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Longitudinal Stability and Change Across a Year in Children's Gender Stereotypes About Four Different STEM Fields

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Gender stereotypes about science, technology, engineering, and math (STEM) are salient for children and adolescents and contribute to achievement-related disparities and inequalities in STEM participation. However, few studies have used a longitudinal design to examine changes in gender stereotypes across a range of STEM fields. In a large, preregistered study, we examined the developmental trajectories of two gender stereotypes (involving interest and ability) in four STEM fields across three time points within a calendar year, starting in Grades 2–8. The diverse sample included 803 students ages 7–15 years old at the start of the study (50% girls; 8.5% Asian, 6.0% Black, 25.5% Hispanic/Latinx, 43.7% White, and 16.3% other). Multilevel growth modeling was used to examine developmental trajectories in students' stereotypes for four STEM fields (math, science, computer science, and engineering) while considering both gender and grade level. We found that different STEM disciplines displayed different developmental patterns: Math ability and science interest stereotypes more strongly favored girls over the year among elementary school participants, whereas computer science stereotypes less strongly favored boys over time, and engineering stereotypes (which largely favored boys) were stable across time. The results highlight that the development of stereotypes is not the same for all STEM fields as well as the need to understand the complexity and specificity of developmental change across fields and types of stereotypes.

Public Significance Statement
This study tracked changes in children and early adolescents' STEM-gender stereotypes over the course of a calendar year, specifically focusing on gender stereotypes about who is interested and capable in STEM. We found greater stability in stereotypes about engineering than math, science, and computer science, and among middle school students compared to elementary school students. Based on patterns within the present study, we suggest that efforts to reduce gender stereotyping in STEM fields should begin early, before stereotypes take root.

Keywords: STEM stereotypes, gender, longitudinal

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Children seek to understand the social world from a young age. One contributor to this social understanding is the pattern of stereotyping that is pervasive in the culture in which the child is raised. Stereotypes are beliefs that link groups with certain traits or characteristics (Bigler & Liben, 2007; Cheryan et al., 2015; Koenig & Eagly, 2014; Master, 2021). Gender stereotypes are salient for children, adolescents, and adults. For example, many adults and children hold stereotypes linking gender and science,

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technology, engineering, and math (STEM) interest and ability; stereotypes such as "men are better at math," or "computer science is more for boys than girls" are prevalent in the United States and other societies (Cvencek et al., 2015; del Río et al., 2019; Master et al., 2021; Nosek et al., 2009). As these stereotypes develop over time, they may influence personal perceptions about STEM interests, self-concepts, self-efficacy, and sense of belonging (Brown, 2019; Cheryan et al., 2015; Master & Meltzoff, 2020). The combined influence of pervasive stereotypes and biased personal beliefs can lead to a reduction of opportunities and participation in STEM for women and girls (Cheryan et al., 2015; Kurtz-Costes et al., 2008; Master, 2021; Nosek et al., 2002). STEM-gender stereotypes limit the opportunities that girls are given and influence the choices they make for themselves (Jacobs et al., 2005). Gender stereotypes contribute to achievement-related disparities and inequalities in participation in STEM fields (Cheryan et al., 2015; Perez-Felkner et al., 2017; Skinner et al., 2021). Gaining a better understanding of when and how STEM stereotypes develop is important for designing programs aimed at remedying these inequalities among children and adolescents.

There are wide variations among STEM fields. The proportion of women earning bachelor's degrees remains lower than men in certain STEM fields (de Brey et al., 2019; National Center for Science and Engineering Statistics, 2021), but the variations among different STEM fields are equally informative. In 2018, the proportion of women who earned bachelor's degrees in biology was 63%, compared to 40% in math and statistics, 22% in engineering, and 20% in computer science (National Center for Science and Engineering Statistics, 2021). Such variations across different STEM fields may reflect girls' stereotypes about these fields, with the roots of these stereotypes traceable to childhood and early adolescence (Master, 2021; Master & Meltzoff, 2020). That is, career choices are more gender-lopsided in fields such as computer science and engineering (only 20% of the bachelor degrees go to women), and these fields are the ones with the strongest gender stereotypes as well. However, most studies of children's STEM-gender stereotypes have focused on math and science, in which many studies have found egalitarian or in-group-favoring stereotypes, rather than stereotypes favoring boys (Kurtz-Costes et al., 2014; Rowley et al., 2007; Skinner et al., 2021; Steele, 2003). Few studies have examined computer science and engineering (for exceptions, see Master et al., 2021; McGuire et al., 2022), even though these are the fields in which women are most underrepresented.

Theoretical Framework: Factors Influencing the Development and Maintenance of Stereotypes

We use developmental intergroup theory (Bigler & Liben, 2006) and other related models (Leaper, 2015; Master & Meltzoff, 2020) as a framework for the present work on children's stereotypes about STEM. One factor that can influence the original formation of stereotypes involves proportional group size or salience; when one group is strongly underrepresented in terms of an attribute (such as fewer women than men who are computer scientists), that attribute becomes more salient (Bigler & Liben, 2007). In addition, developmental intergroup theory identifies several factors that influence the development of stereotypes, including in-group bias, explicit statements/attributes in the environment (e.g., a teacher who says, "It's okay that you're not good at math because you're a girl"), and physical attributes in the environment (e.g., a classroom poster of computer scientists who are all men; Bigler & Liben, 2007; Master et al., 2016). Within math and science fields, young children may begin with in-group biases that favor their own gender group (e.g., Kurtz-Costes et al., 2014; Steele, 2003) which lessen over time as they are exposed to stereotyped messages about these fields (McGuire et al., 2022) or realize that social norms discourage expressing biased views (Rutland et al., 2005). Moreover, it is thought that children learn stereotypes through a social constructivist process (Liben & Bigler, 2002). Children's active construction of stereotypes means that there may be meaningful individual differences, because individual children's stereotypes are influenced by the interaction between what children bring to the environment and what the environment brings to children (Bigler & Liben, 2006; del Río et al., 2019; Master, 2021; Master & Meltzoff, 2020; Skinner et al., 2021).

In contemporary society, children are exposed to environmental information that promotes STEM-gender stereotypes favoring boys through multiple channels including: (a) media sources including television shows, movies, toy ads, and books (Lewis et al., 2022; Lyda Hill Foundation & Geena Davis Institute on Gender in Media, 2021; Schlesinger & Richert, 2019), (b) explicit language (including generic language) and implicit information from adults such as parents and teachers (Gunderson et al., 2012; Leaper, 2015; Leshin et al., 2021; Tiedemann, 2000; M. M. Wang et al., 2022), and (c) the gender representation that they see in role models and informal learning environments such as summer camps and afterschool programs (Cheryan et al., 2011; Google Inc. & Gallup Inc., 2015). Even well-intentioned statements designed to counter stereotypes, such as "Girls are just as good at math as boys!" may ironically reinforce stereotypes by implying that boys serve as the natural reference point (Chestnut & Markman, 2018). At early ages, children's stereotypes may be influenced by both in-group bias and by early exposure to these cues favoring boys. The more that girls encounter these types of inputs, the more their stereotypes may shift toward favoring boys over time with age.

Developmental intergroup theory (Bigler & Liben, 2006) and other related frameworks (Leaper, 2015; Master & Meltzoff, 2020) also provide explanations for why stereotypes are largely resistant to change. Once social categories and schemas are in place, they are used to filter new information. Children (and adults) may ignore, forget, or distort information that does not match their existing stereotype schemas (Leaper, 2015). Even knowledge of counter-stereotypical individuals can be overlooked if those individuals are classified into a subtype or subgroup, leaving the overall group stereotype intact. Cognitive development plays a key role in this process. Older children are better able to use multiple classification to sort along two or more dimensions simultaneously (such as classifying a person as both a "woman" and a "computer scientist"). This greater capacity to sort along multiple dimensions has been shown to lead to less distortion and better memory for counter-stereotypical information (Bigler & Liben, 2006). Young children's stereotypes often function as rules, while adults' stereotypes are more likely to function as probabilities (Bigler & Liben, 2006). As they develop in middle childhood, children become increasingly able to recognize within-group variability in gender groups (Halim et al., 2011). Yet, children's beliefs may shift if counter-stereotypical individuals are classified in a way that results in changing the stereotypes about their group (Bigler & Liben, 2006). This is most likely when stereotype-inconsistent information is observed across multiple individuals and when the deviance is somewhat weak (because strong deviance may lead to the creation of subtypes; Gershman & Cikara, 2023).

Taking all this together, we hypothesize that systematic differences in children's everyday academic experiences across different STEM fields could lead to systematic variations in the development of their stereotypes. In STEM fields that children encounter more frequently in daily life (like math and science), with more opportunities to observe actual interest and performance within each gender, children's stereotypes may be more likely to gradually shift based on those experiences. Given that girls typically receive higher grades than boys in math and science in Grades 1–12 (O'Dea et al., 2018; Voyer & Voyer, 2014), observations of girls' success could cause children's stereotypes in these particular fields to shift toward favoring girls (Kurtz-Costes et al., 2014; Rowley et al., 2007). Although children may simultaneously be exposed within the classroom to cues that math is for boys, the visibility of girls' success may mitigate those cues. Cues that math and science are for boys may also be weaker, given the more equal representation of women in those fields than is the case for computer science and engineering.

In contrast to math and science, children are less likely to have direct exposure to peers engaging in computer science and engineering. Less than 10% of U.S. children in elementary and middle school are enrolled in computer science classes, with only 14% of elementary students gaining exposure to coding through platforms such as Code.org or Scratch (Code.org Advocacy Coalition et al., 2021; Code.org et al., 2022). Even fewer U.S. children get formal exposure to engineering in school (Nord et al., 2011). In these STEM fields that children encounter less frequently (like computer science and engineering), children may chiefly be driven by the pervasive adult stereotypes and the observed underrepresentation of women in these domains, and not encounter enough counter-stereotypical examples in their everyday first-person experience to shift their initial stereotypes (Master & Meltzoff, 2020; Master et al., 2017). If some children are beginning to receive some exposure to computer science during school, then their stereotypes about computer science may be more likely to shift than their stereotypes about engineering.

Consequences of Stereotypes

Stereotypes matter because children and adolescents' stereotyped beliefs about their own gender group can shape their attitudes, motivation, achievement, and future academic goals (Bian et al., 2017; Bigler & Liben, 2007; Master et al., 2021). Gender stereotypes preferentially linking one gender group over another to particular academic fields may lessen participation and reduce motivation. Members of negatively stereotyped groups tend to underestimate their own abilities, neglect personal interests, or disengage from learning activities (Kurtz-Costes et al., 2014; Vuletich et al., 2020). For many girls in STEM learning situations, gender stereotypes ("Girls are not as good as boys at computer science") may interact with their gender identities ("I am a girl") to influence their perception of themselves in that specific field ("Since I'm a girl, I must not be good at computer science"; Cvencek et al., 2011, 2014; Tobin et al., 2010). Over time, such gender stereotypes curtail girls' motivation and achievement (Master et al., 2021). Subsequently, lower performance may impede their persistence and pursuit of education or a professional career in STEM (Makarova et al., 2019). At the same time, positive STEM stereotypes about boys may lead to stereotype lift or boost effects for boys (Kurtz-Costes et al., 2008; Master et al., 2021). Additionally, negative stereotypes about boys in other domains such as language arts or healthcare, early education, and domestic roles may limit boys' motivation and achievement in these domains, pushing them toward STEM instead (Block et al., 2018; Chaffee & Plante, 2022; M. T. Wang et al., 2013).

Moreover, with long-term exposure to gender stereotypes linking STEM with men and boys, girls are likely to be concerned about whether they will fit or "belong" in STEM fields (Master et al., 2016). Therefore, it is critical to examine the acquisition of children and adolescents' STEM stereotypes longitudinally, because these provide clues to the development of later inequities in STEM motivation and participation.

Distinction Between Two Types of Gender Stereotypes in STEM

Researchers have distinguished between two common types of gender stereotypes that are particularly meaningful for STEM education: interest stereotypes versus ability stereotypes (Huguet & Régner, 2007; Master et al., 2016; Master & Meltzoff, 2020; Petzel & Casad, 2022; Steele, 2003; Thoman et al., 2013).

Interest Stereotypes

Interest stereotypes refer to beliefs that one gender group has more enjoyment, interest, and predisposition to engage in a specific field than another group does (Master et al., 2021). Only a few studies have directly examined interest stereotypes (e.g., Master et al., 2021), so the current study provides a significant contribution to this area in which research is limited. Interest stereotypes may be particularly influential for motivation by shaping students' sense that they belong to a group that enjoys STEM. According to motivation theories, interest can be seen as a key aspect of motivation that influences engagement and achievement (e.g., Bernacki et al., 2021). Students' interests do not emerge purely from internal sources but are also profoundly shaped by social context and environmental influences (Harackiewicz et al., 2016; Hidi & Renninger, 2006; Hong & Lin-Siegler, 2012; Renninger & Hidi, 2019). For instance, students' judgments about their own gender group's preferences may influence their own interests (e.g., "girls are more interested in language arts, so I am too"), because young children actively compare themselves to others perceived to be "like me" (Meltzoff, 2007).

Gender-interest stereotypes that are held by children and adolescents in turn contribute to subsequent gender gaps in the fields of computer science and engineering (Master et al., 2021). In terms of math, research shows that children believe math-interest stereotypes favoring boys as early as second grade (Cvencek et al., 2011). In terms of science, a meta-analysis reviewing the Draw-A-Scientist task across five decades established that children tend to draw scientists as men, and this increases with age (Archer et al., 2012; Miller et al., 2018). In terms of engineering and computer science, a recent study found that children believe stereotypes that girls are less interested than boys in engineering and computer science as early as first and third grade, respectively (Master et al., 2021).

Ability Stereotypes

Ability stereotypes (e.g., "boys are better at math") refer to beliefs that one gender group has superior abilities, skills, or performance in a specific field than another gender group (Master & Meltzoff, 2020; Petzel & Casad, 2022). Ability stereotypes have been well-studied in various education settings, especially in terms of math and science. Ability stereotypes are endorsed across age groups (from young children to adults) and across many school subjects (STEM, music, and language arts; Burnett et al., 2020; Cvencek et al., 2011; Wyer et al., 2000). Although prevalent adult stereotypes link men with ability in math and science, cross-sectional research on math and science has suggested that children often report egalitarian beliefs about girls' and boys' math/science abilities or report a preference for their own gender group until late childhood or adolescence (Kurtz-Costes et al., 2014; Master et al., 2017; Rowley et al., 2007; Skinner et al., 2021; Steele, 2003). In terms of computer science and engineering, very little research has examined the development of children's ability stereotypes. Some studies found that ability stereotypes favoring boys in these fields occurred during early elementary school (Master et al., 2017, 2021). It has been argued that ability stereotypes can influence children's motivation (Cimpian et al., 2012; Master et al., 2017, 2021).

Interest Versus Ability Stereotypes: Similarities and Differences

In sum, although interest and ability stereotypes share similar attributes, functions, and impacts on motivation, they can be distinguished conceptually (Master et al., 2021). Interest stereotypes may especially influence students' values and academic choices, while ability stereotypes may especially influence students' ability self-concepts. Empirically, they may also develop along different trajectories in different STEM fields (Master et al., 2021; Master & Meltzoff, 2020). Ability stereotypes may be more susceptible to in-group biases because they go beyond noting a difference between gender groups to making a value judgment about which group is superior or better in a domain (Verkuyten, 2021).

Both types of stereotypes, when assessed using children's self-report, are also distinct from implicit stereotypes, which reflect associations between gender and academic fields. Children's implicit stereotypes and attitudes about STEM are automatic ones that lie outside of children's awareness and deliberate control, and can be distinguished conceptually and empirically from their explicit responses to verbal questions about which gender is "better" or "more interested in" selected academic subjects (e.g., Cvencek et al., 2021). Several studies using the child implicit association test (IAT) have found that young children significantly associate math with boys and that this association becomes stronger (i.e., more adult-like) with age (Cvencek et al., 2014, 2015). However, it must also be noted that IATs assess the relative strength of association among multiple categories; so it can be difficult to tease apart the degree to which the pattern of results is driven by a math/boy association or a girl/reading association.

Gender and Grade Level Differences in Gender Stereotypes in Different STEM Fields

The current study focuses on children personally subscribing to stereotypes—their own personal belief that girls are less interested in engineering than boys are—not simply their awareness that others hold this view (Master et al., 2021). The current study also focuses on results based on children's self-reported stereotypes, rather than results from IATs. The extant evidence suggests that there are gender and grade level differences in such stereotypes for STEM fields (e.g., Kurtz-Costes et al., 2014; Master, 2021). In terms of math and science, developmental patterns suggest that in-group preferences may lead elementary school students to report academic stereotypes favoring their own gender group. Thus elementary school boys are more likely than girls to hold stereotypes favoring boys in math and science (e.g., Cvencek et al., 2011; Kurtz-Costes et al., 2014), although this pattern was not uniformly found for older boys and in all countries (Kurtz-Costes et al., 2008; Martinot & Désert, 2007; Steffens et al., 2010; Vuletich et al., 2020). Moreover, girls across elementary to secondary school also tend to report in-group preferences, which means that they largely report stereotypes favoring girls in math and science.

Importantly, fewer studies have assessed children and adolescents' gender stereotypes about computer science and engineering, although there are newly emerging data bearing on these particular fields (for exceptions, see Master et al., 2017, 2021; McGuire et al., 2022). The overall pattern of results to date suggest that: (a) children and adolescents hold strong stereotypes (favoring boys) for computer science and engineering and (b) boys are more likely than girls to believe that boys are more interested in and better at computer science and engineering. However, this previous research has not specifically tested for developmental changes and/or longitudinal stability in computer science and engineering stereotypes, which represents a central contribution of the current study.

Taken altogether, the extant cross-sectional studies suggest that children and adolescents' gender-STEM stereotypes vary by gender and potentially grade level. Although previous research has suggested ages in which gender stereotypes first emerge in STEM fields, systematic longitudinal studies are still needed. Additionally, more studies are needed comparing developmental trajectories for different STEM fields, including not only math and science but also computer science and engineering, especially because the latter two fields are significantly more underrepresented in terms of women's participation than the former two fields.

Value of the Current Longitudinal Study

The current preregistered investigation allows us to examine changes in interest and ability stereotypes over time (one calendar year) for specific grade levels. Moreover, the magnitude of change in longitudinal trajectories in a specific demographic group (e.g., gender and grade level) can be examined (Burnett et al., 2020; Skinner et al., 2021). Knowing which and whose stereotypes change is valuable for efforts to counteract negative effects of stereotypes across STEM fields, as well as for a better theoretical understanding of what factors are likely to change children's stereotypes.

To our best knowledge, no study has yet used longitudinal data to examine developmental trajectories of children's and adolescents' gender stereotypes in computer science and engineering. In formal and informal educational settings, however, more computer science- and engineering-related curricula and activities (e.g., coding and robotics activities) are beginning to be introduced starting in elementary school (Code.org Advocacy Coalition et al., 2021); and among adults, the stereotypes and participation of men and women differ as a function of STEM fields. Therefore, it has become a pressing need to understand the development of youths' gender stereotypes in a carefully chosen set of different STEM fields. The developmental trajectories of children's gender stereotypes about engineering may differ from their stereotypes about math.

The current study uses a longitudinal design to examine developmental trajectories across a year of two types of gender stereotypes (interest and ability) among children and early adolescents in four separate STEM fields: math, science, computer science, and engineering. Students reported their perceptions about the interest and abilities of girls and boys at three time points in a single calendar year. We used a longitudinal design to investigate: (a) changes in gender-interest and gender-ability stereotypes in these four fields over time within individuals (longitudinal change) and (b) gender and grade level differences (cross-sectional change) using group-level data. Our first specific aim examined the longitudinal trajectory of interest and ability stereotypes across three time points within 1 year for each STEM field, averaging across gender and grade level. Our second specific aim examined whether the longitudinal trajectories for interest and ability gender stereotypes varied across the year by gender and grade level for each STEM field considered individually.

Our theoretical framework supported predictions that included: (a) an increase in stereotypes that conform to cues of prevailing stereotypes in the social environment (favoring boys) with age, (b) an increase in stereotypes that favor girls over the calendar year in fields that children experience more frequently in school (i.e., math, science, and computer science in this sample), and (c) main effects of gender due to in-group bias that will generally be weaker among older than younger children. We hypothesized that gender stereotypes would vary across both gender (with stereotypes favoring boys stronger among boys than girls) and grade level (with stereotypes favoring boys stronger among older students than younger students, especially in certain fields) in general. Based on previous research, we also predicted that boys would tend to show initial in-group preferences across fields, while girls' stereotypes would favor girls or be egalitarian for math and science but favor boys for computer science and engineering. Given that previous research found consistently strong associations of computer science and engineering with boys (Master et al., 2021), we predicted that trajectories for gender stereotypes would be less stable over the calendar year in math and science than computer science and engineering and could vary by gender and grade level. In sum, children at young ages should start with in-group biases (potentially stronger for certain fields) that are subsequently shaped by cues of stereotypes in the environment as well as classroom experiences.

Method

Participants

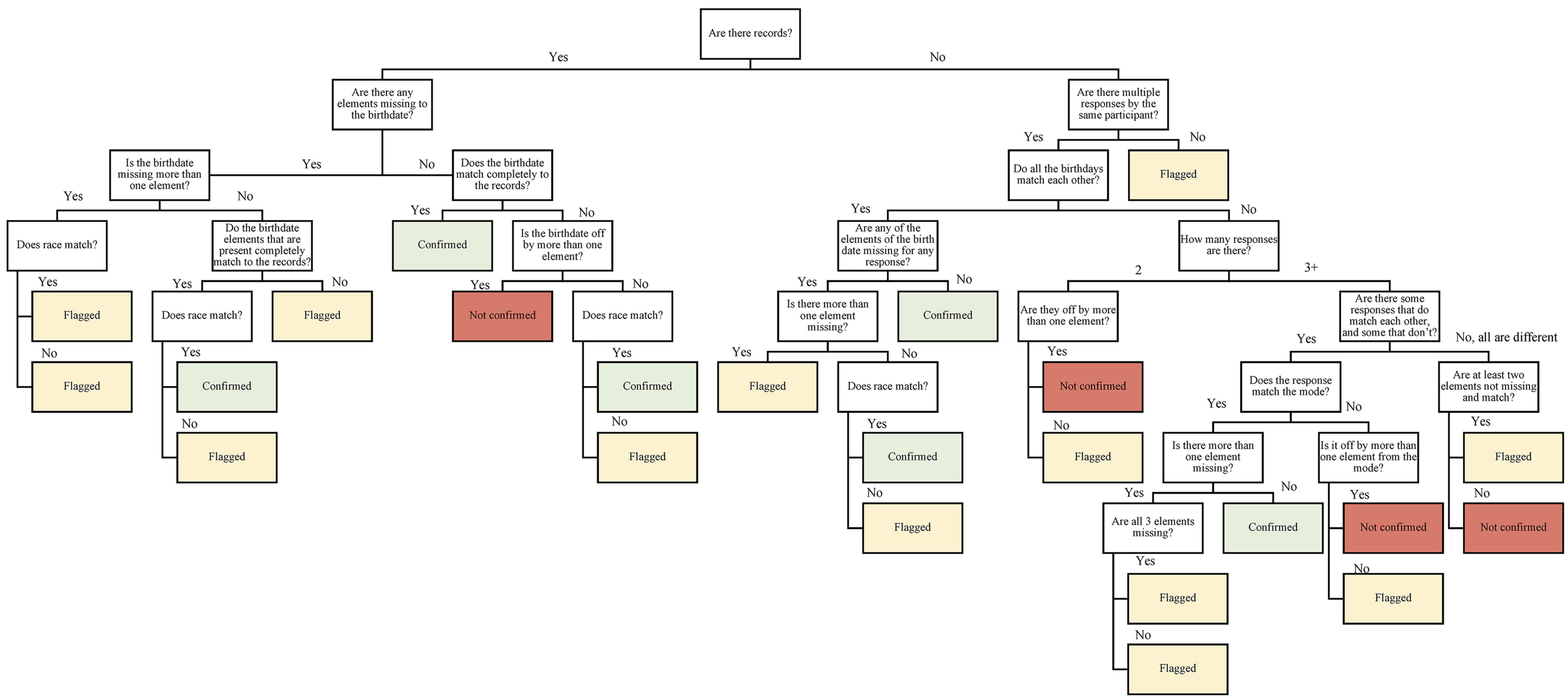
Participants began the study in Grades 2–8 from four elementary schools and one middle school (plus one high school by the end of the study) in a diverse school district in Rhode Island in which 43% of students receive free/reduced-price lunch (see participants' demographics below). The school district was selected by state officials due to its diversity and participation in a statewide STEM initiative. A combination of convenience and reference sampling that depended on accessibility to schools was used to recruit participants in three data collections over a year in 2019. The data were collected in the winter (Time 1, ∼January), spring (Time 2, ∼May), and fall (Time 3, ∼November) of 2019, ending with students in Grades 3–9. Data from the first time point only were also reported in Master et al. (2021, 2023). The sample size was based on all students who agreed to participate across schools in the seven grade levels (49 classrooms). Based on power analyses, the target sample size was 126 students per grade level (18 students per classroom), for an estimated sample size of 882. A total of 1,127 participants initially in Grades 2–8 took the survey, including 3,431 total responses across three time points (we discarded duplicate responses at the same timepoint).

This study represents a subset of hypotheses and plans preregistered prior to analyses, and the preregistration is available on the Open Science Framework repository: https://osf.io/gndaj. Deviations from this preregistration are listed in the online supplemental materials. According to our preregistered exclusion criteria, participants who failed to pass an attention check question were excluded from analyses. In addition, to estimate the initial status (i.e., stereotypes at Time 1) and growth trajectory of the two types of gender stereotypes, participants without responses at the initial time were excluded from the final analysis. Students were matched across time points using their self-reported student ID numbers. During data cleaning, we found that some participants with matching student ID numbers reported inconsistent demographic information (including gender, race, and birthdate) across three time points. In these cases, we compared participants' responses to school records when available and categorized all responses into confirmed, flagged, and unconfirmed (see Figure 1 for the decision tree). Responses labeled as unconfirmed or flagged were excluded from analyses because these categories indicated high possibility that the responses were not provided by the same participant across three time points. (Students self-reported their gender identity, and participants who did not identify as girls or boys were excluded only from analyses based on gender, $n = 164$). This left a total of 1,883 survey responses for the final analysis, including 803 students at Time 1 (7.25–15.07 years old, $M = 11.56$, $SD = 1.98$; 49.94% girls, 49.94% boys, 0.12% unknown; 8.47% Asian, 5.98% Black, 25.53% Hispanic/Latinx, 9.46% multiracial, 1.12% Native American and other, 43.71% White, and 5.73% unknown), 581 students at Time 2, and 499 students at Time 3. See Table S1 in the online supplemental materials for the number of students in each grade level at each time point. There was no gender difference between girls and boys in attrition across time points, $\chi^2(2, N = 1882) = 0.85$, $p = .65$.

Procedure

The university Institutional Review Board and district administrators' offices approved all procedures for this study. Parents were sent an opt-out information letter by the school district. Research assistants in the classrooms facilitated the survey and read all survey questions and responses aloud for students in Grade 2 in the first two time points (January and May). This adjustment in the procedure is typical for studies that span a range of developmental capabilities (e.g., Harris et al., 2018; Wigfield et al., 1997). A majority (58%) of the eligible children and adolescents in these schools completed the survey. The

Figure 1
Decision Tree for Data Selection



Note. Decisions to categorize and select responses with inconsistencies in demographic information, either with school records or with other responses. See the online article for the color version of this figure.

survey included: (a) practice questions (e.g., "How much do you agree or disagree? I like to eat ice cream"), (b) an attention-check question requesting that participants mark a particular response, (c) gender-interest and gender-ability stereotypes about girls and boys; and (d) demographics (gender, race/ethnicity, birth date, grade level, and parent education level). Stereotypes were measured for four STEM fields (math, science, computer science, and engineering; although only the first three were preregistered, engineering stereotypes were ultimately included to provide a more comprehensive picture of gender stereotypes across the four primary STEM fields). The order of STEM fields for each measure followed a random order (although each individual student saw the fields presented in the same order for all questions). The order of STEM fields was randomized by classroom for students in Grade 2 (since questions were read aloud for the class) but was randomized by individual for students in Grades 3–8. The order of interest and ability stereotype questions was counterbalanced so that participants either saw all interest stereotype questions followed by the ability stereotype questions or vice versa. The survey also included other measures which are not part of this report (e.g., open-ended questions; see the online supplemental materials for complete list).

The four STEM fields were the only domains measured in the survey. The questions about computer science used the term "computer coding." Computer coding and engineering were defined for all participants within the survey as follows: "Some of these questions are about engineering. Engineering means to design and create large structures (such as roads and bridges) or new products or systems using scientific methods. Other questions are about computer coding. Computer coding means to write instructions for a computer, robot, tablet, or phone app to do a task." Children in Grades 2–5 attended elementary schools that provided opportunities for all students to engage with computer coding, typically once each week in library classes (e.g., using the online platforms Kodable or Scratch). Children in Grades 6–8 took a required series of middle school technology courses ("Technology Education" in Grade 6, "Engineering and Design" in Grade 7, and "Introduction to Computer Science and Robotics" in Grade 8).

Measures

Outcomes

Gender stereotypes include two types: interest and ability stereotypes. Interest stereotypes were calculated from two items measuring participants' beliefs in boys' interest ("How much do you think that most boys like the following subjects?") and girls' interest ("How much do you think that most girls like the following subjects?") in each STEM field, on a Likert scale from 1 (*really do not like*) to 6 (*really do like*). Interest stereotypes were computed as the difference score of beliefs in boys' interest minus girls' interest for each field (Burnett et al., 2020; Cvencek et al., 2015). Positive scores indicate stereotyped beliefs that boys were more interested in each STEM field than were girls; conversely, negative scores indicate beliefs that girls were more interested in each STEM field.

Ability stereotypes were calculated from two items measuring beliefs in boys' ability ("How good do you think that most boys are at the following subjects?") and girls' ability ("How good do you think that most girls are at the following subjects?") on a Likert scale from 1 (*really not good*) to 6 (*really good*). Computed using the same method, positive scores indicated stereotypes favoring boys (beliefs that boys were better than girls) in each STEM field; negative scores indicated stereotypes favoring girls (beliefs that girls were better than boys) in each STEM field (Burnett et al., 2020; Cvencek et al., 2015).

Level 1 (Time Level). Using a multilevel analysis approach (see "Analytic Strategy" for more details), Time was centered at the initial data collection in the winter (Time 1, ~January) of 2019. With spring (Time 2, ~May) and fall (Time 3, ~November) data collections in 2019, the three time points were scaled as 0, 1, and 2.

Level 2 (Individual Level). The Level-2 predictors are individual-level variables, including students' gender ($girl = 0$, $boy = 1$) and grade level. Grade level was used rather than age to better represent the amount of time students had spent in formal classroom settings.

Missing Data

IBM SPSS (Version 26; IBM Corp, 2019) was used for data preparation, and Stata 15.0 (StataCorp, 2017) was used for data analysis. An advantage of using multilevel modeling to test longitudinal changes is that it allows analysis of unbalanced and missing data, in contrast to other analytical approaches for handling repeated-measures data, like analysis of variance, which requires listwise deletion for cases with missing data (Singer & Willett, 2003). Multilevel modeling programs such as Stata use full information maximum likelihood estimation by default. Analysis using full information maximum likelihood methodology is not biased by attrition if data are missing at random; for instance, the missingness is not due to the status of the outcome variable (Hox, 2013; Singer & Willett, 2003). Additionally, regarding model fitting, maximum likelihood estimator was used to handle nonnormality.

Analytic Strategy

Preliminary analyses used Stata 15.0 (StataCorp., 2017) to conduct a series of correlations and *t* tests for gender-interest and gender-ability stereotypes in four STEM fields (math, science, computer science, and engineering), broken down by time points. Descriptive statistics and correlations were calculated to measure the relationship for gender stereotypes (interest and ability) between time points for each STEM field.

A series of two-level growth models were utilized to examine a data structure where students (individual-level/Level-2) were repeatedly measured across three-time points (time-level/Level-1) for each STEM field by using Stata15.0 (StataCorp, 2017). The developmental trajectories of gender stereotypes were separately examined as gender-interest and gender-ability stereotypes in two growth models. Model testing proceeded in three phases: the unconditional model, the unconditional growth model, and the conditional growth model (intercept/initial status and slope/trajectory as outcomes).

First, the unconditional model was conducted separately for each STEM field to provide average scores of gender stereotypes (interest and ability) and the variance in each type of gender stereotypes broken into within- and between-individual components. Intraclass correlations (ICC) were calculated to estimate the specific percentage of the variance of the Level-2 random effect that could be explained by time-invariant variables (gender and grade level). Second, the unconditional growth model built upon the unconditional

Table 1
Descriptive Statistics and Correlations for STEM-Gender Stereotypes

Variable	1	2	3	4	5	6	*n*	*M*	*SD*
Math									
1. Interest stereotype$_{\text{Time 1}}$	—	.34***	.29***	.36***	.23***	.23***	796	−0.28	1.59
2. Interest stereotype$_{\text{Time 2}}$		—	.34***	.16***	.39***	.28***	580	−0.23	1.57
3. Interest stereotype$_{\text{Time 3}}$			—	.17***	.30***	.39***	496	−0.23	1.47
4. Ability stereotype$_{\text{Time 1}}$				—	.31***	.31***	798	−0.36	1.32
5. Ability stereotype$_{\text{Time 2}}$					—	.28***	580	−0.42	1.35
6. Ability stereotype$_{\text{Time 3}}$						—	497	−0.41	1.34
Science									
1. Interest stereotype$_{\text{Time 1}}$	—	.30***	.18***	.29***	.18***	.19***	795	−0.03	1.36
2. Interest stereotype$_{\text{Time 2}}$		—	.22***	.17***	.33***	.16**	580	−0.15	1.40
3. Interest stereotype$_{\text{Time 3}}$			—	.16***	.25***	.39***	498	−0.14	1.23
4. Ability stereotype$_{\text{Time 1}}$				—	.28***	.21***	799	−0.26	1.27
5. Ability stereotype$_{\text{Time 2}}$					—	.19***	580	−0.27	1.21
6. Ability stereotype$_{\text{Time 3}}$						—	496	−0.27	1.13
Computer science									
1. Interest stereotype$_{\text{Time 1}}$	—	.34***	.32***	.31***	.25***	.22***	795	0.58	1.42
2. Interest stereotype$_{\text{Time 2}}$		—	.43***	.32***	.48***	.30***	580	0.60	1.53
3. Interest stereotype$_{\text{Time 3}}$			—	.23***	.39***	.45***	497	0.64	1.42
4. Ability stereotype$_{\text{Time 1}}$				—	.31***	.17***	801	0.36	1.30
5. Ability stereotype$_{\text{Time 2}}$					—	.39***	580	0.21	1.35
6. Ability stereotype$_{\text{Time 3}}$						—	498	0.32	1.34
Engineering									
1. Interest stereotype$_{\text{Time 1}}$	—	.34***	.21***	.38***	.31***	.16***	794	1.11	1.55
2. Interest stereotype$_{\text{Time 2}}$		—	.37***	.28***	.49***	.31***	580	1.08	1.58
3. Interest stereotype$_{\text{Time 3}}$			—	.23***	.28**	.41***	497	1.07	1.35
4. Ability stereotype$_{\text{Time 1}}$				—	.34**	.22**	797	0.77	1.47
5. Ability stereotype$_{\text{Time 2}}$					—	.40***	580	0.70	1.35
6. Ability stereotype$_{\text{Time 3}}$						—	497	0.66	1.35

Note. Interest stereotypes = students' beliefs about boys' interest in each STEM field minus beliefs about girls' interest in each STEM field. Ability stereotypes = students' beliefs about boys' ability in each STEM field minus beliefs about girls' ability in each STEM field. Full possible range of stereotype difference scores was −5 to 5. Positive values indicate stereotypes favoring boys and negative values indicate stereotypes favoring girls. The sample reported in the current study included participants who passed an attention check question in the survey across all three time points. STEM = science, technology, engineering, and math. Data were collected in the winter (Time 1, ~January), spring (Time 2, ~May), and fall (Time 3, ~November) of 2019.
** $p \leq .01$. *** $p \leq .001$.

model by adding a time function (Time) at Level-1; this model estimated the average initial status and the rate of change in gender stereotypes (interest and ability) across three-time points separately for each field (Specific Aim 1). Third, the conditional growth model (with intercept and slope as outcomes) built upon the unconditional growth model by adding gender (boy vs. girl), grade level, and the Gender × Grade Level interaction as Level-2 predictors. This model estimated the initial status and trajectories (Specific Aim 2) of gender stereotypes (interest and ability stereotypes) as outcomes to detect differences between girls and boys, grade levels of students, and the Gender × Grade Level interaction. The Gender × Grade Level interaction was omitted from the final model if it was not statistically significant. In addition, the simple slope was estimated for the rate of change in the two types of gender stereotypes across gender and grade level for each STEM field.

Transparency and Openness

This study's design and its analysis were preregistered. All data, analysis code, and research materials are available on the Open Science Framework (Tang et al., 2024). The Method section reports how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow Journal Article Reporting Standards (Kazak, 2018).

Results

Preliminary Analyses

Descriptive statistics and correlations for the two types of gender stereotypes (interest and ability) for each STEM field, broken down by time points, are presented in Table 1.

See the online supplemental materials for gender differences (Tables S2 and S3 in the online supplemental materials) and gender and race/ethnicity differences (Tables S4–S7 in the online supplemental materials) for each type of stereotype, at each time point, for each of the four STEM fields. For test–retest reliability across timepoints by gender and grade level, see Tables S8–S11 in the online supplemental materials. For correlations across fields by gender, see Table S12 in the online supplemental materials.

Overall Summary

We first present an overall summary of the unconditional, unconditional growth, and growth models before presenting detailed findings for each research question. Unconditional models were used to

Table 2
Longitudinal Trajectory of Gender Stereotypes for Math

	Model 1: Unconditional growth model		Model 2: Conditional growth model			Model 1: Unconditional growth model		Model 2: Conditional growth model	
Interest stereotypes	β	95% CI	β	95% CI	Ability stereotypes	β	95% CI	β	95% CI
Initial status (π_{0i})	−0.27***	[−0.38, −0.16]	−0.52**	[−0.81, −0.22]	Initial status (π_{0i})	−0.36***	[−0.45, −0.27]	−0.58***	[−0.83, −0.34]
Gender (β_{01})			0.43*	[0.05, 0.81]	Gender (β_{01})			0.69***	[0.36, 1.01]
Grade Level (β_{02})			0.09*	[0.02, 0.16]	Grade Level (β_{02})			0.03	[−0.03, 0.09]
Gender × Grade Level (β_{03})			−0.16***	[−0.25, −0.07]	Gender × Grade Level (β_{03})			−0.13**	[−0.20, −0.05]
Rate of change (π_{1i})	0.02	[−0.06, 0.09]	−0.17†	[−0.36, 0.02]	Rate of change (π_{1i})	−0.03	[−0.10, 0.03]	−0.22**	[−0.38, −0.05]
Gender (β_{11})			−0.40	[−0.19, 0.11]	Gender (β_{11})			0.06	[−0.07, 0.19]
Grade level (β_{12})			0.04*	[0.01, 0.08]	Grade level (β_{12})			0.04*	[0.01, 0.07]
Gender × Grade Level (β_{13})	—	—	—	—	Gender × Grade Level (β_{13})	—	—	—	—
Random component:					Random component:				
Within-individual					Within-individual				
Var (r_{ij}) $= \sigma^2$	1.59	[1.40, 1.80]	1.59	[1.41, 1.81]	Var (r_{ij}) $= \sigma^2$	1.23	[1.13, 1.34]	1.22	[1.12, 1.33]
Between individuals					Between individuals				
Var (u_{0j}) $= \sigma_0^2$	0.95	[0.70, 1.29]	0.91	[0.66, 1.24]	Var (u_{0j}) $= \sigma_0^2$	0.55	[0.41, 0.74]	0.53	[0.43, 0.66]
Var (u_{1j}) $= \sigma_1^2$	0.03	[0.001, 2.49]	0.01	[0.00, 2577.25]	Var (u_{1j}) $= \sigma_1^2$	0.00	[0.00, 0.00]	0.00	[0.00, 0.00]
Cov (u_{0j}, u_{1j}) $= \sigma_{01}$	−0.10	[−0.27, 0.07]	−0.09	[−0.26, 0.08]	Cov (u_{0j}, u_{1j}) $= \sigma_{01}$	—	—	—	—

Note. Gender: *girls* = 0, *boys* = 1. Unconditional growth model presents the result for the average trajectory (linear) with only time as the predictor. Conditional growth model presents the final results after including gender, grade level, and the Gender × Grade Level interaction at both Levels 1 and 2. The Gender × Grade Level interaction was omitted at Level 2 from the final model if it was not statistically significant. Var = variance; Cov = covariance; CI = confidence interval.
† $p \leq .10$. * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

examine variance between and within individuals. According to unconditional models, ICCs were between .24 and .35 for interest and ability stereotypes across four STEM fields, indicating that 24%–35% of the between-individual variance in stereotypes could be explained by time-invariant variables (e.g., gender, grade level) at Level 2 (individual level). In other words, 65%–76% of the variance in STEM-interest and STEM-ability stereotypes was within-individual, potentially explained by time-varying variables (e.g., Time) at Level 1 (time level).

Unconditional growth models were used to examine the average initial status and rates of change of interest and ability stereotypes for each STEM field (see Tables 2–5). Overall, the initial status for each field showed that students on average held gender stereotypes favoring girls in math (for both interest and ability stereotypes) and science (for ability stereotypes) at the beginning of the year. In contrast, they held gender stereotypes favoring boys (for both interest and ability stereotypes) in computer science and engineering. Interest and ability stereotypes on average remained constant over the year for all four STEM fields.

Conditional growth models were used to examine whether there were gender and/or grade level differences in terms of the initial statuses and trajectories of interest and ability stereotypes for each STEM field. Results showed differences by gender and grade level at the initial time for both stereotypes in most STEM fields. In terms of rate of change (as testing the simple slope of time for each gender and grade level group), we found some significant changes in math, science, and computer science stereotypes; however, engineering gender stereotypes were stable across time for all groups.

Specific Aim 1: Average Longitudinal Trajectory of Gender Stereotypes

Average Initial Status of Gender Stereotypes

We first present results averaging gender stereotypes across all participants to address the first specific aim (see Model 1 in Tables 2–5). Math stereotypes and science-ability stereotypes were significantly lower than zero at the initial time ($\pi_{0i} = -0.36$ to -0.25, $ps < .001$), indicating stereotypes favoring girls (science-interest stereotypes did not favor either gender, $p = .35$). Computer science and engineering stereotypes were significantly above zero at the initial time for both interest and ability stereotypes ($\pi_{0i} = 0.33$–1.11, $ps < .001$), indicating stereotypes favoring boys. In other words, at the beginning of the calendar year, on average, most participants believed girls were more interested in math, better at math, and better at science than boys. In contrast to math and science stereotypes, participants in general believed that boys were more interested and better at computer science and engineering than girls.

Average Longitudinal Trajectories of Gender Stereotypes

Averaging across all participants, the average change across three time points was not significant for either type of stereotype in any of the four STEM fields (interest stereotypes: $\pi_{1i} = -0.02$ to 0.10, $ps > .15$; ability stereotypes: $\pi_{1i} = -0.06$ to -0.01, $ps > .11$). These results indicate that gender stereotypes in all four STEM fields remained constant on average over the course of the year in the absence of other predictors. The variances of the initial status and rate of change of most gender stereotypes were significant (except for math-ability stereotypes) in four STEM fields, which provided

Table 3
Longitudinal Trajectory of Gender Stereotypes for Science

Interest stereotypes	Model 1: Unconditional growth model β	Model 1: 95% CI	Model 2: Conditional growth model β	Model 2: 95% CI	Ability stereotypes	Model 1: Unconditional growth model β	Model 1: 95% CI	Model 2: Conditional growth model β	Model 2: 95% CI
Initial status (π_{0i})	−0.04	[−0.14, 0.05]	−0.33**	[−0.57, −0.08]	Initial status (π_{0i})	−0.25***	[−0.34, −0.17]	−0.73***	[−0.95, −0.50]
Gender (β_{01})			0.68***	[0.36, 1.00]	Gender (β_{01})			0.97***	[0.69, 1.26]
Grade level (β_{02})			0.03	[−0.03, 0.09]	Grade level (β_{02})			0.08*	[0.02, 0.13]
Gender × Grade Level (β_{03})			−0.09*	[−0.005, 0.07]	Gender × Grade Level (β_{03})			−0.17***	[−0.70, −0.21]
Rate of change (π_{1i})	−0.05	[−0.11, 0.02]	−0.15†	[−0.32, 0.02]	Rate of change (π_{1i})	−0.01	[−0.07, 0.05]	−0.07	[−0.22, 0.08]
Gender (β_{11})			−0.13†	[−0.27, 0.005]	Gender (β_{11})			0.05	[−0.08, 0.17]
Grade level (β_{12})			0.04*	[0.005, 0.07]	Grade level (β_{12})			0.01	[−0.02, 0.40]
Gender × Grade Level (β_{13})			—	—	Gender × Grade Level (β_{13})			—	—
Random component:					Random component:				
Within-individual					Within-individual				
Var (r_{ij}) = σ^2	1.33	[1.22, 1.45]	1.34	[1.23, 1.46]	Var (r_{ij}) = σ^2	1.08	[0.95, 1.22]	1.06	[0.94, 1.20]
Between individuals					Between individuals				
Var (u_{0j}) = σ_0^2	0.60	[0.45, 0.81]	0.43	[0.33, 0.56]	Var (u_{0j}) = σ_0^2	0.55	[0.39, 0.78]	0.50	[0.34, 0.72]
Var (u_{1j}) = σ_1^2	0.01	[0.003, 0.07]	0.00	[0.00, 0.00]	Var (u_{1j}) = σ_1^2	0.03	[0.001, 0.96]	0.04	[0.002, 0.53]
Cov (u_{0j}, u_{1j}) = σ_{01}	−0.09	[−0.18, −0.01]	—	—	Cov (u_{0j}, u_{1j}) = σ_{01}	−0.11	[−0.22, −0.002]	−0.12	[−0.23, −0.01]

Note. Gender: *girl* = 0, *boy* = 1. Unconditional growth model presents the result for the average trajectory (linear) with only time as the predictor. Conditional growth model presents the final results after including gender, grade level, and the Gender × Grade Level interaction at both Levels 1 and 2. The Gender × Grade Level interaction was omitted at Level 2 from the final model because it was not statistically significant. CI = confidence interval; Var = variance; Cov = covariance.
† $p \leq .10$. * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

evidence to include gender and grade level as time- and individual-level predictors in the conditional models.

Specific Aim 2: Longitudinal Trajectory of Gender Stereotypes by Gender and Grade Level

Initial Status of Gender Stereotypes by Gender and Grade Level

To address the second specific aim, we first present results for the conditional models, which add gender, grade level, and their interaction effect to predict the initial status for both types of gender stereotypes in each STEM field. Results are presented in Model 2 in Tables 2–5. Figure 2 shows the initial status of both types of gender stereotypes broken down by gender and grade level for four STEM fields.

Math. Results are presented in Figure 2A and Model 2 in Table 2. There was a significant effect of grade level for interest stereotypes ($\beta_{02} = 0.09$, $p = .011$) and a significant gender difference for both types of stereotypes (interest stereotypes: $\beta_{01} = 0.43$, ability stereotypes: $\beta_{01} = 0.69$, $ps \leq .025$), qualified by significant Gender × Grade Level interactions (interest stereotypes: $\beta_{03} = -0.16$, ability stereotypes: $\beta_{03} = -0.13$, $ps \leq .001$) at the initial timepoint. Girls' and boys' stereotypes by grade level showed a crossover interaction pattern (Figure 2A) for interest stereotypes and convergence for ability stereotypes. For girls, girl-favoring math stereotypes were found only in lower grade levels. Girls in most grade levels held stereotypes favoring girls ($\beta_{\text{initial status}} = -0.58$ to $-.16$, $ps \leq .038$), except for girls in Grades 7 and 8, who reported neutral interest stereotypes. For boys, stronger interest and ability math stereotypes favoring girls were found in higher grade levels. Boys in Grades 2–3 reported neutral stereotypes ($\beta_{\text{initial status}} = -0.09$ to 0.10, $ps > .05$). Boys in Grades 5–8 held stereotypes favoring girls ($\beta_{\text{initial status}} = -0.52$ to -0.19, $ps \leq .003$). However, Grade 4 for interest stereotypes and Grade 5 for ability stereotypes served as turning points in which boys' stereotypes began to favor girls ($\beta_{\text{initial status}} = -0.19$ to -0.23, $ps \leq .015$). Overall, math interest and ability stereotypes generally favored girls at the initial time, with strongest stereotypes for elementary school girls and middle school boys (Figure 2A).

Science. Results are presented in Figure 2B and Model 2 in Table 3. There was a significant gender difference for both stereotypes (interest stereotypes: $\beta_{01} = 0.68$, ability stereotypes: $\beta_{01} = 0.97$, $ps < .001$) and a significant effect of grade level for ability stereotypes ($\beta_{02} = 0.08$, $p = .004$), qualified by significant Gender × Grade Level interactions (interest stereotypes: $\beta_{03} = -0.09$, ability stereotypes: $\beta_{03} = -0.17$, $ps < .012$) at the initial time point. Different patterns of stereotypes between girls and boys were influenced by grade level, with greater convergence between genders at higher grade levels. Across all grade levels in elementary school, girls' interest and ability stereotypes favored girls ($\beta_{\text{initial status}} = -0.73$ to -0.23, $ps < .001$), but boys' interest and ability stereotypes favored boys or were neutral ($\beta_{\text{initial status}} = -0.02$ to 0.35, $ps = .005$ to $.77$). This gender difference decreased during middle school (Grades 6 and 7) and was gone by the last year of middle school (Grade 8). Specifically, for interest stereotypes, girls in Grades 6 and 7 held girl-favoring stereotypes ($\beta_{\text{initial status}} = -0.41$ to -0.17, $ps \leq .022$) and boys reported neutral stereotypes ($\beta_{\text{initial status}} = -0.03$ to 0.10, $ps > .128$), but all students in Grade 8 reported neutral stereotypes ($\beta_{\text{initial status}} = -0.14$ to -0.03,

Table 4
Longitudinal Trajectory of Gender Stereotypes for Computer Science

Interest stereotypes	Model 1: Unconditional growth model β	Model 1: 95% CI	Model 2: Conditional growth model β	Model 2: 95% CI	Ability stereotypes	Model 1: Unconditional growth model β	Model 1: 95% CI	Model 2: Conditional growth model β	Model 2: 95% CI
Initial status (π_{0i})	0.58***	[0.49, 0.68]	−0.29*	[−0.55, −0.03]	Initial status (π_{0i})	0.33***	[0.24, 0.42]	−0.40**	[−0.64, −0.17]
Gender (β_{01})			0.87***	[0.53, 1.21]	Gender (β_{01})			1.15***	[0.85, 1.45]
Grade level (β_{02})			0.19***	[0.12, 0.25]	Grade level (β_{02})			0.12***	[0.07, 0.18]
Gender × Grade Level (β_{03})			−0.13**	[−0.21, −0.05]	Gender × Grade Level (β_{03})			−0.16***	[−0.23, −0.09]
Rate of change (π_{1i})	0.10	[−0.06, 0.08]	−0.17†	[−0.34, 0.01]	Rate of change (π_{1i})	−0.05	[−0.12, 0.01]	−0.22*	[−0.39, −0.04]
Gender (β_{11})			0.06	[−0.08, 0.20]	Gender (β_{11})			0.07	[−0.07, 0.21]
Grade level (β_{12})			0.02	[−0.01, 0.05]	Grade level (β_{12})			0.03	[−0.01, 0.06]
Gender × Grade Level (β_{13})			—	—	Gender × Grade Level (β_{13})			—	—
Random component:					Random component:				
Within-individual					Within-individual				
Var (r_{ij}) = σ^2	1.36	[1.25, 1.48]	1.37	[1.26, 1.48]	Var (r_{ij}) = σ^2	1.09	[0.96, 1.24]	1.09	[0.96, 1.24]
Between individuals					Between individuals				
Var (u_{0j}) = σ_0^2	0.68	[0.52, 0.89]	0.57	[0.46, 0.71]	Var (u_{0j}) = σ_0^2	0.65	[0.48, 0.89]	0.53	[0.37, 0.76]
Var (u_{1j}) = σ_1^2	0.002	[0.00, 0.14]	0.001	[0.001, 0.002]	Var (u_{1j}) = σ_1^2	0.17	[0.09, 0.33]	0.17	[0.09, 0.34]
Cov (u_{0j}, u_{1j}) = σ_{01}	0.04	[−0.04, 0.11]	0.02	[0.02, 0.03]	Cov (u_{0j}, u_{1j}) = σ_{01}	−0.13	[−0.25, −0.001]	−0.13	[−0.25, −0.01]

Note. Gender: *girl* = 0, *boy* = 1. Unconditional growth model presents the result for the average trajectory (linear) with only time as the predictor. Conditional growth model presents the final results after including gender, grade level, and the Gender × Grade Level interaction at both Levels 1 and 2. The Gender × Grade Level interaction was omitted at Level 2 from the final model because it was not statistically significant. CI = confidence interval; Var = variance; Cov = covariance.
† $p \le .10$. * $p \le .05$. ** $p \le .01$. *** $p \le .001$.

ps > .13). For ability stereotypes, all middle school students (Grades 6–8) held girl-favoring stereotypes ($\beta_{\text{initial status}} = -0.11$ to -0.41, *ps* ≤ .081). In summary (Figure 2B), boys' stereotypes changed cross-sectionally from favoring boys in early elementary school to neutral (interest stereotypes) or favoring girls (ability stereotypes), while girls' stereotypes became less strongly girl-favoring across grade levels to neutral (interest stereotypes) or weaker girl-favoring (ability stereotypes).

Computer Science. Results are presented in Figure 2C and Model 2 in Table 4. There was a significant gender difference for both types of stereotypes (interest stereotypes: $\beta_{01} = 0.87$, ability stereotypes: $\beta_{01} = 1.15$, *ps* < .001), and a significant effect of grade level for both types of stereotypes (interest stereotypes: $\beta_{02} = 0.19$, ability stereotypes: $\beta_{02} = 0.12$, *ps* < .001), qualified by significant Gender × Grade Level interactions (interest stereotypes: $\beta_{03} = -0.13$, ability stereotypes: $\beta_{03} = -0.16$, *ps* ≤ .001). Different patterns of stereotypes between girls and boys were influenced by grade level, with greater convergence between genders at higher grade levels. Boys' interest and ability stereotypes favored boys ($\beta_{\text{initial status}} = 0.54$ to 0.91, *ps* < .001) across all grade levels in elementary and secondary schools. However, girls' interest and ability stereotypes were more likely to favor girls or be neutral in elementary school grade levels, including interest stereotypes for girls in Grades 2–4 and ability stereotypes for girls in Grades 2–5 ($\beta_{\text{initial status}} = -0.40$ to 0.08, *ps* = .001 to .33). Girls' interest and ability stereotypes favored boys starting in Grade 5 for interest stereotypes and Grade 7 for ability stereotypes ($\beta_{\text{initial status}} = 0.21$ to 0.83, *ps* ≤ .003). In summary, while boys' stereotypes remained boy-favoring, girls' stereotypes changed from girl-favoring to boy-favoring across grade levels (Figure 2C).

Engineering. Results are presented in Figure 2D and Model 2 in Table 5. There were no significant interactions between gender and grade level for interest or ability stereotypes, so the interaction terms were excluded from the final models. At the initial time point, there were significant gender differences for both stereotypes (interest stereotypes: $\beta_{01} = 0.35$, ability stereotypes: $\beta_{01} = 0.41$, *ps* ≤ .001), and a significant main effect of grade level for both stereotypes (interest stereotypes: $\beta_{02} = -0.06$, ability stereotypes: $\beta_{02} = -0.07$, *ps* ≤ .03). Overall, all girls and boys held stereotypes favoring boys in engineering ($\beta_{\text{initial status}} = 0.40$ to 1.49, *ps* < .001), although boys and elementary school students held stereotypes favoring boys more strongly than girls and middle/high school students (Figure 2D).

Longitudinal Trajectory of Gender Stereotypes Across a Year

Conditional Effects on Trajectories. To further explore the second specific aim of examining longitudinal trajectories of gender stereotypes in STEM fields, we next present the effects of gender and grade level on the rate of change for the conditional growth model (Tables 2–5). Although there were no trajectory changes when averaging across students, more complex patterns emerged when considering gender and grade level. There were no significant interaction effects between gender and grade level for either type of gender stereotype in any STEM field; thus, the interaction term was excluded from the final models.

Moreover, a main effect of grade level was found for math stereotypes (interest stereotypes: $\beta_{12} = 0.04$, ability stereotypes: $\beta_{12} = 0.04$, *ps* ≤ .021) and science-interest stereotypes ($\beta_{12} = 0.04$, *p* = .024).

Table 5

Longitudinal Trajectory of Gender Stereotypes for Engineering

	Model 1: Unconditional growth model		Model 2: Conditional growth model			Model 1: Unconditional growth model		Model 2: Conditional growth model	
Interest stereotypes	β	95% CI	β	95% CI	Ability stereotypes	β	95% CI	β	95% CI
Initial status (π_{0i})	1.11***	[1.00, 1.21]	1.14***	[0.90, 1.39]	Initial status (π_{0i})	0.76***	[0.67, 0.86]	0.79***	[0.56, 1.02]
Gender (β_{01})			0.35**	[0.15, 0.56]	Gender (β_{01})			0.41***	[0.22, 0.61]
Grade level (β_{02})			−0.06*	[−0.11, −0.01]	Grade level (β_{02})			−0.07**	[−0.12, −0.02]
Gender × Grade Level (β_{03})			—	—	Gender × Grade Level (β_{03})	—	—	—	—
Rate of change (π_{1i})	−0.02	[−0.09, 0.05]	0.03	[−0.16, 0.21]	Rate of change (π_{1i})	−0.06	[−0.13, 0.01]	−0.01	[−0.18, 0.17]
Gender (β_{11})			−0.01	[−0.16, 0.13]	Gender (β_{11})			0.03	[−0.11, 0.17]
Grade level (β_{12})			−0.003	[−0.04, 0.03]	Grade level (β_{12})			−0.01	[−0.04, 0.03]
Gender × Grade Level (β_{13})			—	—	Gender × Grade Level (β_{13})	—	—	—	—
Random component:					Random component:				
Within-individual					Within-individual				
Var (r_{ij}) = σ^2	1.47	[1.03, 1.67]	1.47	[1.30, 1.66]	Var (r_{ij}) = σ^2	1.12	[0.99, 1.27]	1.10	[0.13, 0.38]
Between individuals					Between individuals				
Var (u_{0j}) = σ_0^2	0.98	[0.75, 1.30]	0.94	[0.71, 1.26]	Var (u_{0j}) = σ_0^2	1.00	[0.79, 1.26]	0.95	[0.75, 1.21]
Var (u_{1j}) = σ_1^2	0.08	[0.01, 0.43]	0.09	[0.02, 0.41]	Var (u_{1j}) = σ_1^2	0.22	[0.13, 0.38]	0.23	[0.13, 0.38]
Cov (u_{0j}, u_{1j}) = σ_{01}	−0.17	[−0.33, −0.01]	−0.18	[−0.33, −0.02]	Cov (u_{0j}, u_{1j}) = σ_{01}	−0.27	[−0.41, −0.14]	−0.29	[−0.42, −0.15]

Note. Gender: *girl* = 0, *boy* = 1. Unconditional growth model presents the result for the average trajectory (linear) with only time as the predictor. Conditional growth model presents the final results after including gender and grade level at both Levels 1 and 2. The Gender × Grade Level interaction was omitted at both levels from the final model because it was not statistically significant. CI = confidence interval; Var = variance; Cov = covariance.
* $p \le .05$. ** $p \le .01$. *** $p \le .001$.

These findings indicated that math stereotypes and science-interest stereotypes tended to change more among participants from younger grade levels compared to participants from older grade levels across the calendar year.

Significant Change in Trajectories by Group. To understand whether each group of participants significantly changed over time, we examined simple effects of Time (simple slopes) on gender stereotypes for girls and boys at each grade level in each STEM field (Figures 3 and 4). Increasing trajectories indicate gender stereotypes that more strongly favored boys over time, while decreasing trajectories indicate gender stereotypes that more strongly favored girls over time. Results showed that trajectories of gender stereotypes changed significantly for certain groups in math, science, and computer science. Figure S1 in the online supplementary materials shows a cohort-sequential plot of stereotypes by grade level, gender, and time point.

Math. In math, interest stereotypes for boys in Grades 2 and 3 significantly decreased over the academic year (βs = −0.21 to −0.17, *ps* ≤ .036). Specifically, taking into account their initial status, boys at early elementary school levels changed from neutral to girl-favoring math-interest stereotypes over an academic year. Elementary school (Grades 2–5) girls' ability stereotypes significantly decreased over an academic year (βs = −0.22 to −0.10, *ps* ≤ .040), indicating that their beliefs grew more girl-favoring over the year. However, other students' math gender stereotypes remained constant, with no significant increases or decreases over time (Figures 3A and 4A).

Science. In science, all elementary school boys' interest stereotypes significantly decreased over an academic year (βs = −0.28 to −0.16, *ps* ≤ .002). Specifically, taking into account their initial status, elementary school boys' science-interest stereotypes changed from favoring boys to favoring girls over time. Additionally, interest stereotypes for boys in Grade 6 also significantly decreased over an academic year (β = −0.13, *p* = .012), but their beliefs changed from neutral to favoring girls over time. However, other students' science stereotypes remained constant, with no significant increases or decreases over time (Figures 3B and 4B).

Computer Science. In computer science, interest stereotypes for boys in Grade 4 decreased over the academic year (β = −0.15, *p* = .046). Taking into account their initial status, Grade 4 boys' boy-favoring computer science-interest stereotypes became weaker over time. Moreover, most girls' computer science-ability stereotypes significantly decreased over the academic year (Grades 2–6: βs = −0.22 to −0.12, *ps* ≤ .020), except for girls in Grades 7 and 8. Specifically, taking into account their initial status, younger girls' (Grades 2–4) girl-favoring computer science-ability stereotypes grew stronger over time but older girls' (Grades 5 and 6) computer science-ability stereotypes changed from neutral toward favoring girls. However, other students' computer science stereotypes remained constant, with no significant increases or decreases over time (Figures 3C and 4C).

Engineering. For all groups, students' engineering stereotypes remained constant, with no significant increases or decreases over time (Figures 3D and 4D).

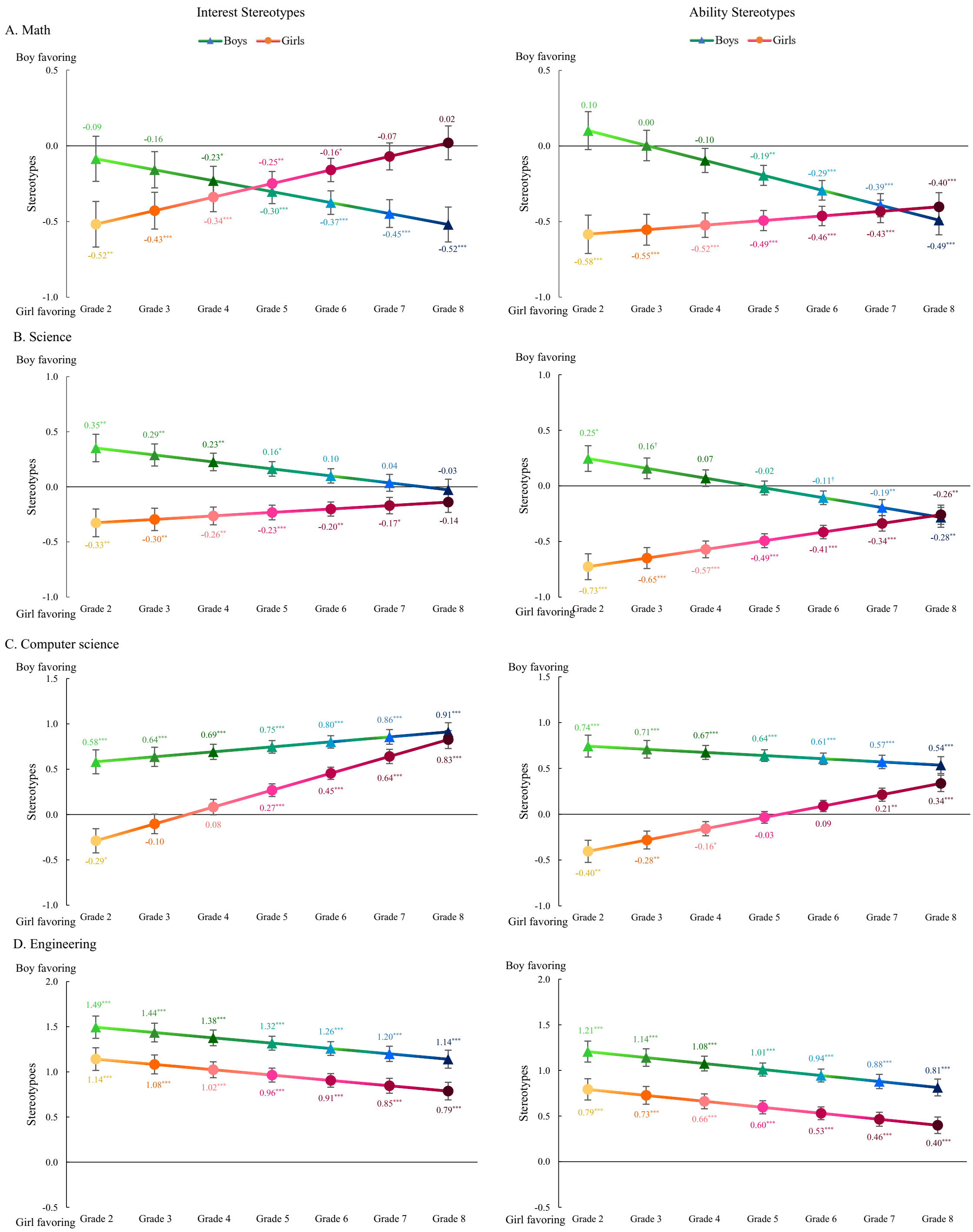
Discussion

As students spend time in school, they receive many messages about gender and STEM fields that can influence their stereotypes about these fields (M. T. Wang & Degol, 2013).

The current study addressed children and early adolescents' gender stereotypes about interest and ability in four STEM fields by

Figure 2

Initial Status of Gender Stereotypes in STEM

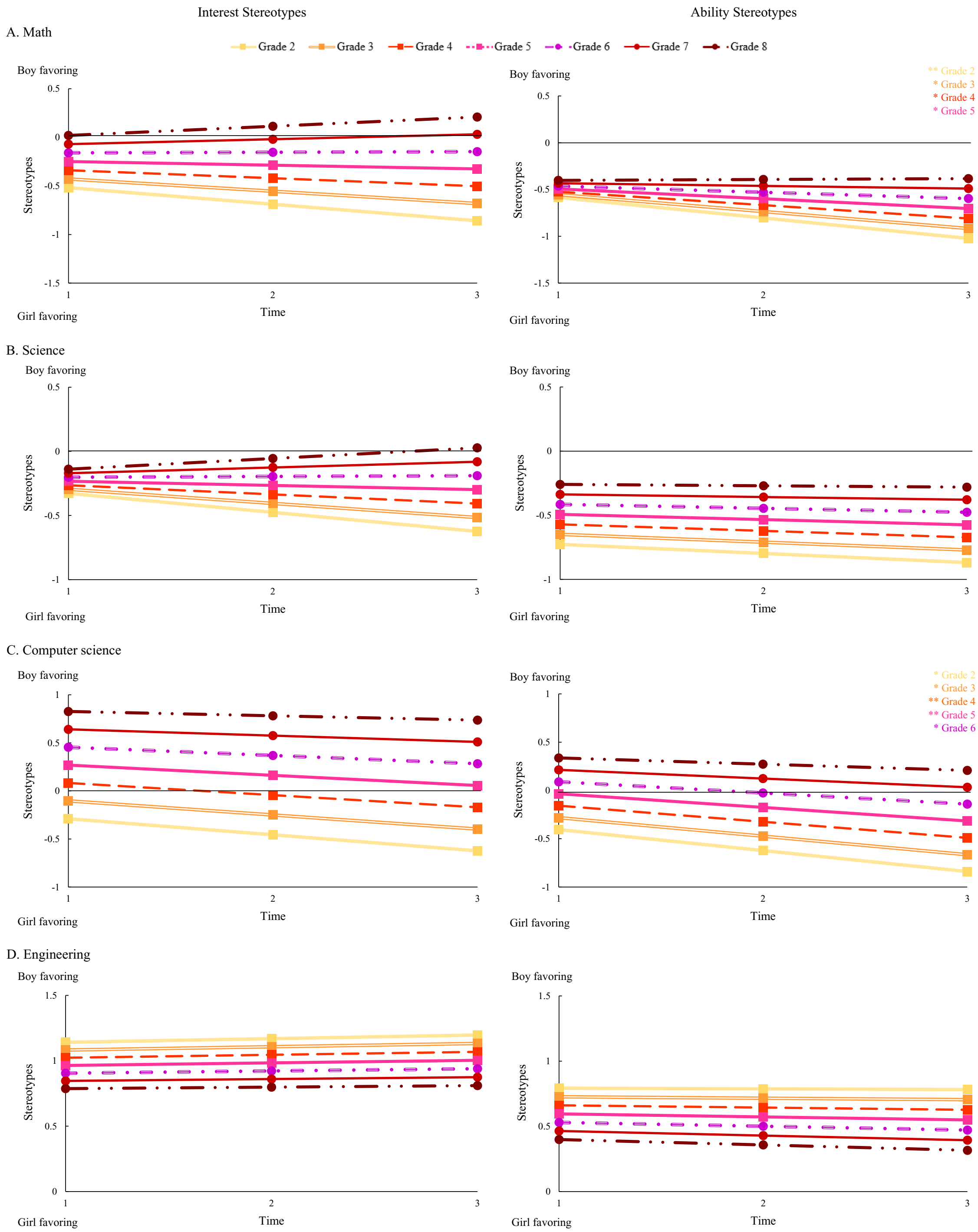


Note. Gender stereotypes (interest stereotypes on the left and ability stereotypes on the right) about (A) math, (B) science, (C) computer science, and (D) engineering for girls (circles) and boys (triangles), with lighter shades for students in lower grades and darker shades for students in higher grades. Interest stereotypes = students' beliefs about boys' interest in each STEM field minus beliefs about girls' interest in each STEM field. Ability stereotypes = students' beliefs about boys' ability in each STEM field minus beliefs about girls' ability in each STEM field. Higher positive scores represent beliefs that more strongly favor boys; lower negative scores represent beliefs that more strongly favor girls. The full possible range of gender stereotype scores was from −5 to 5. STEM = science, technology, engineering, and math. See the online article for the color version of this figure.

† $p \leq .10$. * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Figure 3

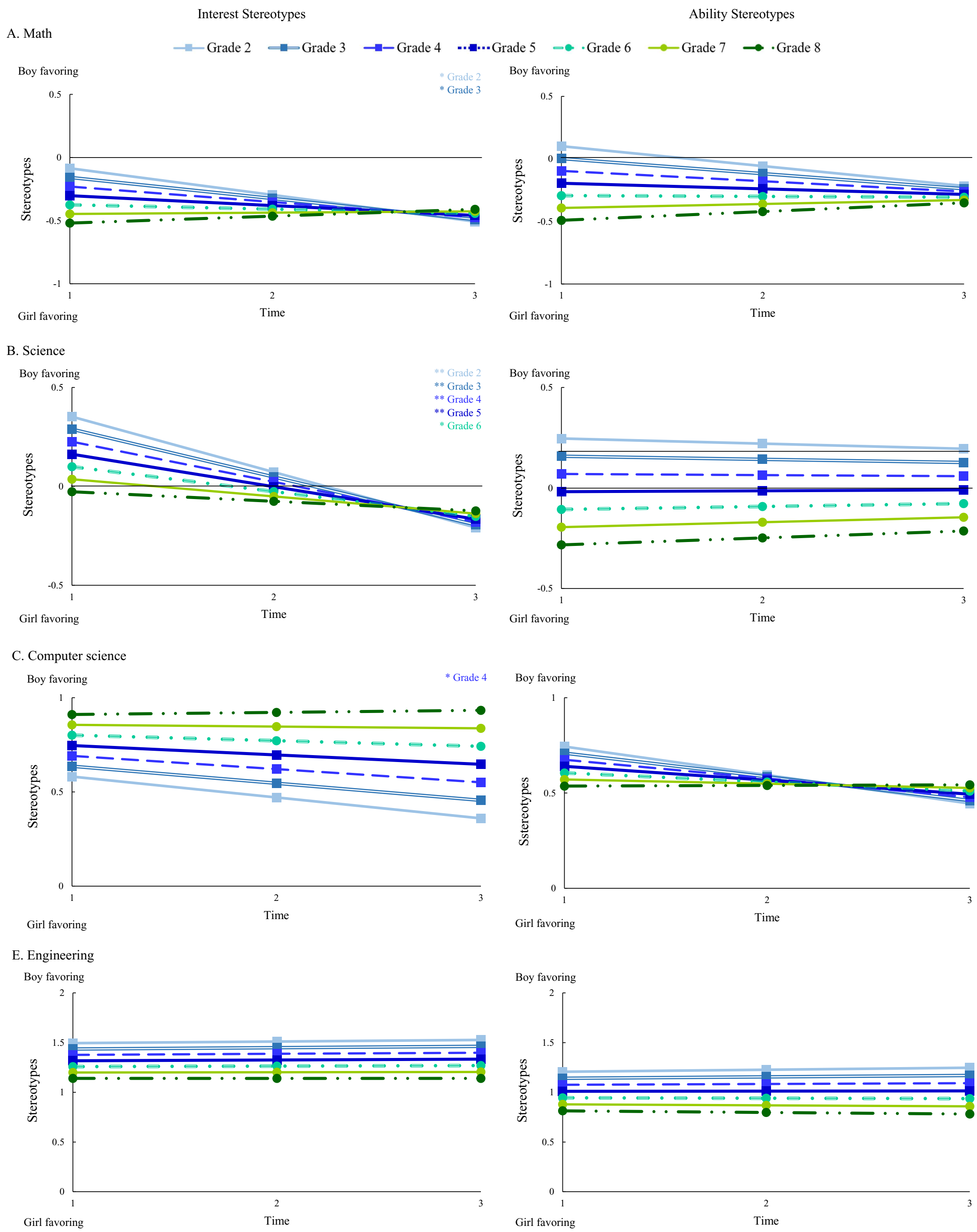
Developmental Trajectory of Gender Stereotypes in STEM (Girls)



Note. Girls' gender stereotypes (interest stereotypes on the left and ability stereotypes on the right) about (A) math, (B) science, (C) computer science, and (D) engineering: higher positive scores represent beliefs that more strongly favor boys; lower negative scores represent beliefs that more strongly favor girls. The full possible range of gender stereotype scores was from −5 to 5. Time 1 = January; Time 2 = May; Time 3 = November (in the next academic year). Lighter shaded lines and squares reflect younger grade levels. STEM = science, technology, engineering, and math. See the online article for the color version of this figure.
$^{*}\ p \leq .05$. $^{**}\ p \leq .01$.

Figure 4

Developmental Trajectory of Gender Stereotypes in STEM (Boys)



Note. Boys' gender stereotypes (interest stereotypes on the left and ability stereotypes on the right) about (A) math, (B) science, (C) computer science, and (D) engineering: higher positive scores represent beliefs that more strongly favor boys; lower negative scores represent beliefs that more strongly favor girls. The full possible range of gender stereotype scores was from −5 to 5. Time 1 = January; Time 2 = May; Time 3 = November (in the next academic year). Squares represent lower grade levels. STEM = science, technology, engineering, and math. See the online article for the color version of this figure.

* $p \le .05$. ** $p \le .01$.

examining: (a) trajectories of interest and ability stereotypes across three time points across a calendar year for each STEM field, averaging across gender and grade level (examining overall initial status and trajectory) and (b) how longitudinal trajectories across the year for interest and ability gender stereotypes varied by gender and grade level for each of four STEM fields across three time points (examining the initial status and trajectory by specific gender and grade level groups).

The key longitudinal findings showed the developmental heterogeneities of gender, grade level groups, and fields. In terms of test–retest reliability, children's stereotypes were significantly correlated across the three timepoints, with correlations ranging from .17 to .43, which is comparable to previous findings of stability in high school students' math-ability and science-ability gender stereotypes over a 2-year span, $rs = .11–.25$ (Starr & Simpkins, 2021). On average, math, science, and computer science stereotypes changed over the year, but not engineering stereotypes. When examining specific gender and grade level groups, significant changes across a year were found among elementary school students in math, science, and computer science, but not among middle school students or the field of engineering. More specifically, we found changes in elementary school girls' math-ability and computer science-ability stereotypes, and elementary school boys' math-interest, science-interest, and computer science-interest stereotypes. Other interest and ability stereotypes did not change across groups or fields.

Examining initial stereotypes, the findings again revealed the differences among groups, as well as differences between fields. Boys were more likely than girls to report interest and ability stereotypes favoring boys across most STEM fields, except for math-interest stereotypes, for which boys were more likely than girls to have stereotypes favoring girls. Additionally, middle school students were more likely than elementary school students to have weaker in-group gender stereotypes in math, science, and engineering, but not in computer science. These findings supported many theoretical expectations, with a few notable exceptions. We discuss these findings in greater detail below in terms of groups and fields, for both initial beliefs and change over time.

Understanding Gender Stereotypes by Gender and Grade Level

Gender Differences in Stereotypes at the Initial Timepoint

These results are aligned with the few other longitudinal studies assessing trajectories of gender stereotypes among children and early adolescents, which found that STEM-ability stereotypes vary as a function of students' gender (e.g., Skinner et al., 2021). First, interest and ability stereotypes at the initial timepoint across most STEM fields were higher in boys than girls (except for math-interest stereotypes). That is, when boys held stereotypes favoring boys, their stereotypes were likely to be stronger than girls' stereotypes; conversely, when boys held stereotypes favoring girls, their stereotypes were likely to be weaker than girls' stereotypes. In general, these findings supported the influence of in-group bias on children's stereotypes. Boys' greater stereotypes favoring boys may be the result of multiple influences, including positive in-group biases (e.g., "my group is good at math"), as well as receptivity to environmental messages (e.g., "boys should be good at math") linking boys with STEM (Master, 2021). The only stereotype for which boys were not more likely than girls to favor boys was math-interest stereotypes. In that case, boys were more likely than girls to hold stereotypes favoring girls (moving from egalitarian to favoring girls across grade levels; see also Prieto et al., 2017). This finding should be replicated in future studies but suggests one meaningful way in which interest stereotypes may differ from ability stereotypes in children: less in-group bias, especially in the field of math. An important direction for future research is to examine the cues in math classrooms (such as girls' enjoyment of math activities) that may lead to these perceptions.

Grade Level Differences in Stereotypes at the Initial Timepoint

Second, regarding grade level differences in initial gender stereotypes, the pattern of differences was not as clear and straightforward as gender differences. Due to the significant interactions between gender and grade level for math, science, and computer science stereotypes, there were no simple conclusions about whether gender stereotypes favoring boys were stronger for students in higher grades across all STEM fields. In general, boys' stereotypes were less likely to favor boys as they got older, while girls' stereotypes were less likely to favor girls as they got older. These findings are consistent with recent research on children and adolescents' gender stereotypes in informal math and science learning showing more equitable and less biased stereotypes as children enter adolescence (McGuire et al., 2020, 2022) and research reporting reduced prevalence of in-group bias in certain STEM domains as elementary school students become older (Raabe & Beelmann, 2011).

Grade-level differences in computer science showed a different pattern from the other three STEM fields, particularly for boys. Boys in higher grade levels reported stronger interest stereotypes favoring boys for computer science. This was the only group and STEM field for which older students showed stronger stereotypes than younger students. This offers another example in which interest stereotypes showed a different pattern from ability stereotypes, and could represent an effect of classroom environments in which girls demonstrate low interest in computer coding. This sample of middle school students took a required series of technology courses. Because girls' interest in computer science tends to drop during middle school (Master et al., 2021), older boys may have had direct classroom experiences supporting their beliefs favoring boys. This interpretation is supported by the longitudinal trajectories of computer science-interest stereotypes for boys, where younger boys' stereotypes changed toward favoring girls, while older boys' stereotypes did not change.

Although stereotypes among adults favor boys across STEM fields (M. T. Wang & Degol, 2017), we did not find that children and early adolescents held stereotypes favoring boys to a greater degree over time. Although girls became generally more likely to favor boys in their stereotypes, this was not the case for boys.

Gender and Grade Level Differences in Trajectories

The trajectories showing how stereotypes changed over the year also offered meaningful patterns. Changes in stereotypes occurred mostly in elementary school students. For example, we found changes in elementary school girls' math-ability and computer science-ability stereotypes, and elementary school boys' math-interest, science-interest, and computer science-interest stereotypes. Previous research has suggested that stereotypes become less flexible after elementary school as students receive more messages about gender stereotypes from environmental influences (e.g., parents' attitudes and media; Cvencek et al., 2011;

Lee et al., 2020; Liben & Bigler, 2002; McGuire et al., 2020). The pattern of "early" and "flexible" supports our findings that only younger students changed their stereotypes across a year.

What factors might influence these developmental changes in stereotypes? Potential reasons for this shift in math stereotypes may include girls' success in classwork and cumulative exposure to women role models in math (Tomasetto et al., 2011; Zhao et al., 2018). This may explain why elementary school girls' beliefs that "girls are better at math" were enhanced over time. The tendency for math stereotypes to favor girls in our sample may suggest that girls have been benefited from research (Master & Meltzoff, 2020; Zhao et al., 2018), educational programs (Kollmayer et al., 2018; Spinner et al., 2021), and social media (Olsson & Martiny, 2018; Papadakis, 2018) that aimed to reduce gender stereotypes about math in recent decades. The current sample came from a U.S. state with STEM-based educational initiatives (https://cs4ri.org) and elementary school exposure to coding, which could have also influenced young girls' computer science-ability stereotypes in positive ways.

Similarly, the direction of the developmental trajectories among boys in our sample showed a shift toward favoring girls in interest stereotypes, especially for younger boys. Students' interest stereotypes may shift to egalitarian or other-gender-favoring when the other gender group shows high engagement or interest in a specific field (e.g., Schiefer et al., 2021). Thus, academic engagement may be a potential reason to explain changes in young boys' interest stereotypes. Young children had the fewest direct experiences with engineering, suggesting that young girls' enthusiastic engagement with math, science, and computer coding activities in the classroom may have changed young boys' stereotypes.

Understanding STEM-Gender Stereotypes by Field

Children and adolescents' stereotypes and trajectories in each STEM field were not monolithic (Cai et al., 2021; Master & Meltzoff, 2020). The inclusion of computer science and engineering stereotypes represents a significant contribution of the current study to the literature, because most studies have focused on math and/or science. In the present study, most children and early adolescents (with the exception of elementary school boys) consistently reported stereotypes favoring girls in math and science, but favoring boys in computer science and engineering, similar to other recent findings across fields (McGuire et al., 2022). Although the term "STEM" is often used in an integrative way (uniting across multiple fields), STEM stereotypes are not interchangeable (Cheryan et al., 2017; Master & Meltzoff, 2020; Park et al., 2011). The large difference in gender stereotypes between math/science and computer science/engineering stereotypes may be a reflection of children's observations of the social world, including the current population pursuing each STEM field (National Science Foundation, 2021). In terms of stereotypes favoring girls in math and science, these findings may reflect shifts in stereotypes over time (Miller et al., 2018) and/or variation in stereotypes due to local variation in STEM representation (Starr et al., 2023). Variations in gender representation within students' immediate communities may play a role and be shaped by their racial/ethnic group memberships. For example, Black women are more likely to earn STEM degrees than Black men (Fry et al., 2021), and Black adolescents have been found to be less likely to believe STEM-gender stereotypes than White children (Starr et al., 2023). However, it is unclear whether changing stereotypes are a cause or consequence (or both) of women's greater entrance into other fields like math, biology, and chemistry.

From a longitudinal standpoint, we found that more changes in stereotypes occurred in math, science, and computer science than in engineering stereotypes, which remained stable over the academic year. Why might gender stereotypes about engineering be more stable, compared to math and science? Children and adolescents commonly experience math and science classes and activities, but computer science and (especially) engineering experiences are much less common for them (Code.org Advocacy Coalition et al., 2021). In this sample, elementary school students only encountered coding activities once per week during their library time, and rarely encountered engineering activities. Thus, their perceptions of these fields may rely more on social media and pervasive stereotypes in the adults in their community. For instance, with long-term exposure to social media in which most role models in engineering or technology are men, children may be less likely to weaken these established gender stereotypes (Cvencek et al., 2011; Ellemers, 2018; Olsson & Martiny, 2018; Papadakis, 2018; Wille et al., 2018). Also in terms of development, classroom experiences over the calendar year appeared to have the biggest effect on younger children. Older students may also be experiencing very different classroom climates, including stereotypes expressed by teachers and peers (Eble & Hu, 2022; Wu & Cai, 2023).

Interest and Ability Stereotypes

The current longitudinal study contributes to the recent body of research on students' gender stereotypes about interests in STEM (Master et al., 2021). Interest and ability stereotypes showed small to medium correlations ranging from .16 to .49 (see Table 1), suggesting that these stereotypes are related but distinct. In terms of mean levels of stereotypes, patterns differed across STEM fields, indicating the importance of considering both types of stereotypes. In math and science, ability stereotypes favored girls more strongly than did interest stereotypes. In computer science and engineering, interest stereotypes favored boys more strongly than did ability stereotypes. There was also less in-group bias for interest stereotypes than ability stereotypes, particularly in math.

There were also different developmental patterns based on type and STEM field (in terms of amount of change and whether change was linked to grade level). Some types of stereotypes showed convergence between girls' and boys' stereotypes in older grade levels, while others showed different patterns (e.g., a crossover pattern in math-interest stereotypes). These findings suggest that future research should continue to examine children's beliefs in both types of stereotypes to replicate these patterns. Future research could also examine how interest and ability stereotypes relate to children's implicit stereotypes about gender and fields, which are often linked to their motivational beliefs and STEM achievement (Cvencek et al., 2014, 2015). Future research using person-centered analyses (such as latent profile analyses) rather than variable-centered analyses could also help shed light on groups of students whose interest and ability stereotypes differ to gain a better understanding of how each type of stereotype is linked to students' STEM self-perceptions and outcomes.

General Theoretical Implications

The current findings provide insight into several factors predicted to impact children's stereotypes (Bigler & Liben, 2006;

Master & Meltzoff, 2020). First, there were some indications of in-group bias, especially at younger grade levels. In-group bias was reflected by main effects of gender on the initial status of all eight stereotypes (see Tables 2–5); for almost all stereotypes, boys' stereotypes were more boy-favoring than girls' stereotypes. In-group bias was also reflected by whether girls' and boys' stereotypes were significantly different from the egalitarian value of zero in directions that favored their own gender group. Boys consistently reported significant bias favoring boys in computer science and engineering, as well as younger boys in science. Girls generally reported significant bias favoring girls in math and science, as well as younger girls in computer science. A notable exception was in engineering, in which both girls' and boys' stereotypes consistently favored boys. This may reflect the impact of stereotype cues in the environment for young children, particularly when they have little direct experience in a subject. These findings support other research on children's STEM stereotypes showing less in-group bias as children get older (McGuire et al., 2022). Thus, although in-group bias and gender identity influenced children's stereotypes, other factors also influenced their stereotypes in meaningful ways (Mandalaywala et al., 2020).

Second, there were mixed findings regarding the influence of cues of prevailing environmental stereotypes favoring boys. Such stereotypes should influence children's stereotypes to increasingly favor boys at older grade levels, as they gain exposure to messages in social media and from others that STEM fields are stereotyped as "for boys" (Starr & Simpkins, 2021). However, we found different patterns of cross-sectional change based on children's gender. Girls' stereotypes generally followed the expected pattern: older girls were typically more likely to hold stereotypes that favored boys compared to younger girls. However, boys' stereotypes did not follow this pattern: older boys were generally less likely than younger boys to hold stereotypes that favored boys. This pattern for boys suggests that direct experiences of seeing girls' engagement and success in STEM, potentially in the classroom, may be particularly salient and meaningful for them. Future research should also examine how children and adolescents' growing awareness of other people's stereotypes influences their personal endorsement (Kurtz-Costes et al., 2014).

Third, there were also mixed findings regarding the influence of classroom experiences (where girls are on average more successful than boys in math and science) on stereotypes. There were differences in children's initial stereotypes across fields, with stereotypes more likely to favor girls in math and science than computer science and engineering. Here, grade level played a particularly large role. Younger girls and boys were the ones most likely to show change across the year that favored girls. Importantly, younger children showed this change only in math, science, and computer coding, the only subjects that they encountered during school time. Elementary school classrooms are environments in which girls show high engagement and achievement, which may shape the development of children's stereotypes. The lack of change among older students suggests that a more fine-grained approach may be needed to demonstrate classroom effects for this group. There may be wide variations in their classroom environments in terms of stereotype-relevant messages from teachers and peers (Wu & Cai, 2023). Future research that measures stereotype cues on a classroom-by-classroom basis would be beneficial.

Educational Implications

Our findings have implications for children and early adolescents' STEM education. Many girls chose to avoid certain STEM majors (e.g., engineering) due to gender stereotypes favoring non-STEM subjects for girls, even though they often outperform boys in STEM subjects (Sáinz & Eccles, 2012; M. T. Wang et al., 2013). Our findings help show the grade levels during which girls are most in danger of first developing negative self-concepts about STEM domains: computer science (especially girls in middle school) and engineering (especially girls in elementary school). Again, it is worth noting that this sample of students had experience with computer science coursework; among students with no computer science experience, change in computer science stereotypes may be more similar to engineering. Looking at whose trajectories change in which fields could point future researchers to those classrooms to examine microgenetic influences on stereotype changes and how those changes are tied to students' self-concepts (Lyons & Kashima, 2003; Philip & Gupta, 2020).

Most children and adolescents reported traditional stereotypes favoring boys in computer science and engineering without changing over a year. Educators and researchers may need to pay special attention to changing stereotypes and supporting girls' interests and abilities in these fields. For example, offering more diverse representation of people in these fields may help change computer science and engineering gender stereotypes among children. Because gender stereotypes were flexible in elementary school children, researchers and educators who are interested in implementing educational programs and interventions to reduce gender bias may focus on younger students to encourage egalitarian beliefs about STEM.

These findings also have implications for educational policies that aim to expand computer science and engineering education for young children (Code.org et al., 2022). An advantage of making computer science and engineering education a required part of K-12 education is that this would eliminate gender disparities in participation in these courses, although students could still encounter disparities in informal learning experiences like afterschool programs and summer camps. Equal representation within these classrooms and activities could promote more egalitarian stereotypes (Master et al., 2017). In addition, for young children, girls' engagement in these courses seems likely to have a positive influence on their gender stereotypes. However, as shown by the patterns of computer science-interest stereotypes in the current study, if older girls show a lack of engagement in these courses, it could potentially reinforce interest stereotypes favoring boys. This suggests that such programs may be more effective during elementary school.

Limitations and Future Directions

Several limitations should be noted. First, we have limited time points in the current data set. Although three time points are sufficient to examine gender stereotype development across 1 year, this does not allow us to understand long-term developmental trajectories in STEM fields from different stages of the lifespan. Future studies could examine development over a longer period of time. Additionally, future research could also consider using a cohort-sequential longitudinal design to examine common developmental trends of gender stereotypes in each STEM field from early childhood to late adolescence. The current findings should be replicated in future preregistered studies to ensure that significant findings from the current study do not represent false positive results.

Second, it would be useful to conduct more research into the best ways to measure stereotypes among children. To date, the verbal questions put to children have asked children to rate boys and girls on a single bipolar scale as well as on separate scales, and with differently worded questions, and such methods have not been directly compared to one another. The specific words used to refer to computer science and engineering (and how well children understand those terms; Lampley et al., 2022) may also influence their responses. Furthermore, children's own experiences with these domains may differ at the start versus end of an academic year. Another factor to consider is that individual children may be thinking of different subfields when answering verbal questions about "science" (e.g., biology vs. chemistry vs. physics), which could impact their responses. Finally, researchers should examine consequences of asking children to rate "most" girls and boys rather than the generic groups "girls" and "boys." The term "most" is a quantifier that is linked to generic beliefs about social categories (Cimpian et al., 2010).

Third, there is a need for future research to better document causal influences on stereotype development (in addition to gender, grade level, and field). For example, randomized interventions to offer coding experiences to young children could provide supportive evidence that STEM stereotypes change more when young students receive more exposure and experiences with them in school (Master et al., 2017). Other important influences to examine include how social-cultural factors (e.g., socioeconomic status, parents' education level), self-beliefs, peers, or achievement shape the formation and development of stereotypes. To gain better insights into influences on children's stereotypes, researchers should also consider incorporating mixed methods. Asking children to explain the reasoning behind their stereotypes could help tease apart effects of in-group bias (e.g., "I think girls are better at math because I'm a girl"), stereotypes in the surrounding environment (e.g., "Boys are more interested in computer science because my teacher said so,"), and classroom experiences (e.g., "I know a girl in my class who loves coding, so I think girls are more interested in computer science.").

Fourth, in addition to causal influences on STEM-gender stereotypes, future research should examine the causal consequences of STEM-gender stereotypes, including academic performance and achievement motivation. Recent research suggests that gender stereotypes are powerful predictors of many aspects of achievement-related motivation in STEM fields, including STEM self-concepts, interest, and sense of belonging (e.g., Master et al., 2021) and peer interactions (McGuire et al., 2022). Future studies could use cross-lagged panel designs to examine whether changes in stereotypes predict later changes in motivation. A better understanding of how gender stereotypes predict achievement-related motivation in which fields and for which groups remain meaningful questions for future studies.

Conclusions

The present study contributes to developmental research on gender stereotypes in STEM fields by sampling more different STEM domains in a single study than are traditionally used, measuring interest stereotypes in addition to ability stereotypes, and by incorporating a longitudinal element. We found that the stereotypes and developmental trajectories of all STEM fields are not the same, and that there are useful differences between ability stereotypes and interest stereotypes. This study and future ones along these lines will help us develop a more systematic understanding of the development of STEM-gender stereotypes among children and adolescents, which is the first step to designing evidence-based programs for countering the negative gender stereotypes in young students.

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