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Exploring Features That Play a Role in Adolescents' Science Identity Development

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Abstract

Many studies done in the last three decades show that, beginning with adolescence and sometimes even earlier, many adolescents undergo a process of distancing themselves from science as they age. This longitudinal study attempts to deepen our knowledge and understanding of factors that play a role in early adolescents' science identity development. For 3 years, we followed nine early adolescents at school, at home, and at their after-school activities, interviewing them 162 times. A thematic analysis of the interviews led to the identification of 32 themes. When comparing these themes across different participants, we identified three motifs that distinguished between the participants. Our findings suggest that (A) having a clear area of interest, not necessarily in science, positively affected the participants' self-efficacy in science and self-assessment of their ability in science studies; (B) being or not being the eldest child in a family with multiple siblings played a role in the participants' identity development in relation to science; and (C) the participants who were wholly dependent on their grades as an indication of their ability in science rejected the possibility of a future in science and studied science out of compliance rather than out of any internal motive. The implications of our findings are discussed and offer insights into ways that may nurture the positive science identity development of early adolescents.

Keywords Science identity development · Adolescents · STEM

Introduction

The phenomenon of adolescents gradually losing interest in science as they grow older is a multifaceted issue observed across various countries (Archer et al., 2010; Balta et al., 2023) and being seen in both genders. Numerous studies have shown that this distancing begins and develops during adolescence (e.g., Galton, 2009; Jenkins, 2019; Osborne et al.,

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2003; Vedder-Weiss & Fortus, 2012). In some cases, the process starts with the transfer to middle school (Lee et al., 2016; María & José, 2020; Vedder-Weiss & Fortus, 2011), while in others, it starts as early as the third year of elementary school (Toma et al., 2019; Tröbst et al., 2016; Yager & Penick, 1986). Several studies have shown that a career choice in science often begins to develop at a young age (Archer et al., 2010; Barmby et al., 2008; Bonnette et al., 2019; DeWitt et al., 2013; Scholes & Stahl, 2020; Tai et al., 2006). By examining questionnaires from over 9000 students, DeWitt et al. (2013) found that by the age of 14, many students had already decided that they did not aspire to a career in science. Using a longitudinal survey of professional people involved in STEM (science, technology, engineering, and math), Tai et al. (2006) found that 28% reported that they knew they wanted to work in STEM by age 11. These findings show that many students have a sense of direction early in life (Scholes & Stahl, 2020). Few studies have adopted a longitudinal perspective when investigating this distancing of young adolescents from science (Bricker & Bell, 2014), and even less have followed their participants in school, out of school, and at home.

Theoretical Framework

To address this issue and deepen our understanding of the movement away from science during early adolescence, we used identity theory as our guiding framework. Specifically, we utilized the lens of identity development and its dimensions (Carlone & Johnson, 2007): science self-efficacy, interest, and perceptions of significant others. This approach enabled us to explain how students perceive themselves in relation to science and their engagement in science learning. We took a longitudinal perspective and over 3 years followed nine early adolescents at school, at their homes, and at their after-school activities, looking at them not just as students but as whole people with families and friends, with interests and goals that often lay outside of science. We searched for factors that may not have been traditionally associated with science identity yet played a role in guiding the development of our participants' science identity; we identified a few that have been under-reported in the science education literature. The question that directed this study was as follows: Which factors play a role in the development of early adolescents' science identity?

The Development of Science Identity

Science identity was described by Aschbacher et al., (2010, p. 566) as "the sense of who students are, what they believe they are capable of, and what they want to do and become in regard to science." Young adolescents seldom know clearly who they are. They often have nascent ideas what they would like to become and what they do not want to be, but it is rare to find a young adolescent who has a clear identity (Erikson, 1994). They have positions on many topics and in relation to many possible professions, but these positions are still far from a defining identity.

Aschbacher et al. continued: "Science identity is informed by students' lived experiences and social interactions at home, in school, and in the larger world. It is based on how students view themselves and believe others view them as they participate in scientific endeavors." Like Aschbacher and colleagues, we too tracked our participants' science-related experiences at school, at home, and at their after-school programs. Unlike them, we focused on early adolescents, aged 9–12, for whom, in line with what was stated above, the development of their science identities was likely still in its early stages, and not on high school students who were already in the science pipeline.

Science identity has been theorized as being composed of four dimensions (e.g., Carlone & Johnson, 2007; Hazari et al., 2010): (a) a perception of one's ability to complete tasks in science; (b) a belief in one's ability to understand science ideas. These two dimensions are two different aspects of self-efficacy in science, a performance-oriented aspect and a mastery-oriented aspect (Dorfman & Fortus, 2019), so we combined them in this study and called them science self-efficacy; (c) an interest in science combined with a drive to understand science; and (d) acknowledgement by others as being good at science. We felt that this fourth dimension was too limited to describe the ways in which the environment contributes to the shaping of young adolescents' science identity, so we expanded it to include not only the recognition by others, but in general the experiences of young adolescents at home, at school, with friends, and in after-school programs in relation to science (Archer et al., 2014).

Many studies have investigated one or more of these dimensions. For example, using questionnaires, Cohen et al. (2021) asked college students about their elementary school science experiences and showed that these early experiences were often formative on the students' later attitudes towards and interest in science. DeWitt and Archer (2015) did a longitudinal questionnaire-based study with elementary and secondary school children and showed that parental attitudes to science had a significant impact on the aspirations of their children in science. There have been several additional quantitative studies (e.g., Archer et al., 2010, 2015; Barmby et al., 2008; Caspi et al., 2020; DeWitt et al., 2013; Vedder-Weiss & Fortus, 2011). There have also been a few qualitative studies (e.g., Carlone et al., 2014; Zimmerman, 2012). For example, Bricker and Bell (2014) conducted a qualitative short-term study of the path of a young girl in science, showing that her interest in science was years in the making. Zimmerman (2012) conducted a qualitative longitudinal study of a single girl's out-of-school science learning, showing that even though she was engaged in science-related activities, she sought to be recognized as uninterested in science due to pressures she felt from her friends and her adolescent status.

However, we felt that a qualitative longitudinal perspective, that followed early adolescents over several years and looked at various spheres of their lives, not just at their activities in science classes or just their out-of-school activities or just at home, was missing. We assumed that there were factors that appear at first glance to be unrelated to science identity, but that under deeper scrutiny would prove to be influential. To this end, we closely followed a group of early adolescents for 3 years, in their schools, at their homes, and at their after-school programs, thus allowing for a broad, in-depth picture highlighting many of the features that contributed to these adolescents' developing science identities. Below, we expand on each of the three dimensions of science identity, as these served as the basis for the analysis of the data we collected.

Science Self-Efficacy

Science self-efficacy (SSE) is a person's "belief in their ability to succeed in science courses or activities" (Britner & Pajares, 2006, p. 486). Science self-efficacy is developed through four sources: mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states (Dorfman & Fortus, 2019). For example, past successful experiences in science, observation of others similar to oneself succeeding in science, and supportive messages from science teachers, parents, and friends can enhance one's

SSE. Self-efficacy influences the courses of action people choose and follow. If students lack the belief that they can succeed in science, it is unlikely that they will engage with science. On the other hand, students with high SSE tend to be more engaged in science class and persevere in challenging activities (Britner & Pajares, 2006).

Interest

Interest is "a content-specific motivational characteristic composed of intrinsic feeling-related and value-related valences" Schiefele (1991, p. 1). Individual interest is conceived of as a relatively enduring preference for certain topics, subject areas, or activities, whereas situational interest is an emotional state brought about by situational stimuli (Schiefele, 1991). Interest plays an important role in motivating learning and exploration. Interest ensures that people (students) will develop a broad knowledge, skills, and experience (Silvia, 2008).

Schools often have a large impact on students' interest in science as much of students' exposure to scientific knowledge occurs at schools (Barmby et al., 2008; DeWitt & Archer, 2015; Wang et al., 2020; Wood, 2019). For example, Rachmatullah and Wiebe (2023) demonstrated how engaging students with computationally intensive science increased their interest in the field of science and science careers. However, teachers may underestimate the level of interest student have in out-of-school science programs (Carol-Ann Burke, 2020). Jenkins (2019) described a connection between interest in science and a positive attitude towards science and scientists. An accessible family member that works in science or a science-related profession can inspire and encourage interest in the same field (Franse et al., 2020; Gilmartin et al., 2006).

Perceptions of Significant Others

Parents and Other Family Members

The parents' attitudes towards science and the home, in general, have the greatest influence on children's stances towards science, especially when they are pre-adolescents and in their early adolescent years. Kewalramani et al. (2020) reported that parental aspirations for their children consciously or unconsciously develop children's science aptitudes. Gilmartin et al. (2006) showed that the attitudes and values of family members significantly affect students' academic and career goals. Family members can give access to information and opportunities that may shape students' sense of possibilities in school and beyond. As children grow older, their parents' influence decreases, while the influence of the peer group increases and the science teacher increases (Vedder-Weiss & Fortus, 2013). The parents' influence increases again in situations where the children need to choose a major in high school (Aschbacher et al., 2010).

Science Teachers

Teachers are likely to significantly impact students' interest in and attitudes towards science as much of students' exposure to scientific knowledge occurs at schools (Barmby et al., 2008; DeWitt & Archer, 2015; Wang et al., 2020; Wood, 2019). Science teachers influence their students' science self-efficacy by providing formal and non-formal feedback and opportunities to succeed. They can also serve as role models (Pajares & Schunk, 2001; Schunk & Meece, 2006).

Peers

Peers can influence adolescents' engagement with science and sometimes help them maintain or strengthen positive or negative attitudes towards science (Caspi et al., 2020; Zimmerman & Bell, 2014). They can draw an adolescent's attention away from science or focus it on science. The peer groups' effects can change from year to year with the advance in the students' age and changes in their character and the composition of their peer group (Caspi et al., 2020; Vedder-Weiss & Fortus, 2013; Wood, 2019).

Methods

We observed and interviewed eleven 4th and 5th grade elementary school students at their science classes, after classes and during recesses, at their homes, and at their after-school programs. These participants were interviewed over 3 years, approximately every 6 weeks, about their lives in general, but especially about their experiences, aspirations, and thoughts regarding science. The aim was to grasp how these participants interpreted their surroundings, with a special focus on science and its impact on other facets of their lives. We chose to follow two differently aged cohorts for two main reasons: (a) Past studies have indicated that many young adolescents begin to distance themselves from science towards the end of their third or fourth year of elementary school (e.g., Vedder-Weiss & Fortus, 2011). Thus, one of our cohorts was composed of 4th graders at the start of the study. (b) The shift to junior high school (JHS) (in 7th grade in Israel) has been identified as a major as a major transitional event in students' stances towards science (e.g., Dorfman and Fortus, 2019). For administrative and financial reasons, it was clear at the start of the study that data could not be collected for more than 3 years. So, to be sensitive to the role the transition to JHS may play in our participants' stances towards science, we included a second cohort that was composed of 5th graders at the start of the study. The members of this second cohort moved to JHS in the third year of this study. Thus, the interviews were the main instrument used. Two participants requested to leave the study in its second year. The interviews continued with the participants who transferred to junior high school in the last year of the study. All the names appearing in the article have been anonymized.

Participants

Schools

The study was conducted in two Israeli schools, an elementary school (ES, grades 1–6) and a junior high school (JHS, grades 7–9) which is adjacent to the ES. The selection of these schools was based on the willingness of their principal and staff to participate in the study consistently over the course of 3 years. Both schools were located in the center of Israel and provided services to children from their nearby communities. The socio-economic status of these communities was medium–high (The Israeli Central Bureau of Statistics, 2019). Almost all the students in the ES continued their studies at the JHS. The average number of students per class was 32 in both the ES and the JHS. In the 2016–2018 school years, only students at the ES participated; in the 2018–2019 school year, students from both schools participated (some of the ES students had graduated and transitioned to the JHS).

The science curriculum of both the elementary school (ES) and the junior high school (JHS) encompassed 4 h of science instruction per week. At the ES, the 4th graders focused on states of matter and geology, while the 5th graders delved into astronomy and general problem-based learning. The 6th grade curriculum covered states of matter, photosynthesis, energy, and human body systems. In the JHS, the 7th graders studied cell structure, energy, photosynthesis, mass, and volume.

Students

1. After obtaining parental approval in the 2016–2017 school year, 4th and 5th grade students ($n = 91$) from the ES completed an affective mapping survey that was adapted from one previously used and validated by Vedder-Weiss and Fortus (2011) (see the Appendix). The main objective of this survey was to obtain a broad picture of the participants' perspectives on science, both within and outside of the school context. The dimensions of the survey were self-efficacy in science, continuing motivation, interest in science, mastery and performance orientation, and attitudes towards science and scientists. The reliabilities of the various dimensions, as measured by Cronbach's alpha, were from 0.73 to 0.91.
2. Within the constraints of the academic year's end, we conducted interviews with as many students as possible ($n = 62$), striving for diverse student representation, as illustrated by the affective mapping survey. This approach aimed to encompass a broad spectrum of affective characteristics. The interviews primarily explored students' interest or disinterest in science learning, willingness to participate in the study, and openness to sharing their experiences.
3. The first author observed the science classes at the start of the study for three to 4 months, from the middle to the end of the school year. The primary goal of these observations was to gain a deeper understanding of the students' experiences in these classes, grasp the classroom atmosphere, and observe teaching methods. This in-depth observation provided a broader foundation for meaningful conversations with the students, particularly focusing on the 62 students who were interviewed, ensuring a more informed and familiar context for these discussions. She documented observations in a notebook while positioning herself discreetly in a corner of the room to minimize disruptions and maintain the classroom's natural flow. These notes encompassed a range of occurrences within the classroom, detailing scientific, social, and academic interactions.
4. We invited fifteen 4th grade and fifteen 5th grade students to participate in the longitudinal part of the study. This "trimming" from 62 to 30 students was done because of limited resources we had available to gather all the necessary data for the study. These 30 students were chosen based on their willingness to actively engage in a long-term research project and based on our observations and initial interviews with them as representing a range of affective characteristics. The longitudinal study involved having us continue interviewing them at school and visiting them at their homes and at their after-school activities. We obtained written consent from seven 4th grade and four 5th grade students and their parents.
5. In 2017–2018, two students from the 5th grade cohort, who had been part of the study since its first year, asked to stop being part of the longitudinal study. This left us with seven students who were in 4th grade at the start of the study and two students who

were in 5th grade, all of whom remained until the study's conclusion. We were left with only two 6th grade participants, limiting the variety of participants in this age group. In Ofek-Geva and Fortus (2024), the same group of students is described in an article that portrays each individual participant's personal story regarding their self-positioning in relation to science and science learning.

Family

Nine families were actively involved in the study throughout, and Table 1 presents their profiles, focusing on their STEM characteristics and overall socio-economic status.

Teachers

At the start of the study, the elementary school (ES) had three science teachers: Sharon, with 5 years of experience and a background in elementary education and science, was also the "Green Committee" head; Natalie, with 17 years of experience in teaching, initially focused on literature before shifting to science due to a lack of elementary science teachers. After undergoing the necessary training, she became a science teacher and later the science coordinator at the ES. Natalie taught all the students in the study's third year. Rosa was a substitute teacher working towards a science teaching certificate.

The junior high school (JHS) had two science teachers whose students participated in the study: Charlotte, holding a MSc in science and 15 years of teaching experience, and Megan, a new teacher with a marine science degree, concurrently completing her teaching certification.

Table 1 Participant demographics and family background table

Student name	Educational backgrounds of parents		Stem professionals		Number of siblings	SES
	Parent 1	Parent 2	Parent 1	Parent 2		
Iris	High school	High school	N	N	2	Low
Sarah	College	College	N	Y	2	Average
Nathan	College	High school	N	N	3	Average
Anna	College	College	N	Y	4	Average
Dan	College	College	N	N	4	High
Carrie	College	College	Y	Y	3	High
Ruth	College	High school	N	N	2	Average
Jacob	College	College	Y	Y	2	Average
Ave	High school	High school	N	N	3	Low

Legend. Educational backgrounds of the parents: This column indicates the highest level of education attained by the parents of the participant, categorized as "High school" or "College."

Professions in STEM: the presence (Y) or absence (N) of a career within STEM fields for each parent. Number of siblings: the total count of siblings each family. SES: the assessed socio-economic status of the participant's family, rated as "Low," "Average," or "High."

Instrument—Interviews

The first author held semi-structured interviews (Cros et al., 1986; Hokayem & Gotwals, 2016) with each participant approximately every 6 weeks in the school yard. Additional interviews were held after classroom events that were deemed to be possibly significant to the development of the participant's science identity and after each of our visits to an after-school program, with the goal of understanding what happened during class or during the after-school program from the student's perspective. Each interviews lasted approximately 20 min. Each participant was interviewed at least six times each year. Our opening questions were mostly open-ended, for example, "What happened today?" "What did you think of the events?" "How did it make you feel?" "What did you learn in science class last week?" "What do you think of how you learned science in school? Or at your after-school program?" "How would you like to learn science in school?".

Based upon their responses, the first author guided the discussions to address general issues in the early interviews, such as parents and homes (e.g., "Is your family involved in your science studies? Do you do anything with your family regarding science?"), thoughts about science studies at school (e.g., "What do you remember from science studies two years ago? Six months ago? One month ago?"), thoughts about science (e.g., "What do you think of scientists? Do you think that you would like to engage in science in the future?"), and general interests (e.g., "What do you like to do in your free time?").

The follow-up interviews conducted throughout the rest of the research aimed to delve into their personal experiences with science studies and explore their specific areas of interest in greater detail. By using a similar set of questions, which closely resembled those asked earlier, the researchers aimed to assess any potential changes in the students' responses over time. This iterative approach allowed for the identification of shifts in their perspectives and provided valuable insights into the underlying reasons for such changes.

From the participants' responses, we identified possible reasons for the interactions they had with science and science learning that guided our subsequent conversations (Glaser & Strauss, 2017). All the interviews were audio-recorded, with the participants being asked for their consent each time an interview was held. The authors then listened to every interview several times and transcribed them. In addition, informal discussions were held with the participants during school recesses. All the relevant information, including important utterances, was organized in sections dedicated to each participant in a digital research journal (Polkinghorne, 1995).

Reflexivity

Both researchers had predominantly positive experiences with science during their early years of study. However, like anyone else, they can recall certain incidents where they encountered less favorable attitudes towards science and science-related studies from their environment. Despite these instances, both researchers maintained their desire and passion for engaging in scientific pursuits. Drawing from their personal experiences and a comprehensive understanding of the intricacies involved, they recognized the significance of highlighting the complexity inherent in the development of scientific identity.

Analyses

The analyses were conducted in three steps. First, the interviews were thematically analyzed. Second, we divided the participants into two groups multiple times, each time using a different binary feature that differentiated between the participants to place them in two groups. Finally, we searched among the themes that were identified in the first step for ways in which these themes may have been represented differently by the members of the two groups. When we identified a difference (a motif), we identified statements made the participants that represented the motif.

Thematic Analysis

The thematic analysis consisted of five steps: (a) familiarizing ourselves with the data, (b) generating initial codes, (c) searching for themes, (d) reviewing potential themes, and (e) defining and naming the themes (Braun & Clarke, 2019). We initially used an inductive approach to code the data, with the codes closely matching the content of the data, leading in our data set to codes such as school, teacher, parents, peers, and fields of interest. Our initial approach was intentionally focused on extracting themes directly from the data provided by the students, without seeking pre-existing concepts from documented studies. Our aim was to prioritize the voices of the students and provide them with a platform to express their perspectives. Only after thoroughly considering their viewpoints did we turn to the previously reported themes to further enrich our analysis.

We then continued to code the data with a deductive approach (Braun & Clarke, 2019), bringing codes derived from the dimensions of science identity: SSE, areas of interest, and views of significant others—teachers, parents, friends, etc. We then searched for themes that united several codes as organizing concepts (Braun & Clarke, 2019). Some of these themes were reflected in many interviews and some only in a few. The authors continuously reviewed the potential themes, rejecting some and keeping others and finally deciding on names for the themes. Using the ATLAS.ti 9 software, we used the themes to code the full transcripts. The same utterances could code, and sometimes were coded, with more than one theme. When an utterance appeared relevant to a theme, the utterance was also coded with the time at which the statement was made, allowing us to map the changes to the themes that occurred over the years of the study as "Year 1/2/3 of the study," for each participant individually and for all of the participants together. For example, "What would you say your brother is good at?" "Computers, math, science, all those things that I'm not so good at" [Sarah]. This utterance was coded as "Siblings," "Self-Concept," and "Year 2 of the study."

Dividing into Groups and Identifying Motifs

With the intention of trying to shed light on different motifs that may have played a role in shaping the students' science identity, we prepared a list of binary features that potentially distinguished between the science identity development of the nine participants (see 1–6 below). These features were drawn from the three dimensions of science identity (SSE, interest, interactions with different environments) and with the longitudinal nature of the study. Based on these binary features, each participant was placed into one of two groups. Examples of these features are as follows:

1. Whether or not the participant had a field of interest (not necessarily science) that was a major and significant part of their life, talking about it and engaging with it for at least a year and a half during the study
2. Whether or not a participant was the eldest child in their family (all had siblings)
3. Whether or not a participant mentioned in the first interviews that they thought of science as something they might be interested working in
4. Whether or not a participant underwent a significant change in their relation to science learning during the study. For example, a student who initially disliked science, but with time began talking about science as a possible profession
5. Whether or not one or both of the participant's parents had any kind of post-secondary education in science
6. Whether or not a participant took part in an after-school science or mathematics program

After we divided the participants into two groups for each feature, we examined the number of references made by the members of each group to each theme. When there were at least ten references to a theme by each group and more than one participant in each group had made these references, we returned to the actual utterances made by the members of these groups and tried to find if there was a recurring motif for all the utterances made by the members of a group in relation to this theme. When a motif was found within one of the groups, we interpreted the meaning of the motifs in the context of the feature that distinguished between the groups.

Trustworthiness

The first author became familiar with a participant by reading their transcript and then coded all of the interviews from each student separately. First and second authors discussed the themes that arose until complete agreement for each student was reached and changes were made according to those decisions. To verify the validity and reliability of the coding, two science education researchers coded independently 15% of the data. Two rounds of comparing and discussing the coding were held to reach joint agreement. At the end of the process, a 90% agreement of the coding was reached.

The two researchers then worked together to find features that could distinguish between the participants and were potentially related to the participants developing science identity, for example: which teacher taught the students, whether the participant had a parent with post-secondary education in science, or whether there was any change in their interests or in their relations to science during the study. Each of these features were discussed in light of the findings.

Ethics

This study received IRB approval from the authors' institute and from the Ministry of Education. Consent forms were obtained from the parents at the beginning of the study and a waiver for each of the following years. The students were asked before each conversation whether they were interested in talking and then whether they were willing for the conversation to be recorded.

Results

We identified altogether 32 themes, which are presented in Table 2.

All of these themes have been already mentioned or studied in the research literature and do not merit, in our view, further elaboration here. Interestingly, themes such as gender and the influence of science teachers, which have been extensively studied, were not identified by us a being significant themes. However, after dividing the participants into two groups, there were three themes that led to significant motifs that differed for the two groups. These themes were SSE, siblings, and attitudes to science. Each quote is presented in relation to the time of the conversation. To adhere to the journal's word limit, only one quote from each participant is displayed. However, to showcase the changes or lack thereof in each distinguishing feature, two quotes from the same participant are included, providing evidence of the observed shifts or consistency throughout the course of the study. The motifs that were identified were as follows:

The first theme—SSE. Distinguishing feature—whether or not the participant had a well-developed field of interest and whether it was in science or not. Motif—the three participants *with a well-developed interest* had higher SSE, even when their field of interest was not related to science. They seemed to have a more balanced approach to school (Fig. 1A). The six participants without a well-developed interest tended to be preoccupied with the grades they received in science and had lower SSE (Fig. 1B)

The second theme—siblings. Distinguishing feature—whether or not the participant was the *eldest child in the family*. Motif—the four participants who were *not the eldest child in their family* were occupied with comparing themselves to their older siblings with respect to science, both positively and negatively (Fig. 2). On the other hand, the five participants who were the *eldest child in their family* did not refer at all to their siblings regarding their science studies.

The third theme—attitudes towards science. Distinguishing feature—whether or not the participant *thought of their science studies mainly with reference to their grades*. Motif—the four participants who *thought of their science studies mainly terms of their grades*, rejected science as something they might be interested working in the future. They struggled to describe what they were learning, what was happening in class, and what was the subject of study (Fig. 3A). Questions posed to these participants about their classroom science studies were answered with references to their grades, even when they were not asked about their grades. However, the five participants who answered similar questions by describing *what was being taught in the classroom* and by referring to the study material thought of science as something they might be interested in working in the future (Fig. 3B). In addition, they mentioned that talking with people about science topics made it possible for them to know whether or not they understood the material, not only their grades. Their grades were not their main reason for studying science.

Discussion

This longitudinal study followed a group of early adolescents for 3 years and, from interviews conducted throughout the study, generated three motifs that were connected to the participants' developing science identity. These three motifs have not received

Table 2 List of the 32 themes and the number of citations for each one, with one example quote for each theme

Theme	Quote
Fields of interest	*What's fun in soccer?* "I'm very competitive, I love to win, I just love it. Because I'm good at it. It's fun to know you're good at something. And it's fun to be a part of a team."
Connection to science studies	Does it interest you? "Yes! Science, yes, but I'm not going to buy books for it because my dream is to be a scientist, not a doctor or a confectioner, something like that, because a scientist is to peacefully research."
Pedagogy	"I like working in the workbook, Natalie gives a lot of work in the workbook with lots of questions."
Parental influence	When we leave for a second all our nonsense and quarrels, we can really talk and share, we think similarly and we are interested in the same things. I also want to do a degree in philosophy, it's very interesting
Parents' reflections	Even though she gets 98 in math, she is not happy. It's true I ask her where the other two points are, but it's a joke
Reference to grades	*What pleased you the most in your report card?* "The truth is, I did get a good grade in science."
Internal motive	I don't like math and science classes and do not understand why they I have to learn them. I'm never going to be a scientist, so it does not matter
Desires from science learning	*Next year there, you can be in the science excellence classes. Would you like to go?* "No, it's boring."
Future aspirations	"My goal in life is to be an actress; I'm not ashamed and can explain myself in front of an audience …"
Self-concept	'With time, I realized that there are things I just connect to less, it's my nature." *So science is not one of them?* "No." *So to what do you connect?* "Math."
Peer group	How are you preparing for the transition to middle school? "I'm stressed out, cause to get to know new friends, I'm so short. What will they think of me? I see huge kids walking around and looking. But I have my existing friends and they'll help me."
Comparing teachers	Because I was terribly bored, I thought all science was like that, but when Rosa came, I realized it could be different. *Did it change you that Rosa came to teach science?* "Yes, very." *Because it's Rosa or how she teaches?* "It's the way she conveyed the subject and the activities."
After-school program 1	*Do you think what you learned at the program helps you?* "At school? No."
What is left?	*Are there things you remember doing in the program?* "Yeah, I remember we made the electric chair." *Do you remember the final project?* "Yes."
Teacher attitude	Science last year… it was really bad. I was really upset, there was no respect for me. It was terrible. I just said to myself, she does not give me respect I will not give her respect. I will not study science
Thoughts about a future in science	*Would you choose to study science in high school? In high school, you can decide.* "It seems to me … it seems to me I will."
Parental involvement	*How did you choose to go to the program?* "I did not choose, my mother talked to my friend's mother. And my friend's mother said that my friend is going to the program acceptance test, then my mom told me I should go too, so I went. I tried. I passed the test and decided I wanted to go."

Table 2 (continued)

Theme	Quote
Siblings	*Are there things you would not like to do like them?* “I think the Science-School.”
Maturity	*How did you suddenly know that?* “I do not know, suddenly I began to understand topics that interest me more about the real world.”
Role model	*Where did you hear about marine biologists? About this profession?* “First thing I really like is the sea, I like to look and explore the sea. Then I heard that there is such a thing as a marine biologist who studies animals.” *From whom did you hear about this?* “Megan [the science teacher] is a marine biology, she did her degree in marine biology. But I think the part of being an actual marine biologist is more serious.”
Thoughts about science and scientists	*What do you think about science and scientists?* “I don’t know, I really like science. I don’t know if it is the thing I’ll work in the future, but I think it’s really interesting.”
Fantasies about life	I want to move to Mars. We need to build a high ceiling there and put flower pots there so we will have oxygen and everything we need
Vision of science studies in school	I was glad we were going to learn about astronomy. I expected it to be like this: that we could raise theories, maybe there are humans living on Mars? And check the climate that exists on Earth and on Mars and on which planets humans can live
Science excellence classes	*How did you feel about being accepted?* “Great.” *Are you happy?* “Yeah, those are things I like.”
Continuing motivation	“I like answering questions. Most of the time I don’t succeed at all, but I keep trying.”
After-school program 2	*What else was good this year?* “The fact that I was not supposed to be in the program, at first I was not supposed to be and then I was sent to the program anyway.”
Image of science teacher	If you will ask her a question, a good question, she will be happy, and she’ll happily answer the question. You can see she understands what she’s talking about. There are teachers that you can see that they don’t like what they do
Self-efficacy	*What happens in science classes?* “I like to answer questions. Most of the time I don’t succeed, but I keep trying.”
After-school program 3	*You’re going to the program in mathematics. Did you want to go?* “The truth I really wanted it, because I really like math.”
Media	*Do you watch things on TV related to science?* “Sometimes when I’m bored.”
Responsibility	*What classes do you like this year?* “English, more fun for me, and at the petting farm I’m now in charge of a hydroponic system.”
Jealousy	“I have too many jealousies. I so jealous. You’ll succeed now in sports and I will envy you so much. I hate, hate it when they beat me.”
Desire to please	*Is it important for you to please your parents?* “Yes very much. If I get a bad grade on something, then I have to study like mad without being told, in order to please them.”

The reference to “After-school program 1–3” pertains to scientific activities in which the students engaged during the afternoon. For comprehensive information about these programs, please refer to Ofek-Geva & Fortus (2024)

A

Example quotes from participants *without a well-developed interest*:

Dan consistently connects his attitudes toward and understanding of science directly with the grades he receives in school

How do you know you're good at something without getting grades?

"If I succeed in it."

How do you know that?

"If you try something new and you succeed in it and slowly you get better and get a higher grade, then you know." (Dan, 6^{th} grade)

Near the beginning of the year, Carrie studies for the test, that's the reason she studies.

Why do you study?

"It's very important. I have a notebook and a book. When there is a test, I have to study for it. That's what I think the test is about." (Carrie, the second conversation in the 5^{th} grade)

As the following quote shows, as the year proceeds, tests are perceived not just as tests, but as high stakes requirements.

What do you think about the sixth grade?

"I'm afraid of sixth grade".

Why?

"Because they told me that sixth grade is my entrance card for JHS, so it scares me, what if I won't succeed and that"...

Why don't you succeed?

"I don't know".

Do you think you won't succeed?

"I hope I will succeed" (Carrie, the last conversation in the 5^{th} grade)

Sarah attributes her knowledge to her success in giving correct answers

"I don't know..."

Can you tell me why you think that?

"Yes, I know, many times in assignments or something in our textbook they ask things I do not know how to answer so I say I do not know and that is really true." (Sarah, 5^{th} grade)

B

Example quotes from participants *with a well-developed interest*:

A pending failure in a test doesn't deter Avi – he loves biology.

"Later in the day, there is a biology test, and I think I will fail."

Why do you say that? What are the topics for the test?

"The characteristics of living creatures."

So which subject do you prefer in science?

"No, I didn't say I do not like it, I love biology. I'm just less good at it." (Avi, early 7^{th} grade)

In fact, as the year progresses, he prefers to be challenged.

Is this year challenging? Is it hard or easy?

"At the beginning of the year, they started with the easy subjects, then moved on to the difficult subjects."

So, is it easy or hard?

"It starts easy and then... and now we've gone through about half a year..."

And so, it's gotten more difficult?

"Yes."

How do you feel about that? Would you prefer it to be less difficult?

"I'm looking forward to it. I like challenges." (Avi, late 7^{th} grade)

Anna does not see her lack of success/love for science as being dependent on her grade or her success in class assignments

"Over time, I realized that there are things I just don't connect to as much, that come less naturally to me."

So, science is not one of them?

No. What is? Math, also English, even though I'm less good at them than in science." (Anna, 6^{th} grade)

Nathan is able to evaluate his science knowledge independently.

Is there a way to know that you understand science other than through grades?

"Maybe if we get into some kind of science talk when I go to my grandmother's. Dad's sister is a science teacher, and we talk sometimes." (Nathan, 6^{th} grade)

Fig. 1 Citations for SSE

full attention in the science education literature. These motifs indicate that there are factors that may play an important role in young adolescents' developing science identity, even though they may initially seem unrelated to science.

Example quotes from participants who were not the eldest child in their families:

In 5th grade, Sarah feels that the science spot in her family is taken by her elder brother.

What about science? Do you think they [your parents] want you to learn science?
"They want my brother more to study science."
Why do you say that?
"It's understandable, I understand that too." (Sarah, 5th grade)

However, as she matures, rather than stepping away from potential competitions with her brother, she sees as a challenge she needs to meet, she needs to show that she can do anything he can do.

"Ahhh, my brother influences everything in my life."
About that too?
"Maybe."
Why do you say that?
"Ahhh, yes, you're right. Like an effect, but good."
Good?
"Yes, because mom keeps saying how smart a student he is, and he knew all the names... I don't even remember... oh, he knew all the names of all the countries, had his own atlas and learned it all by heart. All the countries and all the names and how are all their flags. And he knows what the country is. And how he used to put together puzzles in kindergarten with more than 100 pieces, and the kindergarten teacher said to my mother, you should bring the puzzles he puts together to kindergarten because all the puzzles he puts together are at a higher level than the rest of the kindergarten. So, she always brought games at a higher level for my brother to kindergarten."
And how does that affect you?
"I said to myself, if he can, so can I."
Yes?
"Yes. So, what if he's my older brother, and what if he's a boy. Both because he's a boy and because he's my older brother, that means I can be exactly as he is." (Sarah, 6th grade)

Carrie looks up to her brother who is majoring in science in a special school that emphasizes science. He convinces her that having friends is a s important if not more important than studying.

"He [my brother] thinks it's too much work, that it's my time to meet friends. Sometimes I do not feel like it, so I work instead. And he's like, 'No one will care. I don't know if you want to be a doctor, but no one will look at your grades from 5th grade and say getting a 100 in math is good.'"
Do you think about what your brother told you?
"I think he's right. On the one hand, not everything always matters. It's just a test in the 5th grade but the test will enter my mind..." (Carrie, 5th grade)

In 6th grade, Carrie undergoes a noticeable shift; it appears that the message communicated to her by her brother has been internalized, influencing her aspirations and desires.

Are there things you wouldn't want to do like as your siblings?
"I think I wouldn't want to go to a science school like my brother; I'm not sure I want to do that. On the one hand, I really like science, but on the other hand, it's moving away from all my friends and starting from scratch. After the four transitions we've endured in the last five years, I think I've built relationships and I don't want to destroy them again." (Carrie, 6th grade)

Jacob explains the impact of his brother's experiences on his attitude towards the sciences. He expresses attentiveness to the events that have unfolded and a desire to chart a different path for himself.

What do you think is most important for your mother for you to study at school?
"Ahhh, it seems to me that she mostly wants me... she just wants me to succeed..."
In which subjects?
"I don't think she has a specific subject in mind. She just wants me to work in something that will help me in the future. She keeps telling us to take easy subjects so that we will get bonuses. She tells this to my brother, and I just listen. She keeps saying that my brother almost failed in.... in my year" (Jacob 7th grade)

Iris describes how her brother shared and included her in his spontaneous scientific research and thus she was exposed to a telescope

How did you know that?
"My brother."
What does he have to do with it?
"We used to have a big, big telescope and every time he would show me the different weird stars, so that's how I got to know it." (Iris, 5th grade)

Fig. 2 Citations for siblings

Well-Developed Interests

We found that participants who had a well-developed area of interest with which they regularly engaged, though not necessarily in science, had a higher SSE than their peers who did not have a field of personal interest, and this SSE was not grade-driven. They learned science, not because they necessarily found it interesting (some did, but not all), but because they realized it could lead to valued outcomes (see Fig. 1A).

In contrast, we found that participants without a clear area of interest were less able to assess their knowledge of science without the teacher's grades, as they evaluated their success and their ability in science directly from these grades (see Fig. 1B). They had chosen to engage in science classes not voluntarily, but in compliance with the rules of the school. They tended to have lower SSE. They did not perceive their actions

A

Example quotes from participants who thought of their science studies mainly with reference to their grades:

Anna doesn't seem to know what is being learned, only which grades she and others get.

What did you learn in science class?
"I got a 77 on the test."
But what did you learn?
"The science teacher passed the material on to everyone in a very, very good way. I think almost everyone got over 70, which is relatively good." (Anna, 5th grade)

A year later, she still thinks about school as a series of tests, rather than a series of topics.

What is studied in science now at school?
"We are studying for the test that is coming soon." (Anna, 6th grade)

Similarly, to previous instances, Dan continues to associate success in the sciences solely with the grades he receives.

Do you feel you understand the material in science?
"Well, if I got 66, I guess so…"
Well done, and did you study a lot at home before this test?
"No."
So, Rosa's method works?
"[Nods]"
How do you know you're successful?
"If you try something and you improve your grade, then you know." (Dan, 6th grade)

Carrie, once again, defines her success in terms of grades, even though she believes that even if her grades are good, there is still room for improvement.

How is science class?
"Now that I found my book, it's much better. The book has most of the material, and in the test, I didn't get a very high score."
What do you mean?
"91." (Carrie, early 5th grade conversation)

Carrie thinks about learning in terms of grades rather than in terms of what she learned. This remained unchanged throughout 5th grade.

How do you sum up the 5th grade?
"I think it was nice, I made a lot of progress in language, I'm not good at this subject at all. In my first language test this year, I got a bad grade, 59. I read a whole series during the year, and in the second test I got a 75, which is progress in my opinion. Then there was another test, and I got an 81. I think, wow, my language teacher is really helping me, and I also have private lessons and I think it gave me the push I needed." (Carrie, the last conversation in the 5th grade)

B

Example quotes from participants who thought about what was being taught in the classroom:

Despite Nathan's lack of interest in science studies, he displays the ability to accurately describe the activities taking place in his science class.

What do you study in science?
"Science... ahhh now we're learning... I think it's called astronomy, about stars and solar systems." (Nathan, 5th grade)

Despite Ruth's absence from the class, she demonstrates a clear understanding of the general topic being studied in the class.

What are you studying in science these days?
"Studying in science… I think we are learning now about the human body; I thinks we are learning about the lungs and all that. I have not been in school for many days, so I don't know what the subject is at this moment." (Ruth 5th grade)

Sara describes her approach to studies and tests, highlighting that they do not incentivize her.

Are grades important to you?
"Let's start with the fact that I don't study for the exams. Ask me why."
Why?
"Because you don't need to study for a test, I always study. In fact, I always study even outside of school, and when there's a test, it shouldn't be an excuse to study more. I always study, and when there's a test, I don't study more than usual." (Sarah, 5th grade)

Avi demonstrates a strong grasp of the content covered in science studies and can identify new ideas he was previously familiar with.

What subject are you currently studying in science?
"Now… we're done with mass and volume."
Have you learned anything new?
"No… no… ahhhh, a little, but not much." (Avi, 7th grade)

Fig. 3 Citations for attitudes towards science

as resulting from personal desires, but rather from need to achieve a decent grade or to avoid an unpleasantness. Helping young adolescents identify personally meaningful and important goals can help them progress towards a more self-determined and personally meaningful motivation (Gillison et al., 2009). Kang et al. (2019) described how the self-perception of girls in middle school is positively related to their identification with STEM-related careers. We need to help students learn how to evaluate themselves in ways that are not dependent only on their grades (Lawrenz et al., 2001; Nasab, 2015). For example, Lawrenz et al., (2001) described the value of using alternative assessments, as these may be enjoyable and more meaningful than traditional assessments (i.e., tests and quizzes) for many students.

Siblings

We found that having older siblings played a role in influencing the science identity of the participants. The relationship with the elder sibling played a role in shaping the younger sibling's desires and ambitions towards science (see Fig. 2). The effect of these relationships was felt throughout our acquaintance with the participants. We should recognize that culture influences the roles and importance of sibling relations; our finding reflects the culture in which the data was collected. Our finding contrasts a study by Alexander et al. (2012) that found no effect of birth order on attitudes towards science. In this study, though not by design, all the participants were either the eldest or the youngest child in their families. When examining the differences between these two groups, we saw that the participants who were the youngest siblings tended to compare themselves to their older siblings in relation to their science studies, both positively and negatively. As previously reported (Jenkins & Dunn, 2009; Whiteman et al., 2007), we found that younger siblings sometimes saw the elder sibling as a role model and sometimes as a reason for avoiding science. This relationship helped shape their science identity over time. On the other hand, the firstborns did not refer to their younger siblings at all when discussing their interest in science.

Our findings show that the younger siblings, during primary school and JHS, observed and studied their older siblings' relationships with their parents and reached conclusions regarding the best way for them to act to achieve their own goals. During adolescence, there is often friction with the parents and hence conflicts between the parents and the eldest child from which the younger siblings may learn (Jenkins & Dunn, 2009). Whiteman et al. (2007) presented three fundamental relationships between siblings: role model, difference, and ignoring. They showed that the existence of siblings in a family contributes to the cognitive, emotional, and social development of all siblings in the family. The nature of the relationship between the siblings has consequences on each other's desire to be similar or different from one another and therefore affects their scientific identity (Brody, 2004; Whiteman et al., 2007). For example, the science "spot" in a family may already be held by the elder sibling and may push a younger sibling away from science as they strive to define who they are and distinguish themselves from their elder sibling, carving a new "spot" for themselves in the family. On the other hand, they may be pressured by their parents to be more like their elder sibling. Sometimes there are direct inputs from the elder sibling pushing a younger sibling towards science, such as when they encourage the younger sibling to follow up with something in science, or away from science, such as when they may belittle the younger sibling's struggles to understand something in science. Cian et al. (2022) emphasized the importance of families' ability to foster students' affinity with STEM. Some participants resisted these external pressures, and some internalized them. On the other hand, the elder siblings seemed unaware of their younger siblings in shaping their own science identity.

Attitudes to Science

Similar to the findings presented by Scholes and Stahl (2020), we were able, already in the fourth grade, to distinguish between participants who were contemplating science as a possible profession as an adult and those who were not. This contrasts a previous study by Barmby et al. (2008) that indicated that thoughts of a future career in science start in middle school.

Another motif that emerged was that the participants who aware of and connected to the science ideas being learned in class were interested in discussing their thoughts about science outside of science class and were playing with the idea of a future occupation in science (see Fig. 3B). They wanted to share and discuss their experience of discovery and interest in science with their friends and parents and with other significant adults. We were not aware of any pressure or expectation from the environment to hold conversations in which the participants shared their ideas about science. These findings align with Dou et al. (2019), who found that talking with friends and family about science is a predictor of college career intentions in science. One of the ways in which science identity develops is through social interactions (Aschbacher et al., 2010). These conversations helped shape and promote their science identity. Encouraging such conversations can contribute a lot to students; conversations can be initiated about topics of study or about science-related events that are taking place, thus helping students who initiate conversations and those who do not, to refine their science identity.

Contrary to this, we found that the participants who related to science class only through the grades they received and not through to any learning experience were not contemplating a future in science (see Fig. 3A). They felt that their knowledge was defined and dictated by the grades they received from their teachers on exams and in school report cards. Grades play an important role in learners' self-assessment (Hashemifardnia et al., 2019; Pulfrey et al., 2011). However, since grades define the relationships of many young adolescents to science, it is important to decide when and how to give grades. Classroom discussions on topics being learned and alternative assessments, like encouraging conversations, can help students develop additional perspectives on science learning and their abilities at learning science.

Conclusion

In this longitudinal study, we identified some motifs that may influence the development of young adolescents' science identity. One of these motifs—order of birth in a family—is fixed. While we cannot change the order in which someone was born within their family, we can help them find and engage in a field or activity that interests them, whether it be in science or not. We can create learning environments that build off existing student interests, aim to ignite new interests, and then maintain and amplify them and impact their science identity. Instruction can emphasize the connections between what students are learning and day-to-day issues, thus increasing the chances that may be able to imagine themselves someday doing something that is related to science. We can be more thoughtful how we give grades and how often we give grades, being aware that they can have a large emotional impact on young adolescents and their science identity. Our findings reveal that while some important ways of nurturing adolescents' scienced identity lie in science instruction, others lie in other areas of their lives that may seem at first unconnected to science. Hopefully one day, we will be able to create learning environments that will support all young adolescents in developing positive science identities, viewing themselves as interested and capable individuals in relation to science.

Limitations

The students who took part in the study, as well as the schools involved, are not representative of the general population. Thus, the findings do not fully encompass the experiences of all students within this same age group. We acknowledge the inherent complexities and multidimensional nature of identity development, encompassing various aspects of life, familial influences, and community dynamics. Due to the expansive scope of these factors, it is acknowledged that not all relevant elements could be comprehensively located or collected for this study. Consequently, while this research makes a significant contribution to the understanding of scientific identity development, it recognizes that there may be additional factors not included or explored in this study. This limitation underlines the need for further research to more fully elucidate the intricate web of influences on identity development.

Appendix

The affective mapping survey

Name

Last name

Gender

Class

Please rate your answer between 1 and 5, where 1 is very true for me, and 5 is not at all true for me.

The questions:

1. If I come across a TV program dealing with science, nature, animals, or environmental issues, I immediately change the channel.
2. I know what I'm going to do in life.
3. To learn science, you have to be smart.
4. I sometimes think about the importance of science.
5. I like to learn new things.
6. I understand everything taught in science class.
7. Getting a good grade in science is more important to me than in other subjects.
8. Science studies do not interest me.
9. It is important for me to understand everything taught in science.
10. Anyone can be a scientist.
11. I intend to study science in high school.
12. I am interested in science.
13. My work will deal with a field related to science.
14. I think I will get a good grade in science.
15. I like to excel more than my classmates in science tests.

16. If I receive a WhatsApp or Instagram message about science, nature, animals, or environmental issues, I usually ignore it.
17. Scientists are smart people.
18. I like to do science tasks from which I will learn, even if I make mistakes.
19. I know what things make me feel good about myself.
20. I don't participate in any extracurricular activities related to science, nature, animals, or environmental issues.
21. I know how to explain to a friend what I study in science.
22. I study science in class because it is important to me to improve my knowledge of science.
23. I am able to understand even the most difficult subjects studied in the sciences.
24. I am interested in journalism covering science, nature, animals, or environmental issues.
25. I talk to friends, parents, or other people about science, nature, animals, or environmental issues.
26. I'm not sure, but sometimes, I think about becoming a scientist.
27. I browse websites dealing with science, nature, animals, or environmental issues.
28. I understand everything that is done in science experiments.
29. It is very important to me to get a high grade in science.
30. I like to explore how things work and what happens if I change something.
31. I complete all assignments in science classes because it's important for me to progress in science.
32. I am confident that I can perform any task in science.
33. Scientists are important people.
34. At school, we should learn more science.
35. I aspire to be a scientist.
36. Knowledge of science will allow me to fulfill my dreams.

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References

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education, 96*(5), 763–786. https://doi.org/10.1002/sce.21018

Archer, L., Dewitt, J., & Osborne, J. A. (2015). Is science for us? Black students' and parents' views of science and science careers. *Science Education, 99*(2), 199–237.

Archer, L., Dewitt, J., Osborne, J. A., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education, 94*(4), 617–639.

Archer, L., DeWitt, J., & Wong, B. (2014). Spheres of influence: What shapes young people's aspirations at age 12/13 and what are the implications for education policy? *Journal of Education Policy, 29*(1), 58–85. https://doi.org/10.1080/02680939.2013.790079

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564–582. https://doi.org/10.1002/tea.20353

Balta, N., Japashov, N., Mansurova, A., Tzafilkou, K., Oliveira, A. W., & Lathrop, R. (2023). Middle- and secondary-school students' STEM career interest and its relationship to gender, grades, and family size in Kazakhstan. *Science Education, 107*(2), 401–426. https://doi.org/10.1002/sce.21776

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. *International Journal of Science Education, 30*(8), 1075–1093.

Bonnette, R. N., Crowley, K., & Schunn, C. D. (2019). Falling in love and staying in love with science: Ongoing informal science experiences support fascination for all children. *International Journal of Science Education, 41*(12), 1626–1643. https://doi.org/10.1080/09500693.2019.1623431

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 11*(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Bricker, L. A., & Bell, P. (2014). "What comes to mind when you think of science? The perfumery!": Documentingscience-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching, 51*(3), 260–285.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching, 43*(5), 485–499.

Brody, G. H. (2004). Siblings' direct and indirect contributions to child development. *Current Directions in Psychological Science, 13*(3), 124–126. https://doi.org/10.1111/j.0963-7214.2004.00289.x

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218. https://doi.org/10.1002/tea.20237

Carlone, H. B., Scott, C. M., & Lowder, C. (2014). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching, 51*(7), 836–869.

Carol-Ann Burke, L. E. (2020). Informal science educators and children in a low-income community describe how children relate to out-of-school science education. *International Journal of Science Education, 42*(10), 1673–1696.

Caspi, A., Gorsky, P., Nitzani-Hendel, R., Zacharia, Z. C., Rosenfeld, S., Berman, S., & Shildhouse, B. (2020). Children's perceptions of the factors that led to their enrolment in advanced, middle-school science programmes. *International Journal of Science Education, 42*(11), 1915–1939.

Cian, H., Dou, R., Castro, S., Palma-D'souza, E., & Martinez, A. (2022). Facilitating marginalized youths' identification with STEM through everyday science talk: The critical role of parental caregivers. *Science Education, 106*(1), 57–87.

Cohen, S. M., Hazari, Z., Mahadeo, J., Sonnert, G., & Sadler, P. M. (2021). Examining the effect of early STEM experiences as a form of STEM capital and identity capital on STEM identity: A gender study. *Science Education, 105*(6), 1126–1150. https://doi.org/10.1002/sce.21670

Cros, D., Maurin, M., Amouroux, R., Chastrette, M., Leber, J., & Fayol, M. (1986). Conceptions of first-year university students of the constituents of matter and the notions of acids and bases. *European journal of science education, 8*(3), 305–313.

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education, 37*(13), 2170–2192. https://doi.org/10.1080/09500693.2015.1071899

DeWitt, J., Osborne, J. A., Archer, L., Dillon, J., Willis, B., & Wong, B. (2013). Young children's aspirations in science: The unequivocal, the uncertain and the unthinkable. *International Journal of Science Education, 35*(6), 1037–1063. https://doi.org/10.1080/09500693.2011.608197

Dorfman, B. S., & Fortus, D. (2019). Students' self-efficacy for science in different school systems. *Journal of Research in Science Teaching, 56*(8), 1037–1059.

Dou, R., Hazari, Z., Dabney, K., Sonnert, G., & Sadler, P. (2019). Early informal STEM experiences and STEM identity: The importance of talking science. *Science Education, 103*(3), 623–637. https://doi.org/10.1002/sce.21499

Erikson, E. H. (1994). *Identity youth and crisis*. WW Norton & company.
Franse, R. K., Van Schijndel, T. J., & Raijmakers, M. E. (2020). Parental pre-knowledge enhances guidance during inquiry-based family learning in a museum context: An individual differences perspective. *Frontiers in Psychology, 11*, 1047. https://doi.org/10.3389/fpsyg.2020.01047
Galton, M. (2009). Moving to secondary school: Initial encounters and their effects. *Perspectives on Education,* (2), 5–21
Gillison, F., Osborn, M., Standage, M., & Skevington, S. (2009). Exploring the experience of introjected regulation for exercise across gender in adolescence. *Psychology of Sport and Exercise, 10*(3), 309–319.
Gilmartin, S. K., Li, E., & Aschbacher, P. (2006). The relationship between interest in physical science/engineering, science class experiences, and family contexts: Variations by gender and race/ethnicity among secondary students. *Journal of Women and Minorities in Science and Engineering*, *12*(2–3). https://doi.org/10.1615/jwomenminorscieneng.v12.i2-3.50
Glaser, B. G., & Strauss, A. L. (2017). *The discovery of grounded theory: Strategies for qualitative research*. Routledge.
Hashemifardnia, A., Namaziandost, E., & Sepehri, M. (2019). The effectiveness of giving grade, corrective feedback, and corrective feedback-plus-giving grade on grammatical accuracy. *International Journal of Research Studies in Language Learning, 8*(1), 15–27.
Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching, 47*(8), 978–1003.
Hokayem, H., & Gotwals, A. W. (2016). Early elementary students' understanding of complex ecosystems: A learning progression approach. *Journal of Research in Science Teaching, 53*(10), 1524–1545. https://doi.org/10.1002/tea.21336
Jenkins, E. (2019). *Science for all: The struggle to establish school science in England*. ERIC.
Jenkins, J., & Dunn, J. (2009). Siblings within families: Levels of analysis and patterns of influence. *New Directions for Child and Adolescent Development, 2009*(126), 79–93. https://doi.org/10.1002/cd.258
Kang, H., Calabrese Barton, A., Tan, E., Simpkins, D., & S., Rhee, H.-Y., & Turner, C. (2019). How do middle school girls of color develop STEM identities? Middle school girls' participation in science activities and identification with STEM careers. *Science Education, 103*(2), 418–439. https://doi.org/10.1002/sce.21492
Kewalramani, S., Phillipson, S., & Belford, N. (2020). How parents engaged and inspired their young children to learn science in the later years: A story of 11 immigrant parents in Australia. *Research in Science Education, 52*(1), 1–16. https://doi.org/10.1007/s11165-020-09919-9
Lawrenz, F., Huffman, D., & Welch, W. (2001). The science achievement of various subgroups on alternative assessment formats. *Science Education, 85*(3), 279–290. https://doi.org/10.1002/sce.1010
Lee, C. S., Hayes, K. N., Seitz, J., DiStefano, R., & O'Connor, D. (2016). Understanding motivational structures that differentially predict engagement and achievement in middle school science. *International Journal of Science Education, 38*(2), 1–24. https://doi.org/10.1080/09500693.2015.1136452
María, J. H.-S., & José, M. M.-R. (2020). Interest in STEM disciplines and teaching methodologies. Perception of secondary school students and preservice teachers. *Educar*, *56*(2). https://doi.org/10.5565/rev/educar.1065
Nasab, F. G. (2015). Alternative versus traditional assessment. *Journal of Applied Linguistics and Language Research, 2*(6), 165–178.
Ofek-Geva, E., & Fortus, D. (2024). Self-positioning in relation to science: The stories of nine adolescents. *International Journal of Science Education*, 46(3), 240–280. https://doi.org/10.1080/09500693.2023.2228994
Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199
Pajares, F., & Schunk, D. H. (2001). Self-beliefs and school success: Self-efficacy, self-concept, and school achievement. *Perception, 11*, 239–266.
Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. *International Journal of Qualitative Studies in Education, 8*(1), 5–23.
Pulfrey, C., Buchs, C., & Butera, F. (2011). Why grades engender performance-avoidance goals: The mediating role of autonomous motivation. *Journal of Educational Psychology, 103*(3), 683. https://doi.org/10.1037/a0023911
Rachmatullah, A., & Wiebe, E. N. (2023). Exploring middle school students' interests in computationally intensive science careers: The CISCI instrument validation and intervention. *Science Education, 107*(2), 333–367. https://doi.org/10.1002/sce.21771

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist, 26*(3–4), 299–323.

Scholes, L., & Stahl, G. (2020). 'I'm good at science but I don't want to be a scientist': Australian primary school student stereotypes of science and scientists. *International Journal of Inclusive Education*, 1–16. https://doi.org/10.1080/13603116.2020.1751316

Schunk, D. H., & Meece, J. L. (2006). Self-efficacy development in adolescence. *Self-Efficacy Beliefs of Adolescents, 5*, 71–96.

Silvia, P. J. (2008). Interest—The curious emotion. *Current Directions in Psychological Science, 17*(1), 57–60.

Tai, R. H., Qi Liu, C., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*(5777), 1143–1144. https://doi.org/10.1126/science.1128690

The Israeli Central Bureau of Statistics, I. (2019). http://www.cbs.gov.il/webpub/pub/text_page.html?publ=58#5

Toma, R., Greca, I., & Orozco Gómez, M. (2019). Attitudes towards science and views of nature of science among elementary school students in terms of gender, cultural background and grade level variables. *Research in Science & Technological Education, 37*(4), 492–515. https://doi.org/10.1080/02635143.2018.1561433

Tröbst, S., Kleickmann, T., Lange-Schubert, K., Rothkopf, A., & Möller, K. (2016). Instruction and students' declining interest in science: An analysis of German fourth-and sixth-grade classrooms. *American Educational Research Journal, 53*(1), 162–193.

Vedder-Weiss, D., & Fortus, D. (2011). Adolescents' declining motivation to learn science: Inevitable or not? *Journal of Research in Science Teaching, 48*(2), 199–216. https://doi.org/10.1002/tea.20398

Vedder-Weiss, D., & Fortus, D. (2012). Students' declining motivation to learn science: A follow up study. *Journal of Research in Science Teaching, 49*(9), 1057–1095. https://doi.org/10.1002/tea.21049

Vedder-Weiss, D., & Fortus, D. (2013). School, teacher, peers, and parents' goals emphases and adolescents' motivation to learn science in and out of school. *Journal of Research in Science Teaching, 50*(8), 952–988. https://doi.org/10.1002/tea.21103

Wang, J., Yang, M., Lv, B., Zhang, F., Zheng, Y., & Sun, Y. (2020). Influencing factors of 10th grade students' science career expectations: A structural equation model. *Journal of Baltic Science Education, 19*(4), 675–686. https://doi.org/10.33225/jbse/20.19.675

Whiteman, S. D., McHale, S. M., & Crouter, A. C. (2007). Competing processes of sibling influence: Observational learning and sibling deidentification. *Social Development, 16*(4), 642–661. https://doi.org/10.1111/j.1467-9507.2007.00409.x

Wood, R. (2019). Students' motivation to engage with science learning activities through the lens of self-determination theory: Results from a single-case school-based study. *Eurasia Journal of Mathematics, Science and Technology Education, 15*(7), em1718.

Yager, R. E., & Penick, J. E. (1986). Perceptions of four age groups toward science classes, teachers, and the value of science. *Science Education, 70*(4), 355–363.

Zimmerman, H. T. (2012). Participating in science at home: Recognition work and learning in biology. *Journal of Research in Science Teaching, 49*(5), 597–630.

Zimmerman, H. T., & Bell, P. (2014). Where young people see science: Everyday activities connected to science. *International Journal of Science Education, Part B, 4*(1), 25–53.