emotional personal factors, including efficacy, personal goal setting, and quality of analytic thinking, (b) environmental factors, and (c) behavioral factors, including overt behavior and choices. Career development theorists have identified various factors that can influence career choice. Some of these factors relate to an individual's personality and self-perception, while others relate to the environment and context surrounding them, as well as how they interact with these aforementioned factors (Holland, 1977; Ajzen and Madden, 1986; Lent *et al.*, 2002, 2008).

Social cognitive career theory (SCCT)

SCCT emerged from Albert Bandura's theory on general social cognition (Bandura, 1986). It combines one's thinking of themselves with social processes that guide a person's behavior (Lent *et al.*, 2002).

Lent *et al.* (2002) claimed that investigating career choices and career paths elucidated *what* happens and *why* it happens. This kind of research is particularly important for policy makers who strive to influence occupational choice (Lent *et al.*, 2008; Kuechler *et al.*, 2009). The Social Cognitive Career Theory (SCCT) (Lent *et al.*, 2002) integrates cognitive and goal aspects, external and internal choice barriers, affective components, gender, culture, and socioeconomic status. SCCT relies on the interplay between personal attributes, external environmental or contextual factors, and overt behavior with respect to the choice of major field of study and career. In the personal aspect, SCCT emphasizes self-efficacy – beliefs about one's abilities, outcome expectations, and personal goals. The environmental aspect relates to family and friends, as well as learning experiences. Finally, the theory connects these two aspects to the third one – behavior as expressed in one's career choice.

Self-efficacy, which is central to SCCT and strongly influences one's career interest, has been the subject of intensive research in the literature on career in general, and STEM careers and STEM education in particular (Betz and Hackett, 1986; Pajares, 1996; Lent *et al.*, 2002; Zeldin *et al.*, 2008; Wang, 2013). Bandura defines self-efficacy as ''people's beliefs about their capabilities to organize and execute courses of action required to attain designated types of performances'' (Bandura, 1986, p. 36). Here is the place to differentiate between self-efficacy and self-concept. In this paper we chose the construct self-efficacy since it refers to one's judgment of succeeding in given academic tasks, at a specific academic level, and is goal-oriented. Self-efficacy refers to perceived capability in a specific task, while self-concept is a general perception about oneself and their self-esteem, not necessarily related to academic performance, and involves affective elements (Zimmerman, 2000; Bong and Skaalvik, 2003).

From the self-efficacy aspect, pursuing higher level science courses and a science career are less likely to happen if confidence in one's science abilities is low (Zeldin *et al.*, 2008; Nugent *et al.*, 2015).

Many studies have applied SCCT for data collection, analysis, and interpretation in the field of STEM education and careers (*e.g.* Maltese and Tai, 2011; Wang, 2013; Chen and Simpson, 2015; Chan and Wang, 2018), strengthening SCCT as a theoretical framework. However, most of the research in this field emphasizes the *Personal* (including self-efficacy) and contextual factors affecting the career choices of K-12 students and undergraduate students. *Environmental* (contextual) factors are also conceptualized and researched through the lens of SCCT and are part of the contextual influences on a career choice. For example, self-efficacy is used to describe the choice of STEM major in relation to external factors, such as the home environment, financial status, and background contexts (Moakler and Kim, 2014; Sax *et al.*, 2015). Distal contextual factors are related to a person's background and include opportunities in their environment, gender role, and social norms, while proximal contextual factors include, for example, support from the close environment and financial status.

Choosing a STEM career

There is a growing demand for a trained workforce in STEM fields to support nations' economic growth and development, and STEM education is a key factor in helping to meet this demand (Schleicher, 2007; Nugent *et al.*, 2015). Recruiting and maintaining a skilled science-related workforce, inspiring and engaging STEM teachers, and improving female representation in STEM careers are further essential for sustainable scientific and technological development (Oon and Subramaniam, 2010; Sadler *et al.*, 2012). People with high self-efficacy in mathematics and science usually feel confident in choosing STEM-related careers. Career aspirations are usually formulated during adolescence, leading to academic choices of STEM careers (Wang *et al.*, 2013; Dorfman and Fortus, 2019). Researchers acknowledge the need to study STEM career aspirations, but it is still unclear what the years during which a change in these aspirations occur are (Jacobs and Simpkins, 2005; Sadler *et al.*, 2012). Most of the studies on STEM career choices relate to interest, aspiration, self-efficacy, and environmental contexts at pre-college educational levels (Hazari *et al.*, 2010; Nugent *et al.*, 2015; Dorfman and Fortus, 2019). Fewer studies have been conducted on career choices and paths of adults in STEM.

There are several junctures that are likely to influence people's future career choice. The first is the transition from high school§ to college and the second is the transition from academia to industry (Tytler *et al.*, 2008). Some studies on secondary and post-secondary education show that choosing a STEM career is influenced, for example, by the value students attach to a specific discipline, salary considerations, and similarities of the work field to the area of specialization they had expanded during their undergraduate degree (Koul *et al.*, 2011; Xu, 2013).

§ Also known as secondary school.

Other studies relate to learning experiences as influencing one's choice (Peterman *et al.*, 2016; Dorph *et al.*, 2018; Reinhold *et al.*, 2018), factors related to one's personality (Betz, 2007; Grunert and Bodner, 2011a; Blotnicky *et al.*, 2018), and external factors, such as relationships with others, family, job opportunities, and position conditions (Albert and Luzzo, 1999; Lyons, 2006; Snyder, 2012). The influence of teachers was also found as either encouraging or hindering students' interest in a STEM career (Haag *et al.*, 2010; Lichtenberger and George-Jackson, 2013; Reinhold *et al.*, 2018).

There is a body of research reporting on interventions aimed at affecting attitudes and perceptions to foster STEM interest and increase the choice of STEM-related careers (Linnenbrink-Garcia *et al.*, 2018; Reinhold *et al.*, 2018). Such interventions include technology-enhanced STEM educational experiences (*e.g.* Peterman *et al.*, 2016), out of school science activities (*e.g.* Dabney *et al.*, 2012; Tsybulsky, 2019), and taking advanced placement science and mathematics courses in high school (*e.g.* Lichtenberger and George-Jackson, 2013). However, not all interventions are evaluated as effective, and the decrease in the number of people who choose STEM careers is still ongoing (Dabney *et al.*, 2012; President's Council of Advisors on Science and Technology, 2012; Chen and Simpson, 2015).

Several studies show gender and sector differences in choosing STEM careers and a percentage decrease of women and minorities interested in pursuing a STEM career (Carpi *et al.*, 2017; Wotipka *et al.*, 2018). Some of the factors mentioned are fewer opportunities for women, science instruction and teaching methods that may favor men (Guzzetti and Williams, 1996; Altermatt *et al.*, 1998), environmental norms, the lack of equality in employment terms, and the lack of support (Koul *et al.*, 2011; Mamlok-Naaman *et al.*, 2011; Xu, 2013; D'Andola, 2016). Suggestions to improve the representation of women and minorities in STEM include early interventions, shattering stereotypes, emphasizing the importance of effort over ability, connecting science with daily lives, role models, reducing academic barriers, and adjusting the work environment to family life (Skerrett and Sevian, 2010; Deemer *et al.*, 2013; Wang and Degol, 2017).

Research on chemistry career choice

Factors that influence career choice in chemistry might be similar to factors related to choosing STEM careers in general, which include social experiences, gender, academic performance, and achievements (Heilbronner, 2011; Wang *et al.*, 2013; Nugent *et al.*, 2015; Ferrell *et al.*, 2016). However, only a few studies relate to chemistry specifically. Ardura and Pérez-Bitrián (2018), who investigated students aged 14–17 and their choice of learning chemistry, have identified the following factors: difficulty with chemistry subjects, the intention to learn chemistry in the future, gender and its influence on students' decisions, achievements (*e.g.* academic record, grade point average), social and cultural factors, school factors, and interest in chemistry. The authors found that in this age group good grades are the most influential factor in choosing to learn chemistry. Ogunde *et al.* (2017) suggested that undergraduate chemistry students have varying career aspirations and the majority choose to study chemistry due to intrinsic motivation, but they need help with career planning and familiarity with career options available to chemists (Solano *et al.*, 2011). In general, enrolment in chemistry is low compared with other science or non-science fields. Factors associated with this phenomenon include the public image of chemistry, difficulties in learning chemistry at school, and perceptions of chemistry, such as "chemistry is dangerous" (Salta *et al.*, 2012; Ardura and Pérez-Bitrián, 2018). McKinney *et al.* (2018) found that the General Chemistry course withdrawal rate among the university students in Texas is about 20%. Chemistry students have inaccurate perceptions of chemistry in academia and industry, are not familiar with different career opportunities, and sometimes lack additional skills needed for the career as a professional chemist (Solano *et al.*, 2011; Tucci *et al.*, 2014).

Regarding gender differences, fewer women earn doctorates in chemistry, and the numbers keep decreasing, making it less likely that women will pursue academic careers in chemistry. Women feel that in order to pursue a chemistry research career, they need to give up some of their femininity, acquire more masculine characteristics, give up time with their families, and wait until after earning tenure to have children (Grunert and Bodner, 2011a, 2011b).

Most of the research in choosing STEM and chemistry related careers to date has been conducted on populations from K-12 education. Research on the population of professionals who already made the choice to major in chemistry at both high school¶ and university levels as well as choosing a career in chemistry can shed light on the factors that influenced their choice.

Research settings

Looking at traditional chemistry professions (*e.g.*, analytical chemistry, organic chemistry, physical chemistry), the percentage of higher education‖ graduates decreased from 2008 to 2016 by 60%. Additionally, each year there has been an increase in available chemistry-related jobs, and in 2018, there were 500 open chemistry-related positions that were unoccupied in Israel (Central Bureau of Statistics, 2018). According to the Israel Bureau of Statistics, each year there is an increase in the number of positions in the chemical industry; however, the number of individuals with a chemistry degree decreases. Thus, there is an increase in unfilled positions. Motivated by the current shortage of chemistry professionals, our research strives to describe and understand career trends prospectively, and individuals' perceptions of their career choices retrospectively. The research goal is to characterize, investigate, and model the processes of choosing to major in chemistry and pursue an industrial or educational career in chemistry, accounting for gender and sector differences. The expected outcome of this study is a comprehensive, theoretically grounded model that can be tested and validated.

We studied the *Behavioral* theme by analyzing data obtained from the Israel Central Bureau of Statistics. The data enabled us to deduce prospective trends of chemistry high school and

¶ Also known as secondary school.
‖ Also known as post-secondary.

higher education majors' career choice. High school chemistry majors are students who choose to study the advanced chemistry program in high school, which is equivalent to the Advanced Placement course (AP) in the United States. The *Environmental* and *Personal* themes were investigated using our specially designed Chemistry Career Choice (C3) questionnaire, which used to investigate the three chemistry-related populations' retrospective perceptions.

In this paper, we define and use: (a) trends – the changes in Israel over the last two decades in majoring in chemistry at high school and university levels, (b) pathways – the transitions from university to a chemistry-related career that high-school and university students went through, and (c) career choice – the *Personal* and *Environmental* factors that influenced our three research groups' career choices.

Research questions

In the following research questions, the first one is related to examining chemistry-related populations and their prospective behavioral choice (N = 545 778), the second is related to the retrospective perceptions of the three chemistry-related research groups (N = 190), and the third is related to differences, if any, in regard to sector and gender.

Our research questions were:

(1) A prospective view – during the last two decades in Israel, what trends have emerged for choosing chemistry as a major at high school and university levels?

(2) A retrospective view – what factors influenced career choices of the entire prospective research group, which includes chemists and chemical engineers, and high school chemistry teachers, and third year undergraduate chemistry students,** according to their perceptions?

(3) Are there any differences in the perceptions between the three research groups?

(4) What factors or other differences, if any, are there between the prospective and retrospective results with respect to sector and gender?

Research method

Guided by the SCCT theoretical framework, we used quantitative methods to analyze and identify the potential predictive power of selected variables, such as self-efficacy and environmental factors (see the Theoretical framework section). For the prospective view of choosing chemistry as a career, we looked at CBS data related to STEM (including chemistry) and non-STEM high school graduates†† as they continue to higher education and choose a career. For the retrospective view, we used our specially designed Chemistry Career Choice (C3) questionnaire to analyze the perceptions about factors that influence career choices of third year undergraduate chemistry students, chemists and chemical engineers, and high school chemistry teachers.

** Post-secondary students in their third year of the baccalaureate degree.

†† Students who graduated secondary school.

Research participants

Data obtained from the Central Bureau of Statistics were based on a population of 545 778 high school graduates and 241 436 undergraduate students, who were STEM (including chemistry) and non-STEM majors (see Fig. 1). The participants in each cohort included the entire retrospective research population of all the high schools and higher-education graduates in the 1992, 1996, 2001, 2006, 2011, 2015, 2016, and 2017 cohorts.‡‡ This longitudinal sample, spanning 25 years, was used to identify behavioral trends in choosing a STEM career and analyze related implications. Regarding the choice of STEM occupation, we examined the population of 16 995 professionals who majored in chemistry or other STEM fields of study in higher education, chose a STEM career, and are defined by the CBS as having a STEM occupation. Table 1 presents the research population distribution by gender and sector for each sampled cohort.

In addition to the sample obtained from the Central Bureau of Statistics, we used a representative sample from higher education and postgraduate chemistry-related populations to investigate factors that influenced chemistry career choices and pathways. The three research groups we sampled included chemists and chemical engineers working in industry, chemistry teachers, and third year chemistry undergraduate students. Our undergraduate students were from different universities in diverse geographical areas in Israel, the chemists worked in different industries and had a variety of seniority, and the chemistry teachers were from different places around the country with different teaching experience.

As Table 2 shows, we included women and minorities within each research group in order to represent the population diversity. The minorities account for 26% of the entire retrospective research group. This is similar to their percentage in Israeli population (based on data retrieved from the CBS). Table 2 also presents a level of seniority for the three chemistry-related research groups, where participants with over 10 year experience were considered seniors. Fig. 1 summarizes the prospective and retrospective study designs, followed by explanations about the research tools and data analysis. As Fig. 1 shows, the 190 participants responded to the C3 questionnaire described in the next section.

The left and middle columns in Fig. 1 describe the prospective research design, showing the number of participants for whom we obtained data from the CBS. As shown in the left column, we analyzed the pathway of high-school graduates as they continue to their bachelor's degree in higher education. This analysis included details regarding the participants' major in high-school and higher education. The middle column shows that for participants who chose a STEM occupation the data included details about gender, sector, income and major in chemistry. The right column, which describes the retrospective research design, shows the number of participants who answered the C3 questionnaire. The questionnaire included questions that guided the analysis,

‡‡ Since the CBS did not have the full records of data related to higher education for students who graduated from high school beyond 2017, our sampling for this population ended in 2017. Until 2015 we used records of years with 4–5 year intervals and then for 2015, 2016, and 2017.

Table 1 Research population distributions of high-school graduates[a] and bachelor's degree graduates[b] by year, gender and sector used for the prospective analysis

Sampled cohort N = 545 778									
Attribute		1992	1996	2001	2006	2011	2015	2016	2017
High-school graduates	N	42 335	54 116	68 385	79 231	80 417	91 458	92 787	85 213
	% Women	54.0	54.2	54.1	53.4	54.1	54.2	53.7	54.6
	% Minorities[c]	12.9	14.3	15.8	19.4	23.4	25.2	25.9	24.2
Bachelor's degree graduates	N	11 042	19 168	29 451	37 628	44 293	49 418	50 436	—
	% Women	54.3	58.9	61.6	59.4	58.3	59.9	60.9	—
	% Minorities	4.9	4.5	7.0	10.6	9.6	10.5	11.4	—

[a] Also known as secondary school graduates. [b] Also known as post-secondary students. [c] By minorities, in the context of our paper, we mean individuals who belong to one of the ethnic minority groups or differ in religious and cultural origin from the majority population in our country.

Table 2 Distributions of chemists and chemical engineers, chemistry teachers, and third year chemistry undergraduate students by gender and sector used for the retrospective analysis

Research group	N	% Seniors[a]	% Women	% Minorities
Entire retrospective research group	190	—	70	26
Chemists and chemical engineers	66	50	56	20
Chemistry teachers	70	48	80	36
Third year chemistry students	54	—	69	22

[a] Participants with over 10 years of experience were considered seniors.

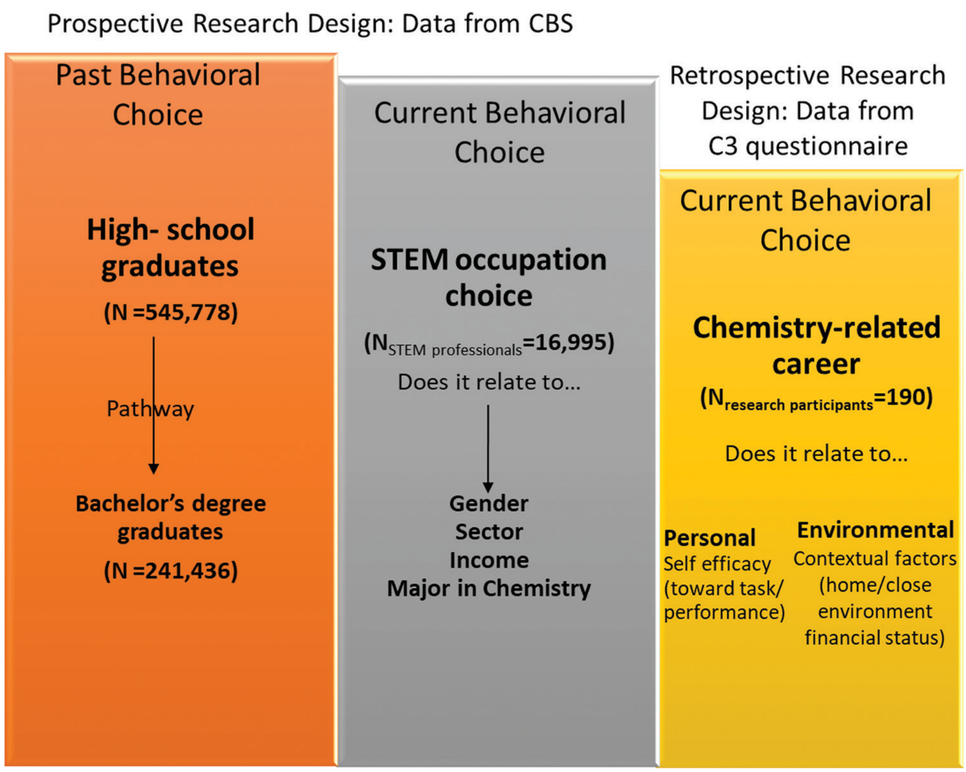

Fig. 1 Prospective and retrospective study designs.

aiming to explore differences between perceptions of participants regarding the *Personal* and *Environmental* themes.

Research tools

After receiving the ethics approval of the CBS Confidentiality Committee, our institutional IRB approval number 2018-034, and informed consent from the 190 participants, we obtained the demographics and field of study data from the CBS and participants' perceptions from the C3 questionnaire.

Data from the CBS – the Central Bureau of Statistics. To identify behavioral trends, we obtained CBS data for high school and higher education. We defined *Major* as a variable with three values: Chemistry, STEM, and Non-STEM. For high school students, STEM was defined as any scientific or engineering subject other than chemistry, including physics, biology, computer science, and electronics. Non-STEM was defined as any other elective high school subject, including literature, history, and art. For higher education records, chemistry was defined as the value of *Major* if the student holds a BSc degree in chemistry or chemical engineering, whereas STEM was defined as a student holding a BSc degree in medical sciences, mathematics, statistics and computer science, physical sciences, biological sciences, agriculture (veterinary medicine), engineering and architecture, mathematics and science teaching, or management sciences. A student who majored in any other field of study was defined as non-STEM. Additional data from the CBS about higher education STEM studies and occupational choice were analyzed by predicting variables such as chemistry as a major in high school and demographics, including gender, income, and sector.

The Chemistry Career Choice (C3) questionnaire. The first part of the C3 questionnaire included personal data, such as gender, sector, experience, and majoring in chemistry in high school. The second part, which originally included 40 Likert type items, was finally reduced to 34 items as explained below. The items were on a scale from 1 to 5, where 1 means "I do not agree at all", and 5 means "I strongly agree". A few items were phrased negatively to ensure that respondents' answers are meaningful or consistent. For these items, the scale was reversed for statistical processing.

The questionnaires, written and administered in Hebrew, were sent either electronically or as hard copies. The aim of the research was explained to the participants, making them aware that their answers should consider their chemistry-related studies or occupation. Each participant completed a questionnaire independently, without any time limitation. The respondents were informed that the questionnaires were anonymous and that their use was for research purposes only. Most of the participants who filled the C3 questionnaire responded to all the items. Yet, for less than 5%, questionnaire items or participant data were missing, so we dropped them from the statistical analyses.

Existing questionnaires such as the Chemistry Self-Efficacy Scale for College Students (Uzuntiryaki and Çapa Aydın, 2009) and the Chemistry Motivation Questionnaire (Salta *et al.*, 2012) were less suitable for this study, for two reasons: (a) they were not aimed at capturing perceptions regarding chemistry career and (b) they aimed only at college students or students in high school, but not at chemists and chemical engineers or teachers. Therefore, the C3 questionnaire was developed for this study. In what follows, we describe the process of establishing the validity and reliability of the C3 questionnaire.

Validity and reliability of the C3 questionnaire. We developed the scale items of the C3 questionnaire in three main stages. Stage 1 included the creation of a pool of items based on a combination of items from existing questionnaires (Holland *et al.*, 1980; Betz *et al.*, 2003; Dalgety *et al.*, 2003; Adedokun *et al.*, 2013) and items we composed to suit the study goals. Three of the science education researchers, who are experts in chemistry education and are fluent in both Hebrew and English, translated the items of the existing questionnaires from English to Hebrew and *vice versa*. In this process, we used the guidelines for reporting research data in a language other than English, as recommended by Taber (2018). Adaptations for language and culture were applied and tested by interviewing several potential representatives from each stakeholder group of this study, and they were not included in the final sample. Following the SCCT, we created a pool of 40 items, of which 22 were attributed to the *Personal* theme and 18 to the *Environmental* theme. The interviewees were also asked about the relevance of each questionnaire's items, namely, whether it was related to the perceptions about these two themes.

Stage 2 included inter-judge content validation, conducted by a discussion between the six science education researchers who read carefully each of the 40 items and approved their compatibility with the SCCT framework. The researchers were specifically asked to approve the assignment of each statement to either the *Personal* theme or the *Environmental* theme. All six judges were in complete agreement on the assignments to the two themes. The researchers grouped the items within each theme into five factors. For the *Personal* theme, the factors were (1) overall self-efficacy and (2) self-efficacy in chemistry. For the *Environmental* theme, the factors were (3) family or friends, (4) the role model of a high school teacher or university lecturer, and (5) monetary rewards, status, or prestige. In this process, two items were excluded, as the experts agreed that they had a dual meaning. Following this content validation, we conducted a preliminary pilot test by administering the questionnaire to about 70 third year undergraduate STEM (not specifically chemistry major) students, who were excluded from the final sample. Cronbach's alpha reliability estimates were calculated for each factor, demonstrating good internal consistency for all five factors: (1) 0.655 for overall self-efficacy, (2) 0.899 for self-efficacy in chemistry, (3) 0.302 for family or friends, (4) 0.891 for the role model of a high school teacher or university lecturer, and (5) 0.739 for monetary rewards, status, or prestige. At this stage, two items from the "family and friends" factor were removed from the questionnaire, increasing the Cronbach's alpha value from 0.302 to 0.706 for this factor. This stage ended with a C3 questionnaire that holds 36 items.

The third and final stage involved structural validity and reliability on the sample of 190 retrospective study participants who responded to the C3 questionnaire. An exploratory factor analysis that employed an oblique rotation yielded six factors that were found to be the best fit for our study, accounting for a combined 50% of the variance. During this stage, two additional items were removed from the questionnaire due to low factor loading, yielding a final version of a 34-item questionnaire. The factors for the *Environmental* theme were found to fit the factors suggested by the researchers in the previous validity stage. However, after performing the oblique rotation we found that within the *Personal* theme there should be three factors rather than the two factors suggested originally by the researchers, which were overall self-efficacy and self-efficacy in chemistry. The three new factors are discipline-specific and include (a) self-efficacy – scientific/chemistry learning, such as *I can understand research processes in the field of chemistry*; (b) self-efficacy – task oriented; and (c) self-efficacy – confidence in one's career in chemistry. Overall, we found a six-factor model for the C3 questionnaire.

Table 3 Factor loading, common variance, and reliability of the six-factor model for the C3 questionnaire

	Theme – *Personal*			Theme – *Environmental*		
	Factor 1: self-efficacy – scientific/chemistry learning	Factor 2: self-efficacy – task oriented	Factor 3: self-confidence in one's career	Factor 4: extrinsic motivation – rewards/status/prestige	Factor 5: influence of teachers/lecturers	Factor 6: family and friends
	0.710	0.007	−0.169	0.100	0.017	−0.175
	0.710	0.081	0.094	−0.179	0.090	0.263
	0.708	0.062	−0.103	0.241	−0.037	−0.238
	0.695	0.002	−0.104	0.009	−0.016	−0.068
	0.682	−0.090	−0.040	−0.058	0.168	0.268
	0.650	0.037	0.091	0.086	−0.029	0.023
	0.621	−0.020	−0.021	−0.027	−0.055	0.076
	0.576	−0.103	−0.109	0.134	0.191	−0.077
	0.523	−0.332	0.276	0.011	0.086	0.029
	0.481	−0.263	−0.062	0.172	0.303	0.263
	−0.955	**0.794**	0.148	−0.078	−0.132	0.053
	−0.787	**0.791**	0.114	−0.002	−0.076	0.011
	−0.653	**0.775**	0.176	−0.085	−0.012	−0.130
	−0.605	**0.720**	−0.038	−0.117	0.107	0.186
	0.100	−0.350	**0.696**	−0.059	−0.091	0.007
	0.071	0.060	**0.674**	0.122	−0.012	0.023
	0.079	0.035	**0.561**	0.051	0.075	−0.320
	0.179	0.210	**0.551**	−0.070	0.100	0.125
	−0.120	0.021	**0.520**	0.107	−0.104	0.115
	−0.020	−0.057	−0.017	**0.855**	−0.055	0.053
	0.011	−0.151	−0.073	**0.754**	0.035	0.240
	0.069	0.085	0.253	**0.732**	−0.032	−0.303
	0.229	−0.303	0.031	**0.699**	0.136	−0.097
	0.202	−0.226	0.058	**0.696**	0.010	−0.087
	−0.033	−0.180	−0.010	**0.694**	0.054	0.111
	−0.195	−0.134	0.011	**0.606**	0.009	0.069
	−0.047	−0.140	0.105	−0.058	**0.884**	−0.051
	−0.052	0.035	0.086	−0.043	**0.828**	0.135
	0.076	−0.101	0.128	−0.061	**0.803**	0.104
	0.133	0.160	−0.031	0.215	0.159	**0.613**
	0.065	0.287	0.040	−0.023	−0.092	**0.532**
	−0.018	0.053	0.054	0.228	0.213	**0.520**
	0.214	0.073	−0.004	0.269	0.028	**0.420**
	−0.121	−0.029	0.334	0.033	0.026	**0.401**
% of variance	7.9	14.1	5.8	10.9	6.6	4.3
Cronbach's alpha	0.88	0.86	0.63	0.86	0.87	0.60

Cronbach's alpha reliability estimates were calculated for each factor, demonstrating good internal consistency for all six factors. Table 3 presents the different factors, the factor loading for the 34 items, common variance, and reliability.

Data analysis

We used quantitative analysis methods that included descriptive statistics, factor analysis, and analysis of variance. The descriptive statistics served for depicting the trends of choosing chemistry as a major in the last two decades based on the CBS records. The Analyses of Variance served to explore the differences in the factors found for the three research groups by gender and sector. The independent variables were (a) the research groups (undergraduate chemistry students, chemists and chemical engineers, and high school chemistry teachers); (b) gender (men and women); and (c) sector (non-minorities and minorities). The dependent variables were the six factors we had found: (a) self-efficacy – scientific/chemistry learning; (b) self-efficacy – task oriented; (c) self-efficacy – confidence in one's career; (d) extrinsic motivation – rewards/status/prestige; (e) influence of teachers/lecturers; and (f) family and friends. These factors were defined as six different dependent variables, and for each variable, we calculated the mean of the items assigned to it. Table 3 and the Appendix provide a list of items and their attribution to the various factors. We also defined two main dependent variables that reflect the *Personal* and *Environmental* themes. For the *Personal* theme, we calculated the mean of the first three factors, and for the *Environmental* theme, we calculated the mean of the last three factors (two dependent variables that represent the *Personal* and the *Environmental* themes, respectively).

Results

We start this section with analysis of the prospective behavioral choice through data obtained from the Israel Central Bureau of Statistics. This analysis aims to answer the first research question – exploring trends of choosing chemistry as a major in high school and in higher education over the past two decades. Responding to the second research question, we present what factors influence career choice for the entire research group. We then describe the differences between the three chemistry-related research groups from a retrospective viewpoint. We conclude by presenting our findings for the fourth research question, referring to gender, and sector differences within each one of the three research groups with respect to (a) prospective trends of chemistry choice, as well as prediction of STEM choice for study and career; and (b) a retrospective view of the various chemistry-related groups.

Trends of choosing chemistry as a major in high school and university levels – a prospective view

Data obtained from the Central Bureau of Statistics show the trends of choosing chemistry as a major at high school and university levels. Fig. 2 and 3 present the same sample of all high school graduates who major in the sampled years. Fig. 2 shows that over the last two decades the overall trend of choosing a STEM pathway in high school has been decreasing. The *X*-axis represents the cohort sampled for the high school graduates, and the *Y*-axis represents the frequency of high school graduates by major: chemistry, STEM, or non-STEM tracks. The graph shows that between the years 1992 and 2017 there was a slight decrease of high school students choosing STEM tracks from about 38% to 36%, and an increase of about 8% of those who chose non-STEM tracks. Fig. 2 shows a decrease of about 6% in the number of high school students choosing the advanced chemistry track over this period. Yet, the students who choose chemistry as a major in high school consistently constitute more than a quarter of the total number of students who major in a STEM subject. Over the years, the choice of high school students to major in STEM in general and chemistry in particular has been decreasing.

Fig. 3 presents the trend in choosing a bachelor's degree in higher education institutes over the last two decades. The *X*-axis represents the cohorts sampled for the bachelor's degree graduates, and the *Y*-axis represents the frequency of bachelor's degree

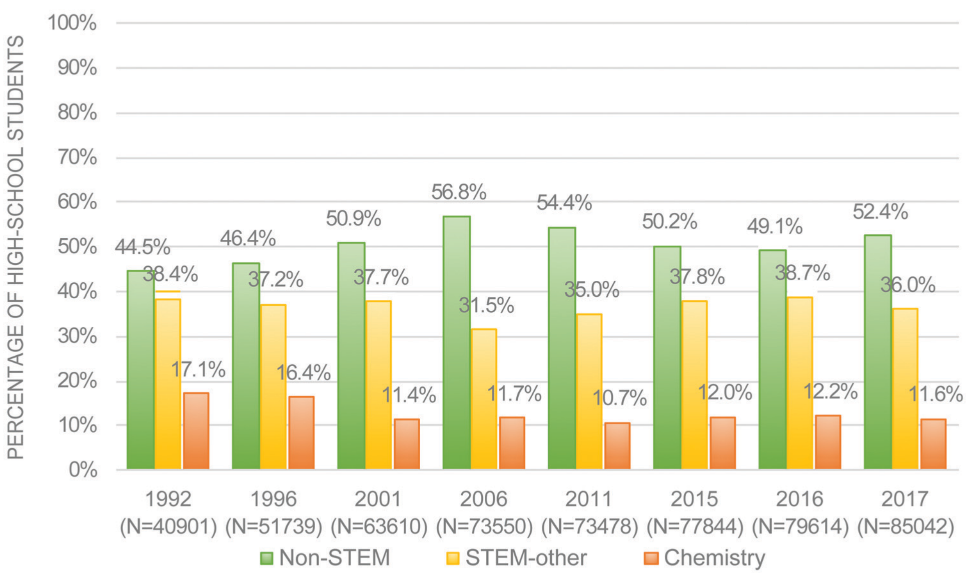

Fig. 2 Distribution of high school students' choices of major studies, by an advanced chemistry track, other STEM tracks and non-STEM tracks.

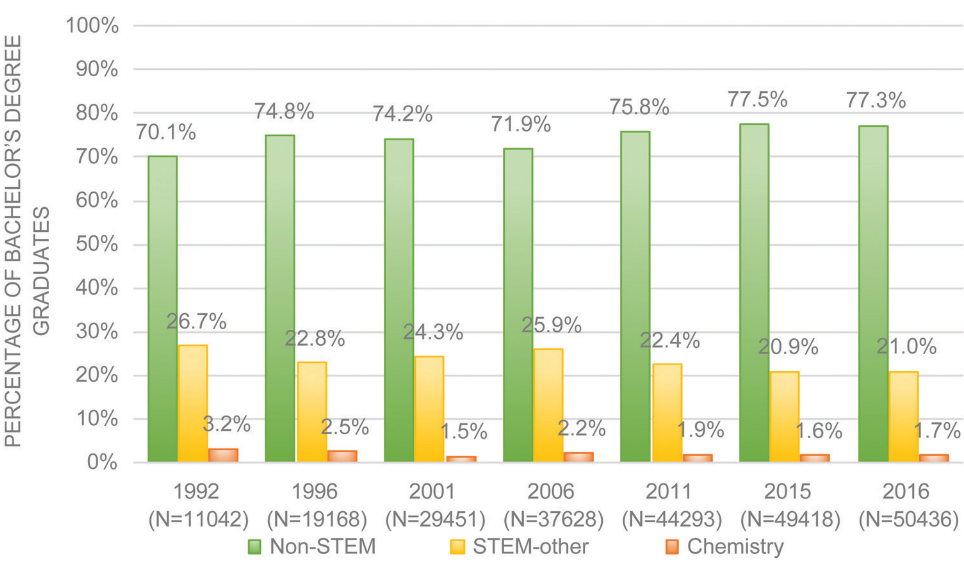

Fig. 3 Distribution of bachelor's degree graduates by their major: a chemistry track, other STEM tracks and non-STEM tracks.

Table 4 Questionnaire themes, factors, descriptive statistics, and examples of items

Factor	Mean	SD	Item example(s)
Theme – *Personal*			
Factor 1: self-efficacy – scientific/chemistry learning	4.16	0.65	I have the ability to understand scientific articles
Factor 2: self-efficacy – task oriented	4.37	0.66	I have the ability to commit to specific tasks and carry them on successfully
Factor 3: self-efficacy – confidence in one's career	4.00	0.78	The decision about chemistry career is an ongoing process and it is difficult for me
Theme – *Environmental*			
Factor 4: extrinsic motivation – rewards/status/prestige	3.53	0.87	My job allows me a high social status
Factor 5: influence of teachers/lecturers	3.20	1.21	My teacher/lecturer encouraged me to read advanced papers in chemistry
Factor 6: family and friends	3.60	0.77	I am interested in a job that will consider my family status

graduates by their major: chemistry, STEM, and non-STEM.§§ Here we observe a more stable trend, where choosing chemistry as a major in higher education is about 2% on average, which is 6.4 times smaller than the frequency of high school students who choose chemistry as a major. About 20–25% of the graduate students majored in one of the STEM fields other than chemistry.

Factors that affect individuals' choices and career pathways in chemistry – a retrospective view

Using the quantitative data collected by the C3 questionnaire, we first present the findings of the entire population and the differences among the six factors. We then investigate the differences between the three chemistry-related groups with respect to their preferences regarding each of the factors that influence choices and career pathways.

One-way ANOVA with repeated-measures revealed that the *Personal* theme influences the choice of chemistry as a major more than the *Environmental* theme, $F(5185) = 50.14$, $p < 0.0001$, $\eta_2 = 0.58$. Simple main effect tests with Bonferroni adjustment indicated that within the *Personal* theme the *Self-efficacy – task-oriented* factor was significantly the most influential on the choice of chemistry for study or career, compared with the other two factors related to the *Personal* theme. Regarding the *Environmental* theme, the influence of *Family and friends* and the influence of *Extrinsic motivation – rewards/status/prestige* were found to be more influential on the choice of chemistry for study or career than the environmental influence of *Teachers/Lecturers*.

Table 4 presents the means and standard deviations of the themes and the different factors within them, along with examples of items for each factor. See the Appendix for additional items from the C3 questionnaire.

Career choices and pathways – differences between the three chemistry-related research groups

To investigate whether there are differences between the chemists, chemistry teachers, and undergraduate chemistry students regarding the six-factor model (including three factors of the *Personal* theme and three factors of the *Environmental* theme), we conducted one-way MANOVA separately for the *Personal* and *Environmental* themes, followed by simple main effect tests with one-way ANOVA for each factor within each theme. Findings revealed significant differences between groups with respect to both the *Personal* theme $F(6370) = 6.64$, $p < 0.0001$, $\eta_2 = 0.097$ and the *Environmental* theme $F(6370) = 18.30$, $p < 0.0001$, $\eta_2 = 0.229$. Delving into the *Personal* theme, no significant difference between the groups was found with respect to Factor 2, *Self-efficacy – task oriented*; all chemistry-related groups viewed it similarly and to the highest extent. However, significant differences were found with respect to participants' *Self-efficacy – scientific/chemistry learning* (Factor 1, $F_{(2187)} = 15.46$, $p < 0.0001$), indicating that chemists and teachers found this factor to be more influential on their chemistry career choice compared with the undergraduate students. Significant differences were found also with respect to participants' *Self-efficacy – confidence in one's career* (Factor 3, $F_{(2187)} = 3.27$, $p < 0.05$), as teachers found this factor to be more influential on their career choice compared with the undergraduate students ($p < 0.05$). Fig. 4 illustrates these findings.

For the *Environmental* theme, the findings revealed no significant difference between the three groups with respect to the influence of *teachers/lecturers* on choosing chemistry as a profession (Factor 5). All three groups viewed it similarly and to the lowest extent. Differences were found with respect to participants' *Extrinsic motivation – rewards/status/prestige* (Factor 4), $F(2187) = 28.16$, $p < 0.0001$, $\eta_2 = 0.231$, and participants' *Family and friends* (Factor 6), $F(2187) = 24.29$, $p < 0.0001$, $\eta_2 = 0.206$. Undergraduate students' choice was influenced more by *Extrinsic motivation – rewards/status/prestige* compared with the chemists', while the teachers were least influenced ($p < 0.01$). *Family and friends* were mentioned mostly positively by the undergraduate students, followed by the teachers, and the least by the chemists ($p < 0.01$). See Fig. 5 for illustration of these findings.

Gender and sector differences

Choosing chemistry as a major by gender and sector differences – a prospective view

There is an increase in the number of girls who choose chemistry as a major in high school over the years, and it is about 1.2 times higher than the frequency of boys (see Table 5). A similar trend was found for higher education: the choice of chemistry as a major by female graduate students is greater than that of men.

Minority student population groups showed a similar trend for chemistry choice in both high school and higher education. A decrease in chemistry choice was found at the higher education level among the non-minority students. Yet, there

§§ In the context of our country which is based on its technology and technological–scientific startups, secondary schools encourage students to choose STEM majors.

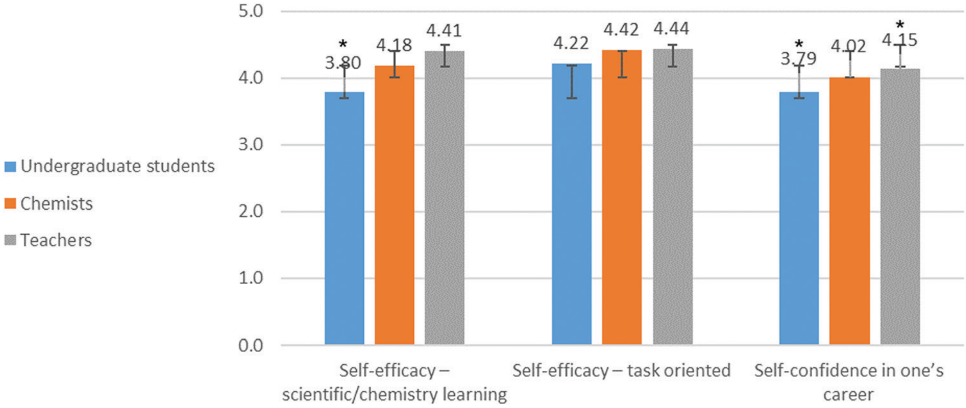

Fig. 4 Differences between the chemistry-related groups for the factors within the *Personal* theme.

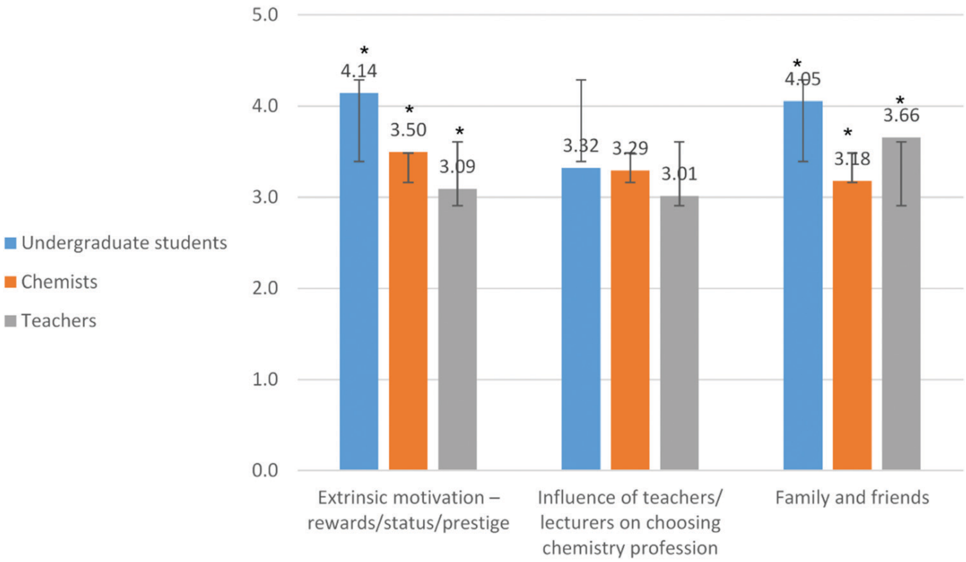

Fig. 5 Differences between the groups for the factors within the *Environmental* theme.

Table 5 Distribution of high school (HS) and bachelor's degree (BD) graduates who majored in the chemistry track, by gender and sector

Sampling cohort	1992		1996		2001		2006		2011		2015	
Attribute	HS	BD	HS	BD	HS	BD	HS	BD	HS	BD	HS	BD
N	6986	345	8467	738	7237	840	8571	537	7847	47	9316	NA
% Girls/women	52.9	49.9	55.4	56.1	61.7	66.9	60.1	71.7	61.9	63.8	63.2	NA
% Minorities[a]	20.4	1.2	20.2	1.4	17.8	1.5	23.4	2.1	19.3	1.4	19.2	NA
% Non-minorities[a]	15.9	1.4	14.9	2.4	9.3	2.5	7.8	1.9	6.8	1.9	7.2	1.4

[a] Note. Percentages for minorities were calculated out of the sample of minorities for each cohort and not out of the total sample size in each cohort; that is, their relative representation in the total sample that ranged between 13% and 28% (over the years) was considered as 100% for this calculation. For this reason, we also presented the percentages of the *non-minorities*, as the sum of percentages obviously do not present the 100% of the total sample for each cohort.

is a difference in the percentage of high school students *versus* higher education graduates. In high school, the percentage of minorities who choose to study chemistry is about twice as high as that of the non-minority group, but the minorities graduate with a first degree in chemistry is 1.3 times less than the non-minorities. This finding means that individuals that are part of the minority group choose to learn chemistry in high school more than individuals that are part of the majority population group, but this trend does not continue in higher education.

Prediction of STEM choice as a major for bachelor's degree and career by gender and sector differences – a prospective view

Multivariable logistic regression was conducted to assess the association of various demographic factors and majoring in high school chemistry with STEM *vs.* non-STEM choice for both graduation of bachelor's degree and career. Career choice was determined by occupation in industry at the year 2015, as received from CBS records. In these models, we consider gender, sector, and economic status (determined by parents' income in the last year of high school), and chemistry as a major in high school as predictors. The regression models were found to be significant ($p < 0.01$) for predicting STEM choice for bachelor's degree with 36.1% variance and for predicting STEM career choice with 15.1% variance. Both models were examined using three indices: regression coefficient (B), Wald's chi-square statistics (which indicates the significance of each individual predictor), and the likelihood ratio (odds ratio). The results presented in Table 6 suggest that all the demographic variables are significant predictors for both graduation of a STEM bachelor's degree and STEM career choice. Chemistry as a major in high school is a significant predictor for graduation with a STEM bachelor's degree (1.56*), but not for STEM occupation (1.03).

Sector was found to be the most predictive factor for graduation with a STEM bachelor's degree and making a STEM career choice. The odds ratios suggest that non-minorities are about 2.29 times more likely than minorities to graduate with a STEM bachelor's degree, and about 3 times more likely than minorities to choose STEM for a career. Gender was found to be the second important predictive factor for graduation with a STEM bachelor's degree, as men are 1.85 more likely than women to graduate with a STEM bachelor's degree. For a STEM career choice, gender is the third predictive factor, with men being 1.40 more likely than women to choose STEM as a career. The least important predictive factor for graduation with a STEM bachelor's degree and the second factor for a STEM career choice is income. The analyses point out that high school students whose parents have high income are 1.20 more likely to graduate with a STEM bachelor's degree and 1.44 more likely to choose a STEM career. Finally, choosing chemistry as a major in high school is found to be the third predictive factor for graduation with a STEM bachelor's degree, as students who chose chemistry as a major in high school are about 1.56 times more likely than those who did not major in chemistry to graduate a STEM bachelor's degree. Unlike the prediction of graduation with a STEM bachelor's degree, majoring in chemistry in high school is not a predictive factor for STEM occupation.

Choosing chemistry as a major by gender and sector differences – a retrospective view

For investigating the differences, if any, between men and women in choosing to major in chemistry (for the undergraduate students) and retaining a chemistry-related career (for the chemists and the teachers), we performed two-way MANOVA for each of the two themes: *Personal* and *Environmental* with gender and group as the independent variables. We found significant gender differences for the *Environmental* theme in choosing a chemistry-related career, $F(3186) = 2.97$, $p < 0.05$, $\eta_2 = 0.05$, but not for the *Personal* theme, $F(3186) = 2.41$, $p > 0.05$, $\eta_2 = 0.04$. Specifically, gender differences were found regarding the importance of the '**Influence of teachers/lecturers in choosing chemistry profession**' factor, $F(1184) = 4.69$, $p < 0.05$, $\eta_2 = 0.025$, which indicated that, on average, males ($M = 3.52$, SD = 0.95, $N = 60$) had a more positive view than females on the importance of teachers in their choice of study and career ($M = 3.05$, SD = 1.29, $N = 130$). These differences were similarly found among all the groups. No significant differences were found regarding the other factors, nor regarding the interaction between gender and group.

Further, two-way MANOVA for exploring *sector* differences revealed that the minorities perceived the '**Family and learning setting**' factor, $F(1183) = 11.90$, $p < 0.001$, $\eta_2 = 0.061$, and the '**Self-efficacy – task oriented**' factor, $F(1183) = 4.81$, $p < 0.05$, $\eta_2 = 0.026$, as more influential on their choice ($M = 3.90$, SD = 0.64 and $M = 4.54$, SD = 0.46, respectively), compared to the non-minority group ($M = 3.49$, SD = 0.79 and $M = 4.31$, SD = 0.72, respectively). These differences were similarly found among all the groups. No significant differences were found neither regarding the other factors, nor regarding the interaction between sector and group.

Discussion

This study comes at a time where the concern regarding the choice of a STEM career is shared by nations, policymakers, researchers in this field, and educators (Wang, 2013; Chen and Simpson, 2015; Sax *et al.*, 2015; Blotnicky *et al.*, 2018; Smith and White, 2018). Our study highlights the prospective trends and retrospective factors related to choosing a chemistry career by chemists and chemical engineers, chemistry teachers, and third year chemistry undergraduate students. Our analysis relies on the Social Cognitive Theory (SCT) and the Social Cognitive

Table 6 Statistical indices of demographics and chemistry as a major in high school as predictors for graduation with a STEM bachelor's degree and STEM career choice

	Graduation with a STEM bachelor's degree			STEM career choice – occupation		
Predictor	B	Wald^2	Odds ratio	B	Wald^2	Odds ratio
Gender: men compared to women	0.615*	815.67	1.85	0.336*	84.82	1.40
Sector: non-minorities compared to minorities	0.826*	366.63	2.29	1.102*	174.75	3.01
Income: top percentile compared to bottom percentile	0.178*	12.95	1.20	0.365*	18.78	1.44
Majoring chemistry in high school: majoring compared to non-majoring	0.443*	237.85	1.56	0.032	0.53	1.03

Note. Values marked with asterisks (*) were significant at $p < 0.001$.

Career Theory (SCCT) (Bandura, 1991; Lent *et al.*, 2002, 2008; Sax *et al.*, 2015). In order to investigate choices of STEM careers, we used in our analysis the categories that are classified into the *Personal*, *Environmental*, and *Behavioral* themes of SCT.

Prospective view

We found a trend of decrease over the last two decades in students' choice of chemistry in high school and higher education in Israel. Looking at the overall trend from high school to higher education, the metaphor of a "leaky pipeline" is in place, as has been found in other STEM disciplines (Blickenstaff, 2005; Tytler *et al.*, 2008; Lyon *et al.*, 2012). The growing need for a workforce in STEM is not fulfilled due to the decrease in the number of students choosing STEM subjects at all levels of education (Jacobs and Simpkins, 2005; Lyons, 2006; Tytler *et al.*, 2008; Oon and Subramaniam, 2010; Smith and White, 2018). According to many researchers, chemistry is among the most affected disciplines (Lyons, 2006; Salta *et al.*, 2012; Ardura and Pérez-Bitrián, 2018).

Analysis of further behavioral trends, as Table 6 shows, implies that students who choose chemistry as a major in high school (see the predictor "Chemistry in high school" in Table 6) will be more likely to graduate a STEM bachelor's degree (see the predicted variable "Graduation with a STEM bachelor's degree"). However, choosing chemistry in high school does not predict the choice of a STEM occupation (see the predicted variable "STEM career choice – Occupation"). One reason for this inconsistency might be associated with the lack of knowledge about chemistry careers even among the third year undergraduate chemistry students in higher education (Solano *et al.*, 2011; Tucci *et al.*, 2014). Our study also showed that economic status (income) influences one's choice. High school students whose parents' income is high are more likely to choose STEM for higher education and occupation, more than high school students whose parents have a low income (see the predictor variable "Income: top percentile compared to bottom percentile" in Table 6). However, Moakler and Kim (2014) found that when the level of income of the parents increased, the students were more likely **not** to choose to major in STEM. Their study did not address STEM degree persistence, STEM degree completion, and STEM career choice upon graduation, and the participants were first year (freshman) students and might have dropped out. The study by Xu (2013) supports our findings and shows that higher family income increases the likelihood of STEM graduates to choose a job closely related to their major than STEM graduates with lower family income. A possible explanation for this is that students with high parental income have more educational opportunities.

Women and minorities in chemistry. Our data show that the percentage of women who choose to study chemistry in high school and higher education is somewhat higher than that of men. However, researchers have found that fewer women are choosing and persisting in STEM occupations beyond their undergraduate degree (Atkin *et al.*, 2002; Goulden *et al.*, 2011; Wotipka *et al.*, 2018). We found that minority groups exhibit an even more concerning pattern: the percentage of minorities who choose chemistry and STEM tracks in high school is higher than that of the non-minorities, but in higher education, the reverse is true. According to our results, factors of gender and sector had the most significant influence on majoring in STEM in higher education and in choosing a career in STEM. Men and non-minorities are more likely than women and minorities to graduate with a STEM bachelor's degree and choose a STEM career. This finding is in line with the findings of lack of women and minorities in STEM studies and occupations (Cannady *et al.*, 2017; Xu, 2017), indicating that this problem persists. Further research may focus on a similar investigation with a greater emphasis on specific underrepresented groups such as minorities and women.

Retrospective view

Our model strengthens the theory and validates that different factors within the *Environmental* and *Personal* themes affect one's choice of a chemistry career. From a methodological point of view, our focus on various chemistry-related groups contributes to designing a tool that refers to chemistry choice in both education and career. With that, we suggest new discipline-based categories that are related specifically to a career in chemistry. We found that the personal aspect influences the choice more than the environmental aspect. Some previous studies on the correlation between self-efficacy (personal aspect) and science career aspiration have found similar trends (Lent *et al.*, 2008; Nugent *et al.*, 2015). However, Dorph *et al.* (2018) surprisingly found that "*the higher an individual's belief in their own competence in science pursuits, the less likely they were to have a career goal at all, let alone to have identified a STEM career*". Yet, like other studies, we found that self-efficacy was more influential than environmental aspects, such as the influence of parents and teachers.

An exploratory factor analysis shows the strength of our 6-factor model. On comparing the factors within the model, it was found that 'self-efficacy – task oriented' was the most significant factor within the *Personal* theme, and no differences were found between chemistry-related groups regarding this factor. A possible explanation for this finding is that students who choose chemistry, chemists in industry, and teachers who choose to teach chemistry in high school believe they can accomplish tasks related to their career, otherwise they would not have chosen this career path.

Examining the factor 'self-efficacy regarding learning science and chemistry', we found that students felt less secure than chemists, chemical engineers, and chemistry teachers regarding learning science and chemistry. This finding can be explained by the fact that students are in the initial stage of their career, so it makes sense that they feel less secure about their knowledge of science and chemistry. This difference might serve as a warning sign for chemistry educators in higher education, telling them to pay more attention to increasing students' self-efficacy in learning science and chemistry, especially toward the end of their higher education degree and before starting their career. Some studies argue that strengthening chemistry students' self-efficacy toward learning chemistry can be accomplished by adopting new and diverse teaching strategies or through social support (Grunert and Bodner, 2011a; Ferrell *et al.*, 2016).

Students were less confident than teachers regarding their choice of career. This observation should lead higher education chemistry educators to consider exposing their undergraduate students to the different opportunities they can pursue when planning their future career in chemistry, and strengthen their confidence in the likelihood of leading a successful chemistry career (*e.g.* Solano *et al.*, 2011; Tucci *et al.*, 2014).

Within the *Environmental* theme, the 'influence of teachers and lecturers' was found to be the least influential factor. This issue needs further investigation, since some research on teachers' behavior and characteristics shows that they can be a source of support, while also posing barriers for students' STEM aspiration. For example, the lack of teachers' knowledge or inspiration and the lack of encouragement were found to be associated with lower interest in STEM among the students, whereas teachers with more experience, who support and encourage their students, were associated with interest in continuing in STEM (Haag *et al.*, 2010; Lichtenberger and George-Jackson, 2013; Reinhold *et al.*, 2018).

Chemists and students, but not teachers, found 'Extrinsic motivation – rewards/status/prestige' as influencing their choice. Third year undergraduate students rated this factor as significant more than chemists and teachers. Among the populations we investigated, students were most influenced by the factor 'Family and friends,' followed by teachers to a smaller degree, and chemists to an even smaller degree.

The findings about gender in the retrospective view were that men considered the influence of teachers as significantly higher than women. Indeed, studies showed that teaching methods may cause gender differences, and this can be a possible explanation for this finding (Guzzetti and Williams, 1996; Altermatt *et al.*, 1998).

In all the groups, the minorities find the influence of 'Family and friends' more significant to their choice than the non-minorities, and their self-efficacy was higher than that of the non-minorities. A possible explanation for this is that minorities, being a challenged sector, are more motivated than non-minorities to prove that they are capable of reaching far and attaining achievements.

Implications of prospective and retrospective views

In a retrospective view, we found that students were less secure regarding their efficacy in science and chemistry. The prospective view revealed that not all students who major in chemistry continue to study it in higher education, and not all graduates of a bachelor's degree in STEM eventually choose to work in this field. Majoring in chemistry predicts graduation as a STEM bachelor, but this does not predict a STEM occupation. The implication is that strengthening students' self-efficacy in chemistry can change the prospective trends we revealed in this study. Another implication of this study is related to gender. In the retrospective view, we found that men were more influenced than women in their choice of chemistry by teachers. In the prospective view, we found that men were more likely than women to graduate with a STEM bachelor's degree and choose a STEM career. To counter this, teachers should encourage females and adopt teaching methods that have a positive influence on them to hold on to their choice in chemistry and science. Educators should be aware that research shows that gender-biased teaching exists in science education (Kerkhoven *et al.*, 2016). For example, girls prefer science teaching methods that involve interactions, discussions, inquiries and group projects which enable them to actively participate in class when compared with traditional teaching methods like lectures (Juuti *et al.*, 2010).

Limitations, further research, and contributions

In order to propose specific recommendations, we conducted a discipline-based investigation regarding the trends and factors affecting individuals' choice in chemistry. We could have gained additional insights into each group's perspective through the use of interviews, delving deeper into the aspect of teacher influence on STEM choice and self-efficacy. In this study we used an exploratory factor analysis, and therefore our conclusions can be applied only to our sample (Field, 2009). However, in a future study we plan to use a different sample and use a confirmatory factor analysis. Still, our analysis enabled us to examine the factors within the research sample and compare between the different research groups. We also did not investigate students who chose chemistry in high school and then decided not to pursue chemistry in academia and as their career. These two aspects are fertile ground for further research. There is a need to investigate the problem of deterioration in choosing STEM careers by various sectors. Whereas studies have reported on factors related to middle and high school choice of STEM (Dorph *et al.*, 2018; Dorfman and Fortus, 2019), there is a need for research on the further decrease between high school and higher education in choosing STEM, and in choosing STEM as a career (National Science Board, 2010; Solano *et al.*, 2011; Xu, 2013; Smith and White, 2018). The strength of this study is that it highlights the need to investigate the specific factors that influence the career choice in a specific discipline, chemistry, which is, in particular, decreasing. To this end, we suggest a 6-factor model that should be considered when planning for interventions to increase the choice of STEM career paths. To the best of our knowledge, this research is the first to combine big, national-scale data from CBS with data obtained from a sample of this population who responded to the C3 questionnaire. Methodologically, we present two important aspects based on the SCCT theoretical framework: (1) a cross-examination of data, referring to the prospective view by using a large data set analysis for investigating the *Behavioral* theme, and (2) the retrospective view *via* the quantitative analysis of the participants' perceptions for studying the *Personal* and *Environmental* themes of the SCCT. The study's theoretical contribution stems from the new chemistry-related factors within the SCCT theoretical framework which extends the self-efficacy construct. We also included confidence in one's chemistry abilities which is differentiated from self-efficacy-task-oriented and from self-efficacy of one's career. Practically, the study provides policy makers and chemical educators with recommendations for encouraging high school and undergraduate students to choose and remain in chemistry-related careers. This might contribute to reducing the acute shortage of skilled scientists in general and chemists in particular.

Conflicts of interest

The authors have no conflicts of interest to declare.

Appendix

Examples of items – Chemistry Career Choice (C3) perceptions questionnaire

Factor and examples of items		**1** Don't agree at all	**2**	**3**	**4**	**5** Strongly agree
Factor 1 **Theme – Personal** Self-efficacy – scientific/chemistry learning	• I have the ability to understand research processes in chemistry • I have the ability to conduct a successful career in the chemistry domain • I have the ability to read and understand scientific articles • I have the ability to follow and understand scientific innovations					
Factor 2 **Theme – Personal** Self-efficacy – task oriented	• I have the ability to handle challenging tasks in my job • I have the ability to critically evaluate information and propose a course of action • I have the ability to meet deadlines					
Factor 3 **Theme – Personal** Self-efficacy – confidence in one's career	• I lack self-confidence in my potential for achieving my chosen occupation • I am not sure about my ability to balance my future career and family • I have tensions regarding my ability to pursue a career in chemistry					
Factor 4 **Theme – Environmental** Extrinsic motivation – rewards/status/prestige	• There is no financial compensation in a chemistry career • My job allows me an adequate salary • Working in chemistry allows high social status					
Factor 5 **Theme – Environmental** Influence of teachers/lecturers	• My teacher/lecturer was interested in my progress in chemistry • My teacher/lecturer have made me feel that I have the ability to continue in science • My teacher/lecturer encouraged me to read advanced chemistry articles					
Factor 6 **Theme – Environmental** Family and friends	• I am interested in a job that will consider my family status • I have a lot of time to spend with my family and my kids • I am encouraged by people surrounding me to continue to study chemistry					

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