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Children's perceptions of the factors that led to their enrolment in advanced, middle-school science programmes

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ABSTRACT

Toward the end of 6th grade, some bright and highly motivated science-oriented Israeli students and their parents are required to make a decision: whether or not to enrol in a non-mandatory advanced science programme for 7th graders (≈12 year olds) upon entering middle-school. In other words, for many students, entry into the STEM pipeline begins at an earlier age than previously reported and, to date, reasons for doing so are unknown. The aim of this study was to identify and model the factors that contributed to enrolment. Data collected from 7th graders in three Israeli middle-schools ($N = 615$) included self-efficacy and interest in STEM learning, perceived parental encouragement to learn STEM, perceived peer interest in STEM, recollections of STEM learning in primary schools and participation in informal STEM programmes. Path analysis showed that 'self-efficacy', 'parents', 'peers' and 'participation' directly predicted enrolment. Self-efficacy mediated the effects of environmental variables on academic choice. The significant effect of participation in informal STEM programmes points toward an even *earlier* entry into the STEM pipeline. Quantitative content analysis was used to categorise the reasons for enrolling in the advanced science programmes ($N = 179$). Unexpectedly, students overwhelmingly cited practical importance ('utility value') vis-à-vis short, medium and long-term goals.

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Introduction

Today, even more so than ever, science, technology, engineering and mathematics (STEM) education is seen almost universally as a path to national security, economic development and scientific literacy (Murphy et al., 2019; National Science Foundation, 2016). Accordingly, nations around the world want students to learn STEM disciplines and enter related career paths (Shin et al., 2019). Consequently a great deal of research has been directed toward understanding the factors that influence students' decisions to pursue STEM learning and careers, and at what age they manifest themselves. To date, research into the reasons underlying the pursuit of STEM learning ('academic choice') has focused

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primarily on students entering high school (e.g. Caspi et al., 2019; Hazari et al., 2010) or university (e.g. Glynn et al., 2011, 2015; Rodd et al., 2013) since *actual* decisions are usually made at these junctures.

In one such study of 9th grade middle-school graduates (≈15 year olds), Caspi et al. (2019) modelled the factors that predicted their actual choices to major in STEM disciplines just prior to entering high school. The findings, grounded in Expectancy-Value Theory, were for the most part commonplace: the direct effects of the motivational factors (interest, utility value and self-efficacy), as well as perceptions of peers' interest and ability in STEM were statistically significant; the indirect effects of parental encouragement to learn STEM and recollections of prior school experiences were significant when mediated by the motivational factors; gender effects were non-significant.

However, one highly unexpected finding emerged: Participation in advanced three-year science programmes for highly qualified *6th* grade primary school graduates (≈12 year olds) upon entering middle-school ('ability grouping with curriculum differentiation') was by far the most significant factor underlying the choice of 9th graders to major in STEM disciplines (92% of the participating students did so); it increased the predictive outcome of choosing a STEM major by nearly *16-fold*. The programmes are described below in sub-Section: *Program goals and description*. In other words, for thousands of students, entry into the so-called STEM pipeline, an ever-narrowing channel that leads to a STEM degree or career (National Academy of Science, 2005), begins with an *actual* decision to do so, made at an early age along with their parents. To date, the factors underlying such decisions have not been studied. Prior research has investigated young students' (10-14 year olds) *hypothetical* choices to pursue further science learning or career aspirations; however, their intentions were speculative and in no way related to an actual real-life decision (e.g. DeWitt et al., 2013; DeWitt & Archer, 2015; Nugent et al., 2015).

The aim of this research, to identify the factors that led the 12 year olds to pursue STEM learning, has both theoretical and practical implications. Theoretically, a literature review revealed no previous studies that investigated the factors that influenced an *actual* academic choice of this scale (commitment to a 3 year programme) at such a young age. Practically, by identifying and modelling the factors that influenced this choice, we may understand how to encourage young students entering primary school to pursue STEM learning and help reduce the well-documented decline in students' interest, motivation and engagement in science learning beginning at early adolescence (Archer et al., 2020; Patrick & Mantzicopoulos, 2015; Vedder-Weiss & Fortus, 2012).

Theoretical and empirical background

Many theories address academic motivation, achievement and choice (e.g. Expectancy-Value theory, Self-Determination theory, Social-Cognitive theory, theories of interest). This research was conducted through the lens of Expectancy-Value theory [EVT, Eccles (Parsons) et al., 1983]. EVT has been used extensively to study individual and gender differences in academic and career choices [see Wang and Degol (2013, 2017) and Watt (2016) for reviews]. Especially relevant to our study is its effective use in studying the factors that lead to the pursuit of STEM learning among middle-school and high school graduates as well as college and university students (e.g. Anderson & Ward, 2014; Caspi et al., 2019; Harackiewicz et al., 2016a; Hulleman et al., 2010; Watt et al., 2017). EVT postulates that academic choice is predicted by the direct effects of two key motivational constructs – 'subjective task value' and 'expectations for success'; these, in turn, mediate the effects of the numerous demographic and environmental constructs and variables that comprise the theory (Eccles, 2005; Wigfield & Eccles, 2002). For a more detailed explication of the theory, see Eccles (2009).

In order to model empirically the factors underlying the academic choices of 6th grade graduates, we identified the *critical factors* that relate specifically or closely to our target population and outcome. This process of model building is based on the premise that among the many factors that may affect a single dependent variable, only critical ones should be used in the resulting model; that is, those that contribute the most variance (Gelso, 2006). The resultant hypothesised model is shown in Figure 1; it is followed by a description of the advance science programmes upon which the academic choice is based, the formal definitions of the model's constructs and variables, and a brief rationale of the reasons that led us to exclude others.

The dependent variable: the academic choice to enroll in advanced science programs

The dependent variable is the dichotomous yes or no response made by the 6th grade primary school graduates (presumably with very high parental involvement) to an invitation made by the middle-schools. A description of the programme and its goals follows.

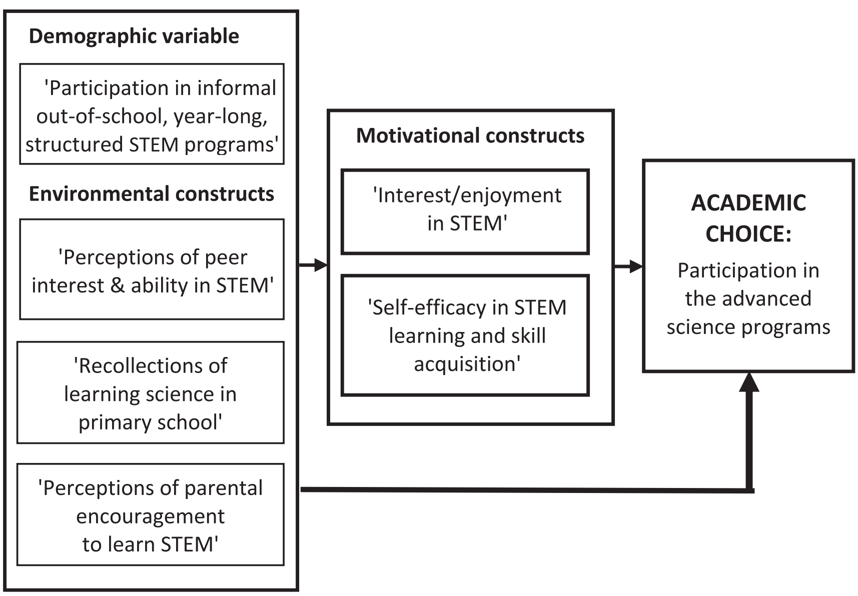

Figure 1. Schematic representation of the quantitative model to be tested.

Programme goals and description

The goals of these programmes are to increase students' knowledge of and interest in STEM learning and careers; they begin at the start of middle-school in 7th grade and end in 9th grade upon its completion. The programmes implement a policy known as 'ability grouping with curriculum differentiation' wherein participants are assigned to different classes based on levels of achievement or abilities. The programme establishes a homogeneous learning environment where teaching matches students' needs, and where students can profit from relating with like-minded peers (Steenbergen-Hu et al., 2016). In addition to covering all the standard topics defined by the Ministry of Education's curriculum, the programme includes additional topics in mathematics, physics and computer science at each grade level. Additional resources include dedicated laboratory equipment and various elective topics (such as biotechnology and astronomy). Emphasis is placed on learning scientific principles and not just rote problem solving.

Enrolment process and selection criteria

We highlight three pertinent points regarding the enrolment process: (1) participation in the programme is not mandatory, (2) schools do not coerce students to enrol and (3) no affirmative actions toward gender or ethnic parity are undertaken. Each middle-school that participates in the nationwide pilot programme (not all schools do) establishes its own procedures for enrolling students and selection criteria. For example, in two of the three middle-schools surveyed, very good, highly motivated science-oriented students from nearby primary schools were invited by the regional middle-schools to submit their candidacy to the programme. In the third school, a different policy for finding candidates was adopted; no invitations were extended and any student could freely submit his or her candidacy to the middle-school. Specific acceptance criteria were defined by each school where different weights were assigned to grades, interviews and teacher recommendations. The criteria aim to identify the brightest and most highly motivated students in the realm of STEM. We do not know how the different selection processes and selection criteria may have affected the target population.

Demographic variables

We identified the highly significant effects of four key demographic variables on academic choice: age, socio-economic status (SES), gender and participation in informal out-of-school, year-long, structured, hands-on STEM programmes. In this study, age (all respondents were ≈12 year olds) and SES were controlled, and thus excluded from the model (how SES was controlled is explained below in sub-section *Procedure*). We also found that gender effects for children *this age* were likely to be non-significant (DeWitt et al., 2011, 2013; OECD, 2007). Although excluded from the model, we tested for its effect in order to corroborate this null hypothesis.

Participation in informal out-of-school, year-long, structured, hands-on STEM programs

Participation in such programmes often contributes to student interest in science and to their ability related beliefs (e.g. Sha et al., 2015; Young et al., 2017). In addition to the worth of such experiences often derived from inquiry-based, hands-on instructional strategies (Pedaste et al., 2015; Zacharia et al., 2015) it has also been reported that the *amount* of science learning also plays a significant role in increasing interest and self-efficacy (Sha et al., 2015).

We note that other kinds of informal STEM activities may influence academic choice. For example, families may discuss science topics at home or visit planetariums; some events are serendipitous. However, in this study, we related only to out-of-school, year-long, informal STEM programmes.

Motivational constructs

Subjective task value

This key predictor includes four sub-constructs: intrinsic value, attainment value, utility value and relative cost; only the first is included in the model.

Intrinsic value: This construct was defined by Eccles and Wigfield (2002) as 'the *enjoyment* the individual gets from performing the activity or the subjective *interest* the individual has in the subject' (p.20; the italics are for our emphasis). They note that this construct is similar to parallel ones in other theories of motivation such as 'intrinsic motivation' (Self-Determination theory: Deci & Ryan, 2002) and to the distinct constructs of interest as defined by Renninger and her colleagues (Renninger, 2000; Renninger & Hidi, 2011) and Schiefele (1991). For example, Hidi and Renninger (2006) distinguish between 'situational' and 'individual' interest. The former is an immediate response to certain conditions and/or stimuli in the learning environment that attract one's attention to a *task at hand* while the latter is a 'relatively enduring pre-disposition to re-engage particular content over time' (p.111).

For this study, we chose the construct 'individual interest' for which a great deal of empirical evidence, obtained from research carried out within the EVT framework, has shown that it is positively related to STEM oriented academic choice (e.g. Caspi et al., 2019; Harackiewicz et al., 2016b; Lichtenberger & George-Jackson, 2013; Maltese & Tai, 2010; Renninger & Hidi, 2011; Renninger et al., 2014; Swarat et al., 2012; Uitto, 2014; Wigfield & Cambria, 2010). Of particular relevance to our study are findings reported by Maltese and Tai (2010) who reviewed 116 interviews collected from graduate students and scientists about when and how they first became interested in science. Findings showed that nearly two-thirds of the participants reported that their interest in science began in primary school.

Utility value: This construct, defined by Eccles and Wigfield (2002) as how well an undertaking relates to current and future goals, was excluded based on findings reported by DeWitt et al. (2011, 2013) who investigated young students (10-14 year olds) non-binding, hypothetical future aspirations to learn science. They found that aspirations were most strongly predicted by 'parental attitudes to science', 'attitudes towards school science', 'self-concept in science', 'images of scientists' and 'engagement in science-related activities outside of school' - not by utility value.

Attainment value: This construct is defined by Eccles (2005) as the 'value an activity has because engaging in it is consistent with one's self-image' (p.109); it was also excluded as being inappropriate for the young students being investigated. Among older 9th grade students, its effect upon choosing a high school STEM major is limited (Caspi et al., 2019;

Taskinen et al., 2013); its effects are much greater on high school or university students' choice of a STEM major or STEM career aspirations (e.g. Hazari et al., 2010; Lent et al., 2018; Lichtenberger & George-Jackson, 2013; Wille et al., 2020).

Cost: This construct, defined by Eccles and Wigfield (2002) in terms of the negative aspects of engaging in a task or committing to a programme, was excluded for theoretical and methodological reasons. Theoretically, Barron and Hulleman (2015) question its placement in EVT as a component of *task value*. They cited previous empirical work (e.g. Conley, 2012; Trautwein et al., 2012) which suggested that cost separates into its own factor and is negatively related to both task value and expectancy. Methodologically, within the current research design, its influence was not measured; that is, it *might* be a significant factor among students who were accepted into the programme but rejected the offer for cost related reasons (e.g. the additional time and effort the programme required, the loss of engaging in other valued activities, a negative social impact among friends and peers). However, based on discussions with school faculty members involved in the selection process, we found that the number of students who declined to participate after being invited was small (no actual numbers were cited). Therefore, for the sake of simplicity and clarity, the questionnaire was not designed to take such cases into account.

Expectations for success

This second key EVT predictor subsumes two related sub-constructs, 'self-concept of ability' and 'activity-specific ability'. The former refers to students' evaluation of their competence in a *domain* while the latter refers to students' evaluation of their competence in performing *specific tasks*. Although 'self-concept of ability' is recognised as a predictor of academic choice and is theoretically distinguished from 'activity-specific ability' [Eccles (Parsons) et al., 1983], empirical studies (e.g. Eccles, 2009; Wigfield & Eccles, 2002) have found that children and young adolescents do not distinguish between the two constructs. Therefore, only activity-specific ability was included in the model.

'*Activity specific ability' (self-efficacy in STEM learning and skill acquisition)*: This construct is defined by Eccles and Wigfield (2002) as 'individuals' beliefs about how well they will do on upcoming tasks, either in the immediate or longer-term future' (p.119). This definition corresponds closely with Bandura's (1986) self-efficacy concept defined as 'people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances' (p.391). Indeed, Eccles and Wigfield (2002) wrote 'These expectancy beliefs are measured in a manner analogous to measures of Bandura's (1997) personal efficacy expectations' (p.119). A great deal of research has found that 'activity specific ability' or, as we will name it 'self-efficacy in STEM learning and skill acquisition' for our target population, predicts actual academic choice; that is, older students (9^{th} graders and above) with high levels of self-efficacy are more likely to pursue further STEM studies (e.g. Adedokun et al., 2013; Caspi et al., 2019; Glynn et al., 2011). Relevant to our investigation of ≈12 year olds' actual academic choices to pursue STEM learning are findings that show the importance of high self-efficacy in science among 10–14 year olds' *hypothetical* science aspirations and career choices (DeWitt et al., 2013; DeWitt & Archer, 2015).

Environmental constructs

We found that the effects of three key EVT environmental constructs on academic choice, especially in the realm of STEM, were highly significant, be they direct or mediated by the motivational constructs described above: ‘perceived parental encouragement to learn science and technology’, ‘perceived peer interest and ability in science’, ‘recollections of learning science in primary school’. In EVT terminology, the first two are associated with ‘child’s perception of socializer’s beliefs, expectations, attitudes and behaviors’ while the third is associated with ‘child’s interpretations of experiences’.

Perceived Parental Encouragement to Learn STEM (‘parents’): Parents exert substantial influence over their children’s motivation to learn in general and to learn science in particular (Perera, 2014). Specifically, *perceived* parental encouragement to learn STEM has a positive effect on children’s interest and engagement in STEM, their achievement in the sciences, and their pursuit of further science learning. For example, Nugent et al. (2015) found that *perceived* parental encouragement increases youth interest in STEM which in turn predicts their further pursuit of such studies. Sha et al. (2016) reported that ‘early adolescents’ *perceived* family support for learning is associated with their choices for and engagement in science learning, and that these effects are mediated by effects on child interest and self-efficacy in science’ (p.450).

Perceived Peer Interest and Ability in Science (‘peers’): The motivation of young adolescents to learn science is influenced by their relationships with peers (e.g. Nugent et al., 2015; Vedder-Weiss & Fortus, 2013). Peer influence may derive from actual behaviour. For example, social interactions with peers encourage or discourage students’ STEM motivational beliefs (McInerney, 2012). Peer influence may also derive from perceptions of peer norms and rules that students believe they must follow (Schunk et al., 2012). For example, Nugent et al. (2015) found that student perceptions of their peers’ interest in and attitudes toward STEM achievement correlated with their own self-perceptions and attitudes.

Recollections of Learning Science in Primary School (‘primary school’): Recollections of learning science in primary school predict students’ interest in science, self-efficacy in science learning, and the pursuit of further science learning (e.g. Aschbacher et al., 2010; Renninger et al., 2014). Positive recollections encourage students to pursue further science learning while negative ones deter them. Especially germane factors are those related to teachers: their personal support and encouragement (Nugent et al., 2015); students’ recollections of instructional strategies (Lee & Anderson, 2013; Swarat et al., 2012) and curriculum (Baram-Tsabari & Yarden, 2005).

Research aim, questions and hypotheses

The aim of this research was to identify and model the factors that led ≈12 year old students to enrol in advanced science programmes for 7th graders upon entering middle-school *from their own perspectives*. The overall *quantitative* research question was: Does the proposed model, derived from EVT and research findings, fit the data collected from the students who chose to participate in the advanced science programmes? The overall *qualitative* research question was: What led students to enrol? Hypotheses regarding the quantitative research question follow:

H1: All the model's predictors will significantly predict the academic choice to enroll in the advanced science programs, either directly or indirectly or both (e.g. Caspi et al., 2019; DeWitt & Archer, 2015; Nugent et al., 2015).

H2: Interest and self-efficacy will mediate the effects of the three environmental predictors on academic choice (e.g. Caspi et al., 2019; Nugent et al., 2015; Renninger et al., 2014).

We reiterate that these research questions have been asked and answered for *older* student populations, not for the younger ones now being studied; in other words we hope to present new findings that add to our collective knowledge.

Methods

Constraints

Despite having gained approval from the Ministry of Education for carrying out the research, schools were reluctant to allow researchers to enter classrooms and interrupt learning, especially at the very start of the school year. Two of the three schools limited overall research time to 20 min (from the moment the research assistant entered the classroom until he or she left).

Given this constraint, we strived to develop a questionnaire with minimum items and maximum internal reliability. On the one hand, it is generally accepted that lengthy questionnaires increase internal reliability (Streiner, 2003); on the other, it has been argued that lengthy questionnaires increase the possibility of receiving spurious or non-conscientious responses due to respondent boredom or antagonism, especially from young adolescents (Burisch, 1984). Typically, the use of abbreviated measures has been seen as a compromise in which one maximises convenience but gives up some internal reliability and, presumably, predictive validity (Rammstedt & John, 2007; Thalmayer et al., 2011). However, it has also been argued that short forms may increase validity by obtaining more accurate responses (Vinni-Laakso et al., 2019). This is especially relevant in our study where many respondents may have been less inclined to participate in the survey given their lack of intrinsic interest in the items being surveyed (Gogol et al., 2014; Gorard, 2010; Symes & Putwain, 2016).

Research design

In order to gain deeper insight into the factors that led the young students to enrol, we augmented the qualitative data from an open-ended question with quantitative data from closed-ended questions. These data types complement and reinforce each other. The qualitative data should point toward general non-statistically significant patterns of causality while the quantitative data should indicate the significant correlations among and between the different factors at play.

Qualitative approaches

We used one open-ended question to elicit students' reasons for enrolling in the advanced science programme. Such an approach is widely used in qualitative studies (Lincoln et al., 2011). Quantitative content analysis was used to categorise responses. Reliability was determined by measures of inter-rater agreement; validity was assessed by the *representativeness* of the sample and by respondents' *willingness to cooperate.*

Quantitative approaches

Data were obtained via a questionnaire (Appendix 1) that included 2 checkboxes [gender (b/g) and participation in out-of-school STEM programmes (y/n)] and 15 closed-ended items which surveyed students' perceptions of the factors known to influence academic choice. Renninger and Hidi (2011) have noted that such self-report measures are currently the most widely applied approach in research on motivation, especially academic choice. We used a four-point Likert scale with options ranging from 'strongly disagree' to 'strongly agree'; variables were computed as mean scores. Two reasons underlie this choice: First, such scales are appropriate for young or poorly motivated respondents: they are easy to understand and need less effort to answer than 6 or 8 point scales (Adelson & McCoach, 2010). Second, using a scale without a neutral middle forces respondents to indicate a clear direction made relatively easy when the intermediate points ('somewhat agree' or 'somewhat disagree') are moderate (Nemoto & Beglar, 2014). Content validity was assessed by six science education experts who independently reviewed the items; reliability was established by internal measures (e.g. Cronbach's α and correlations).

Procedure

The first step, getting permission to carry out the research from the Ministry of Education, was achieved. Given the non-invasive items in the questionnaire, the letter of permission (addressed to the school Principals) included exemption from obtaining individual parental consent.

The second step was to find schools willing to participate with similar socio-economic status. This self-imposed requirement was made in order to control the influence of SES which significantly influences academic choice (Archer et al., 2014, 2020). The Ministry of Education ranks all schools by SES. Ranks, ranging from 1 (lowest) to 10 (highest), are calculated from sets of weighted variables (e.g. parental education, standard of living, etc.). Since all three schools are ranked 'mid-level' (6-7), this variable was controlled. We emphasise, however, that these school-wide averages do not capture the level of SES variance among individuals at the schools. The three middle-schools which agreed to participate were located in urban, middle-class predominantly Jewish neighbourhoods. The language in these schools is Hebrew; there is no extreme wealth, poverty or affiliation with extreme religious groups.

Participants

Participants included 621 7th graders enrolled in the three middle-schools at the very start of the 7th grade school year; that is, during the first week of school ('orientation') prior to the start of any formal classroom activities of any kind, including those in the advanced science programme; they constituted all the 7th graders in each school except for students in the special education classes. The rationale was explained and the anonymous, paper-and-pencil questionnaires were distributed by research assistants who had no prior or current association with the schools; students were told that they need not respond at all or that they may choose not to answer any question at their full discretion with no penalties of any kind. We obtained 615 forms whose responses seemed reasonably careful and meticulous. This is based on the observations of students made by assistants and a review of the forms themselves. Six were discarded for spurious responses or very large chunks of missing data or disrespectful behaviour while filling out the forms. Table 1 shows programme type distributions (advanced science vs. regular science) within the participating schools and gender distributions between the two programme types.

As expected, no significant gender difference in the science class was found [$\chi^2(1) = 1.553$, $p = .213$]; that is, girls and boys participated equally.

Instrumentation

Quantitative data

Interest/enjoyment in STEM ('interest'): Four items measured students' current levels of '*individual interest*' (Hidi & Renninger, 2006). Items included: 'I like to do science at home even if I don't have to (like experiments, science kits, or looking at science movies on YouTube or TV)' and 'There are things in science and technology that I'd like to learn more about'. Together, the items signify affective, behavioural and cognitive dimensions of interest that go beyond token responses like 'I'm interested in science' or 'I like science' the likes of which were excluded. In other words, we hoped to ascertain if students' academic choice emerged from a deeper 'individual interest' as opposed to a less developed 'situational interest' often characterised by superficial or commonplace expressions (Cronbach's $\alpha = .79$).

Self-efficacy in STEM learning and skill acquisition ('self-efficacy')

We used four items from an instrument developed by Lin and Tsai (2013) which measures five dimensions of self-efficacy in science learning: conceptual understanding, higher-order cognitive skills, practical work, everyday application, and science communication. The total number of items in this instrument (32) is unacceptable for our purposes. Therefore, we used one item from each of the first four dimensions such as 'I easily understand scientific theories and laws' and 'I know how to collect data in experiments'. The dimension 'science communication' was judged irrelevant. Five science education experts confirmed the content validity of this construct (Cronbach's $\alpha = 0.82$).

Perceptions of parental encouragement to learn STEM ('parents'): One unique item only was used as the index for perceived parental encouragement: 'My parents encourage me to

Table 1. Programme-type and gender distributions

Schools	Advanced	Regular	Totals
1	69 (32.2%)	145 (67.8%)	214 (100%)
2	36 (22.0%)	128 (78.0%)	164 (100%)
3	74 (31.2%)	163 (68.8%)	237 (100%)
Totals	179 (29.1%)	436 (70.9%)	615 (100%)
Gender	**Advanced**	**Regular**	**Totals**
Girls	87 (26.9%)	236 (73.1%)	323 (100%)
Boys	92 (31.5%)	200 (68.5%)	292 (100%)
Totals	179 (29.1%)	436 (70.9%)	615 (100%)

study science, technology and math'. The use of a single item holds that the effect of parental encouragement on a child is a function of the child's long-term cumulative perceptions of parental behaviour and not the parent's actual behaviour (Finley et al., 2008). In other words, we intentionally chose not to include items that asked about *how* such encouragement was manifested (e.g. help with homework, trips to planetariums, etc.). Furthermore, single items are often more appropriate for measuring motivational and affective constructs in educational settings, especially for younger participants (Vinni-Laakso et al., 2019); they may actually increase predictive validity by reducing ambiguity, boredom and antagonism (Gogol et al., 2014; Symes & Putwain, 2016).

Students' perceptions of their peers' interest and ability in STEM ('peers'): This four item variable, grounded in theory (Schunk et al., 2012), is based on statements used by Nugent et al. (2015). Example items included 'My best friend likes science' and 'Most of my friends are good students when it comes to science' (Cronbach's $\alpha = .69$).

Recollections of learning science in primary school ('primary school'): This two item variable broadly characterises students' recollections: 'School science classes were very interesting' and 'I liked learning science in school more than anything else'. The reliability of this construct was confirmed by Spearman's correlation ($\rho = .595$, $p < .001$).

Participation in informal out-of-school, year-long, structured hands-on STEM programs ('out-of-school'): Participation in at least one such programme over the span of primary school was the criterion (yes/no) for this item.

Qualitative data

Qualitative data were obtained from students enrolled in the advanced science programmes since only they could answer the following open-ended question presented *before* all other items: 'What led you to enroll in the advanced science program? List all the reasons you can think of, important and seemingly unimportant'. Starting with this open-ended question gives respondents the opportunity to freely assign reasons for enrolling and to avoid any bias or influence that may result from reading the suggestive closed-ended items that followed.

Results

Descriptive statistics

We performed multilevel modelling to analyse a data structure where students (level 1) were nested within the three schools (level 2). Schools have no significant effect vis-a-vis variation in the predictors (Wald z = .800, $p = .424$). Therefore, in subsequent analyses, we pooled all students together given that schools were not a source of variance.

Differences between students in the two programs (advanced science vs. regular science)

We performed a MANOVA to test for differences between programme types for all the predictors. An omnibus test revealed a significant main effect for programme type (Wilks' $\Lambda = 0.781$, $F(6,594) = 27.718$, $p < .001$, partial $\eta^2 = .219$). Students in the advanced science programmes had statistically significant higher scores for all predictors than students in the regular programmes. Table 2 shows these effects.

Modelling the factors that influence student enrollment

We first calculated Pearson correlations between all the variables. All were significant (see Table 3).

Next, we performed path analyses. We began by testing the full model (see Figure 1 above) which included all possible hypothesised paths; as such, the model was fully saturated (df = 0) and accordingly model fit could not be tested. However, in order to achieve a model with significant paths only, we fixed the *non-significant* paths to zero. We then tested two theoretically feasible models regarding the relationship between interest and self-efficacy. In Model 1, self-efficacy predicts interest; in Model 2, interest and self-efficacy mutually predict each other. We eliminated Model 2 which showed spurious results (the direct effects of both self-efficacy and interest on academic choice were non-significant). The resultant model is shown in Figure 2 [Fit indices: χ^2(df) = 2.495 (3); CMIN/DF = .832; RMR = .004; GFI = .999; TLI = 1.000; RMSEA = .000; ECVI = .087]. Table 4 shows the standardised path coefficients for the mediating effects of self-efficacy. For clarity, we summarise the main findings in terms of the two hypotheses:

- In partial accord with hypothesis H1, all the models variables showed statistically significant direct or indirect effects on academic choice; only interest did not.
- In partial accord with hypothesis H2, self-efficacy mediated the effects of three environmental factors on academic choice; it did not mediate parental effects.
- Contrary to hypothesis H2, interest did not mediate the effects of the environmental factors on academic choice; although correlated with self-efficacy, it predicted and mediated nothing.

Qualitative data

Qualitative data were obtained only from the students who chose to enrol in the advanced science programmes (N = 179); they were asked one open-ended question: ‘What led you to enroll? List all the reasons you can think of, both important and seemingly unimportant’. Responses showed high rates of *representativeness* (92.18% cited at least 1 reason) and *willingness to cooperate* (87.15% cited 2 or more reasons).

To categorise the data, tentative a-priori codes were prepared prior to the coding process (interest, self-efficacy, family, peers, primary school experiences and informal

Table 2. Summary data for predictor variables: programme type (regular science vs. adv. science)

Variables	Regular science M	Regular science SD	Adv. science M	Adv. science SD	Programme type F(1,599)	partial η^2
Interest[1]	2.23	0.83	2.85	0.73	74.481*	.111
Self-efficacy[1]	2.33	0.84	3.01	0.60	94.267*	.136
Primary school[1]	2.09	0.90	2.52	0.89	28.899*	.046
Parents[1]	3.58	0.85	3.89	0.41	21.685*	.035
Peers[1]	2.01	0.72	2.59	0.69	81.893*	.120
Out-of-school[2]	0.21	0.41	0.49	0.50	47.722*	.074

* p < .001; [1] Scale: 1-4; [2] Scale: no = 0, yes = 1.

Table 3. Correlations between all variables.

Variables	Enrollment[2]	Interest[1]	Self-efficacy[1]	Primary[1]	Parents[1]	Peers[1]
Individual interest[1]	.369**					
Self-efficacy[1]	.333**	.590**				
Primary school[1]	.215**	.547**	.439**			
Parents[1]	.187*	.196**	.121*	.110*		
Peers[1]	.347**	.477**	.388**	.433**	.203**	
Out-of-school[2]	.272*	.311**	.299**	.179**	.121*	.202**

* $p < 0.01$ level; ** $p < 0.001$ level; [1] scale range: 1–4; [2] no = 0; yes = 1.

STEM participation). Each of the two independent raters, experienced science educators, categorised *all* student responses; that is, both scored all 395 responses and then compared their results. Interrater reliability was 91.2% (Cohen's κ = .87). Disagreement was resolved through discussion and consensus.

Reasons cited by the students for their academic choices

Table 5 shows the reasons cited by the students for their academic choices (categories that obtained less than 4% were discarded).

Given high percentages of utility value and interest, we sought a more in-depth understanding by categorising the responses into sub-codes. For interest, we found three codes:

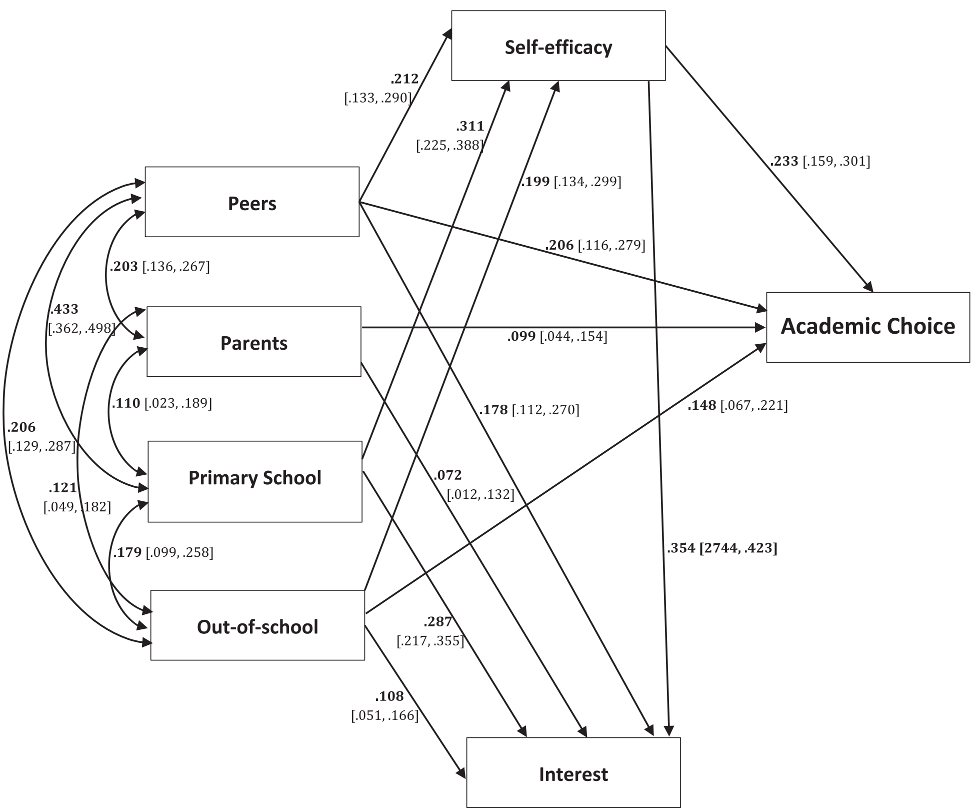

Figure 2. Standardised path coefficients (all are significant at $p < .03$) and 95% confidence intervals [brackets].

Table 4. Indirect effects on academic choice mediated by self-efficacy.

	Peers	Primary school	Out-of-school
Standardised indirect paths [95% confidence interval]	.049* [.028, .075]	.072* [.048, .103]	.046* [.028, .071]

* All coefficients are significant at $p < .02$

(1) interest/enjoyment, (2) learn science/acquire scientific skills, and (3) challenge or discovery. Interrater reliability for these 123 items was 89.3% (Cohen's $\kappa = .85$).

For utility value, we defined three sub-codes in terms of short vs. medium vs. long-term goals. Short-term goals (<3 years) were associated with benefits derived from enrolling in the advanced science programmes during middle-school, medium-term goals (3-6 years) were associated with high school plans, and long-term goals (>6 years) were associated with military service or university studies or career aspirations. Interrater reliability for these 165 items was 92.7% (Cohen's $\kappa = .89$). Sub-codes, along with examples and frequencies are shown in Table 6.

To conclude, given the very likely possibility that parents exerted pressure on their children to enrol or may have actually decided for some of them, we reviewed all 31 responses (18.79%) that indicated *parents* or *family*. We identified two sub-codes: 'parental pressure' and 'parental approval'. A third category, 'siblings' was cited only once and discarded. Interrater reliability for these 31 items was 93.6% (Cohen's $\kappa = .88$). Examples and frequencies are shown in Table 7.

Despite expectations to the contrary, based on common sense and findings from Sha et al. (2015), not a single student indicated that parents or care providers made the choice. In other words, whatever 'really' happened in the decision making process, less than 20% of the students indicated any kind of parental influence at all.

Discussion

In this section, we present the broad model of academic choice for young adolescents (≈12 year olds) that emerged from the juxtaposition of the quantitative and qualitative data, the further kinds of research needed for its validation, its implications for science education policy and practice, and its limitations. We end with a summary of conclusions.

Self-Efficacy and interest

The direct effect of self-efficacy on academic choice was significant. This finding is fully congruent with EVT and Social Cognitive Theory, and needs no further elaboration. In addition, self-efficacy predicts interest ('individual interest' as defined in our model)

Table 5. Reasons cited by the students for their academic choices.

Categories	Frequencies/respondents	Frequencies/total responses
1. Utility value	138/165 **(83.64%)**	128/395 (32.41%)
2. Interest	124/165 **(75.15%)**	178/395 (45.06%)
3. Self-efficacy	47/165 (28.49%)	47/395 (11.90%)
4. Parents	31/165 (18.79%)	31/395 (7.85%)
5. Attainment	25/165 (15.15%)	25/395 (6.33%)
6. Peers	17/165 (10.30%)	17/395 (4.30%)

Table 6. Sub-codes for interest and utility value

Interest	Examples	Frequencies/ Respondents
Learn/acquire skills	'I want to learn astronomy and the big bang'; 'I want to learn a programming language'	86/123 (69.92%)
Interest/enjoyment	'I'm really interested in science'; 'I like doing experiments'	71/123 (57.72%)
Challenge/discovery	'Science is a challenge and I like challenges'; 'I want to make a great scientific discovery'	21/123 (17.07%)
Utility value		
Short-term: middle-school	'I'm really going to learn science now the way I want and with the best teachers'	83/165 (50.30%)
Medium-term: high school	'I want to major in physics (or math or computer science) in high school'	26/165 (15.76%)
Long-term: university, career, successful life	'This is the way to learn medicine'; 'Entering the program will lead to a good job'; 'Math and science are the keys to success'	69/165 (41.82%)

and the two are highly correlated. These relationships are widely reported in the literature and deemed important (e.g. Bong et al., 2015; Caspi et al., 2019; DeWitt & Archer, 2015; Eccles et al., 2015; Lent et al., 2018; Sha et al., 2015). For example, Caspi et al. (2019) found that middle-school graduates who chose to major in high school STEM disciplines had high concurrent levels of interest and self-efficacy. For high school students, Bong et al. (2015) found that 'possessing high enough interest and strong enough confidence appears to be particularly critical in the decision to pursue mathematics and science-related college majors and careers' (p.33).

Both self-efficacy and interest were predicted by environmental factors. These findings too are fully congruent with EVT, SDT and theories of interest; they are consistent with the work of many researchers (e.g. Caspi et al., 2019; Nugent et al., 2015; Sha et al., 2015). Viewed holistically, the environmental factors that comprise the model may constitute a 'learning ecosystem' defined by Barron (2006) as 'the set of contexts found in physical or virtual spaces that provide opportunities for learning' (p. 195). Each individual context is characterised by a unique set of activities, resources, interpersonal relationships and interactions. The ecosystem metaphor has been adopted by researchers specifically in relation to STEM education; it includes family, peers, schools, and out-of-school activities and experiences (Falk et al., 2012), precisely those that comprise our model.

Although the hypothesised direct effect of interest ('*individual interest*' as operationalised in our study) on academic choice was grounded in theory, informed by prior research on *older students*, content validated and internally reliable, it did not *directly* predict enrolment for the *younger students* being investigated. At first glance, this finding apparently contradicts EVT, SDT and theories of interest. A deeper second glance, however, shows its reasonableness.

Table 7. Sub-codes for family

Sub-codes	Examples	Frequencies (%)
Parental pressure	'My parents really want me to enroll'; 'My parents promised me a smartphone if I enroll'	15/165 (9.10%)
Parental approval	'I want my parents to be proud of me'; 'It'll make my parents really happy'	15/165 (9.10%)

The direct effect of interest that predicts academic choice, widely reported throughout the literature, is clearly a function of its formal and operational definitions (see Renninger & Hidi, 2011). Although *individual* interest (Hidi & Renninger, 2006) did not significantly predict academic choice, 75% of the students who enrolled cited '*interest*' as a reason for doing so. Perhaps other formal and operational definitions of *interest* based on the young students' responses in this study (Table 6) would show a significant direct effect on academic choice. Indeed, the students' responses appear to be closely aligned with the formal EVT definition of *intrinsic value* cited above: 'the … subjective *interest* the individual has in the subject' (Eccles & Wigfield, 2002, p. 20). This definition is different from and less rigorous than Hidi and Renninger's (2006) *individual interest*. Only further research will clarify the very important implications of how interest is defined and measured.

Perceived peer interest and ability in science ('peers')

We found that *peers* directly predicted enrolment and that its effects on enrolment were mediated by self-efficacy; it also predicted interest. These findings fully corroborate those reported by Nugent et al. (2015); however, in both studies, they were limited to one aspect of peer effects only, namely the highly significant relationship between 'perceived peer interest and ability in science' and academic choice. Other kinds of peer effects such as positive social interactions also influence academic choice. For example, McInerney (2012) found that academic support among peers (e.g. discussion groups, tutoring) predicted student motivation to learn math. Kindermann (1993) found that within highly motivated peer groups students' motivation to learn increased over the school year; in peer groups with low motivation, students' motivation decreased. Such findings point to further research questions about what kinds of peer relationships among primary-school students influence their academic choice and how.

Participation in informal, out-of-school, year-long, structured, hands-on STEM programs (out-of-school)

Participation in informal, out-of-school, year-long, structured, hands-on STEM programmes directly predicted enrolment in the advanced science programmes. Its effect on academic choice was mediated by self-efficacy; it predicted interest. In other words, it is an important element in the learning ecosystems of the 12 year olds.

Forty-nine percent of the students who enrolled in the advanced science programmes participated in such informal programmes. This finding signposts an unexplored research avenue, namely, what led the 1st-6th grade primary school children to choose *specific programs* in science or computers or robotics at such an early age? Perhaps these decisions mark an even earlier initial entry into the STEM pipeline.

Perceived parental encouragement to learn STEM ('parents')

Perceived parental encouragement predicted enrolment directly; it predicted interest but not self-efficacy. The effect of *parents* on interest supports the large body of literature cited above. Given the severe twenty minute time constraint imposed on our study, we limited this construct to one item only. We emphasise that this finding does not explain the actual role of parental effects in the process of academic choice – it reveals the children's subjective perceptions of how the choice was made. It may even reflect students' denial of losing their autonomy in the decision making process.

In any case, this finding harbingers further research, grounded in the concept 'science capital' (Archer et al., 2014; DeWitt & Archer, 2017), which would inquire into the specific kinds of encouragement provided by parents and the specific effects of each. Science capital is the sum of the resources invested in a child (e.g. parental scientific knowledge and science based careers, talking with others about science, receiving encouragement to learn science, engagement with science-related media and informal science experiences). DeWitt and Archer (2015, 2017) found that the likelihood of a child maintaining STEM career aspirations over time is strongly mediated by science capital. Children whose families have higher levels are more likely than their peers with less science capital to express such aspirations.

Recollections of learning science in primary school ('primary school')

We found that the direct effect of *primary school* was non-significant; its indirect effect on enrolment, mediated by self-efficacy, was significant; it predicted interest. These findings illustrate the important relationship between school experiences and academic choice. They reinforce what we already know about the practice of science education, namely the need to trigger and sustain interest in science, to increase a sense of its relevance and utility value, and to develop self-efficacy in science learning for all students at all grade levels. For example, in the context of STEM learning, research has shown the positive effects of Inquiry-Based Science Education on student interest and achievement (Pedaste et al., 2015; Zacharia et al., 2015). These findings point to the kinds of practices that could and should be implemented in primary schools and to a research agenda for investigating their relationship with academic choice.

Qualitative data: toward a broader model of actual academic choice for ⍰12 year olds

We now discuss how the qualitative findings regarding utility value and attainment value point toward a broader model of academic choice for younger students.

Utility value

In EVT, utility value is an assessment of how well an undertaking relates to current and future goals, such as success in high school or university or career (Eccles & Wigfield, 2002). We excluded this construct from the quantitative model in light of findings reported by DeWitt et al. (2011, 2013) that showed the non-relevance of this factor for young children. However, in our case, this proved to be unjustified: utility value was extremely relevant at this early age – 84% of the young students cited their short, medium and long-term goals associated with their academic choice. In light of these findings, closed-ended utility value items should be included in future research in order to determine the magnitude of their effects on academic choice and how they interrelate with the other predictors.

Based on the previous research cited above that investigated the factors influencing academic choice among *older* students, we would hypothesise that the inclusion of quantitative measures of utility value in the model would show the following results:

- A very strong positive correlation between intrinsic value (interest/enjoyment) and utility value, both of which are subsumed under *subjective task value*, one of the two key motivators (Bong et al., 2015; Caspi et al., 2019; Eccles et al., 2015; Hulleman et al., 2010; Lent et al., 2018).
- Assuming the strong additional effects of utility value, *subjective task value* may directly predict academic choice. This would support the basic assumptions of EVT (Eccles (Parsons) et al., 1983; Eccles, 2005).

In other words, it is plausible that young adolescents are influenced by the same factors that motivate their older counterparts.

Attainment value

In our study, attainment value is associated with being accepted into the advanced science programme. Research has shown the importance of this motivational factor in the realms of academic choice and career orientation for *older* students (e.g. Archer et al., 2010; Caspi et al., 2019; Hazari et al., 2010; Lent et al., 2018). Qualitative data showed that 'pride' or 'achievement' were cited by 15% of the young respondents as reasons for enrolling in the science programmes. Since these responses may be seen as attainment value, it now appears that younger students are also influenced by this construct. Therefore, future research should define and quantify reliable closed-ended items in order to determine how much variance (vis-à-vis academic choice) may be attributed to this factor.

Gender

As expected, girls and boys enrolled equally in the advanced science programmes (DeWitt et al., 2011; DeWitt et al., 2013; OECD, 2007). This indicates that biases and negative cultural expectations from family and schools did *not* come into play as previously reported two decades ago (e.g. Andre et al., 1999; Nichols et al., 1998), at least within the specific sample population being studied. In light of gender parity within the advanced science programmes and confirmation from schools that no affirmative actions toward gender parity were undertaken in the selection process, we view these findings optimistically.

Implications for science education policy

We found that large numbers of students enter the so-called 'STEM pipeline' at the end of 6th grade. In metaphoric terms, the pipeline has lengthened dramatically. Precisely here, we ask: Is this metaphor still useful? Cannady et al. (2014) contend that it has failed on two counts and that its underlying assumptions should be questioned and possibly replaced. They wrote:

> First, it misleadingly suggests a universal and lock-step trajectory toward STEM careers that fails to describe nearly half of all who end up in STEM careers; second, it obfuscates inquiry

> into a range of factors that decades of theory and research have established as critical to understanding the long and winding path toward a career (p.445).

They suggest an alternative *pathway* metaphor which views the trajectories directed toward STEM learning and careers as *complex systems*, not as inflexible *pipelines*. Intuitively, such a flexible and inclusive metaphor seems more apt for understanding the academic choices of diverse populations over time, from youngsters to young adults. It is particularly suitable for ≈12 year olds facing a very long path toward specialised learning and careers.

Limitations

Findings from this study must be viewed within its limitations. Two are especially salient.

Generality

Findings are relevant only in the highly specific context of our sample population: ≈12 year old Israeli children from predominantly urban Jewish middle-class, middle-schools. We would expect different results for participants at different ages, SES levels and ethnic origins; that is, all these key demographic factors would significantly influence the model that emerged. To overcome this limitation, a much larger and diverse sample population is needed.

Data sources

Data in this study were based only on students' self-reports. A more inclusive study should investigate other sources as well (e.g. teachers, parents and peers).

Summary of conclusions

(1) The direct and/or indirect effects of all the model's predictors on academic choice, except *individual interest*, were significant.
(2) Environmental factors: peers, out-of-school, and parents directly predicted enrolment. Peers accounted for the most variance, followed by out-of-school and parents. Whatever 'really' happened in the decision making process, less than 20% of the students reported (via the open-ended question) any kind of parental influence at all.
(3) The significant influence of participation in informal, out-of-school, year-long, structured, hands-on STEM programmes points toward an even earlier entry for some students into the STEM pipeline.
(4) Like their older counterparts, utility value and interest were the leading reasons cited by the young students for enrolling. Attainment value was also cited as a reason for enrolling, but to a much lesser degree than utility value.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix 1. Questionnaire items

This version is for the students participating in the advanced science programmes; for non-participating students, question 2 did not appear.

1. Boy / Girl
2. *What led you to enroll in the advanced science program? List all the reasons you can think of, both important and seemingly unimportant.*
3. Interest toward STEM

- I like (or would like) to do science at home even if I don't have to (like experiments, science kits, or looking at science movies on YouTube or TV).
- After science class is over I often think about what we did or talked about.
- There are topics in science and technology that I want to know more about.
- I work by myself to solve science problems or to figure out how things work.

4. Self-efficacy in science learning and technology

- I easily understand scientific theories and laws.
- I can plan scientific experiments to test hypotheses.
- I know how to collect data in experiments.
- I like to suggest better technological solutions to all kinds of problems.

5. Recollections of learning science in school

- School science classes were very interesting.
- I liked learning science in school more than anything else.

6. Parental encouragement

- My parents encourage me to study science, technology and math.

7. Peer-group influence

- My *very best friend* likes science.
- Most of my friends aren't interested in learning science.
- Most of my friends are really good students when it comes to science.
- My best *classroom friend* is interested in science

8. Over the past 3 years, did you ever participate in any year-long, out-of-school, science, technology or math programmes? Y/N