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Article

STEMming from Childhood? The Role of Childhood in Gender Disparities in Adolescent STEM Aspirations in South Korea*

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Recent research identifies gender disparities in adolescent occupational plans as a key contributor to women's underrepresentation in STEM (science, technology, engineering, and math) fields. Using nationally representative data from two South Korean birth cohorts, this study examines how gender gaps in STEM aspirations emerge in childhood and persist into late adolescence. By 3rd grade, boys are already six to eight times more likely than girls to express interest in STEM careers—a gap not explained by differences in our measures of parenting, math ability and interest, or life goals. Our estimates suggest that roughly 22 percent of the gender gap in STEM intentions by 11th grade stems from boys' stronger 5th grade STEM aspirations and their greater persistence over time. These findings underscore childhood as a critical period in the formation of gendered career pathways.

Keywords: *STEM, gender segregation, occupational plans, occupational aspiration, PSKC.*

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Introduction

Women remain markedly underrepresented in science, technology, engineering, and mathematics (STEM) fields despite decades of policy intervention (OECD 2017). While extensive research has examined the persistence of this underrepresentation (Ceci et al. 2009; Ceci et al. 2014; Kahn and Ginther 2017; Xie et al. 2015), recent scholarship highlights a critical, early driver: gendered occupational aspirations (Law 2018; Legewie and DiPrete 2014; Morgan et al. 2013; Sadler et al. 2012; Sassler et al. 2017; Sikora 2019; Tai et al. 2006; Weeden et al. 2020).[1] Empirical evidence consistently suggests that boys and girls envision distinct future occupations irrespective of ability, and that these adolescent aspirations predict future STEM gaps more accurately than quantitative skills or work–family preferences.

Yet we lack a clear understanding of when these gendered preferences first take root (Thébaud and Charles 2018). Aside from the ASPIRES project in England (Archer et al. 2020), few population-level studies track career ambitions before secondary school.[2] Consequently, the developmental processes through which childhood interests are translated into adolescent career plans, and ultimately into the STEM gender gap in the workforce, remain largely unobserved at a population scale.

We bridge this gap using unique longitudinal data from South Korea (hereafter Korea), drawing on two nationally representative studies of birth and grade cohorts that collectively span early childhood to late adolescence. By repeatedly measuring occupational aspirations across these formative years, these datasets offer a rare opportunity to examine the development and persistence of occupational aspirations at the population level. For our analysis, we classify over 10,000 verbatim responses about occupational aspirations into five categories: STEM, medical, clinical, non-STEM, and an additional category for unclear aspirations.

Our analysis proceeds in two stages. First, we document substantial gender disparities in occupational aspirations as early as 3rd grade and show

[1] While some scholars distinguish between aspirations (idealized ambitions) and plans or expectations (realistic projections that account for constraints), we use these terms somewhat interchangeably in this study (Hanson 1994; see Morgan 2007) given the life stages under consideration.

[2] Outside of ASPIRES, we are not aware of any population-based studies tracking career aspirations before secondary school; for examples based on non-representative data, see Hartung et al. (2005) and references therein.

that these disparities are not explained by standard predictors of STEM interest—parenting, math skills and interests, or life goals. Second, we link these early aspirations to students' career intentions in 11th grade, estimating that roughly 22% of the gender gap in STEM intentions can be attributed to two reinforcing processes: boys' stronger STEM aspirations in 5th grade and the greater persistence of those aspirations over time. As we discuss, 11th-grade career intentions in Korea are likely to be strong proxies for future educational and occupational pathways.

This study offers four main contributions to the literature. First, it demonstrates that gender disparities in STEM aspirations emerge in or before childhood—a stage often overlooked in population-level research, which tends to focus on adolescence—thus deepening our understanding of their developmental roots. Second, by examining the correlates of these early disparities, we provide insight into the social mechanisms that shape gendered occupational orientations. Third, by focusing on an East Asian context—still rare in work linking the STEM gender gap to occupational aspirations—we broaden the comparative and cultural scope of research in this area.[3] Fourth, by tracing how early aspirations predict later STEM intentions, we show that gendered career perceptions take shape well before high school, challenging the timeline implicit in conventional "STEM pipeline" frameworks and underscoring the importance of early-life experiences (Xie and Shauman 2003).

Explanations of the Gender Gap in STEM

The long-standing assumption that gender disparities in quantitative skills drive imbalances in STEM occupations has faced growing skepticism. Recent evidence reveals few, if any, meaningful gender differences in mathematical ability, as assessed through standardized tests or course grades (e.g., DiPrete and Buchmann 2013; Else-Quest et al. 2010; Hyde et al. 2008).[4] Some researchers argue that specialized skills, such as spatial abilities, or the disproportionate presence of men among top math performers may contribute to the gender gap in STEM (see Stewart-Williams and Halsey 2021). Yet, the support for these claims remains inconclusive at best (Ceci et

[3] For examples of related studies on East Asian adolescents, see Liu (2018, 2020).

[4] This section offers a focused review of the literature to frame our empirical analysis; for broader discussions, see the sources cited in the Introduction.

al. 2009).

An alternative line of explanation centers on societal stereotypes that associate math and science with masculinity. In many contexts, these fields are implicitly regarded as "male domains" (Nosek et al. 2009), leading women to undervalue their own abilities and interests in these areas (Ceci et al. 2009; Riegle-Crumb et al. 2011; Seo et al. 2019; X. Wang 2013; Watt 2004). Such processes can deter women from pursuing careers requiring strong quantitative skills. Others suggest that women, more so than men, prioritize family responsibilities over professional advancement, rendering STEM occupations less appealing (Ceci et al. 2009; Hakim 2000). Whether rooted in innate dispositions or socialization, these preferences likely reflect broader gender differences in life goals: women tend to favor relationship-oriented and intrinsic values, whereas men place greater emphasis on extrinsic rewards such as recognition and financial success (Bobbitt-Zeher 2007; Ferriman et al. 2009; Marini et al. 1996). Although STEM careers often promise competitive salaries (Kim et al. 2015; Quadlin et al. 2021), their demanding schedules (Valentino et al. 2016) and perceived lack of relational focus (Diekman et al. 2010) may discourage women, particularly those seeking alignment between their careers and personal values.

Although not direct explanations for the STEM gender gap per se, prominent social-psychological theories emphasize the pivotal role of parents in shaping children's educational and occupational trajectories. The "Wisconsin model" of status attainment positions educational and occupational aspirations as key mechanisms through which individuals are allocated to occupational positions, with these aspirations shaped heavily by "significant others," notably through parental encouragement (Sewell et al. 1969). Similarly, the expectancy-value model asserts that parents' beliefs and expectations strongly affect the values and goals their children embrace, thereby influencing academic performance and career choices (Eccles 1983, 1994).

Parental gender biases, reflected in both socialization practices and patterns of encouragement, can thus reinforce normative expectations about suitable careers for sons versus daughters (Eccles et al. 1990; Eccles and Jacobs 1986). For example, a study in Israel showed that boys receive greater parental support for math-intensive high school coursework than girls, contributing to higher enrollment in math-related college programs (Gabay-Egozi et al. 2015). In Korea, college women's career aspirations are associated with their mothers' gender-role attitudes, highlighting the intergenerational transmission of views on women's roles in society (Song 2001). More broadly, evidence suggests that parents' perceptions of their children's abilities—and the support they provide—differ systematically by the child's gender, shaping both interest and engagement in math from an early age (Frome and Eccles 1998; Rice et al. 2013; e.g., Simpkins et al. 2006).

Pipeline Model, Life Course Perspectives, and Early Occupational Plans

The "pipeline model" has long been the prevailing framework for analyzing gender disparities in STEM fields (see Berryman 1983; Ma 2011). This model envisions a science career as a linear progression through educational and occupational stages, where women's representation hinges on entry rates and attrition at each stage. Addressing the "leaky pipeline"—where women disproportionately exit the STEM trajectory—thus becomes central to enhancing gender equity.

However, Xie and Shauman (2003) criticize this model for its oversimplified, linear depiction of career pathways. They propose a broader life-course perspective, viewing science trajectories as "age-dependent, interrelated, and contingent on (but not determined by) earlier experiences and societal forces" (Xie and Shauman 2003, p. 12). While sharing some assumptions with the pipeline model, this approach emphasizes broader social and life-course conditions and acknowledges multiple entry and exit points along the path to a STEM career.

Recent research has reignited interest in occupational aspirations, particularly gender differences in adolescent occupational interests. Although earlier work by Xie and Shauman (2003) and Jacobs (1989) documented these disparities, newer studies highlight their self-reinforcing nature and substantial influence on future career paths. In the United States, adolescent occupational plans outperform other commonly cited factors in accounting for the STEM gender gap (Morgan et al. 2013; Sassler et al. 2017; Weeden et al. 2020). Legewie and DiPrete (2014) show that gendered occupational plans in late high school explain up to 82 percent of the disparity in STEM degree attainment among four-year college graduates. Middle school plans also predict college major choices, though less strongly (Legewie and DiPrete 2014; Tai et al. 2006). Similar patterns appear in Australia (Law 2018; Sikora 2019), and cross-national data suggest that lower STEM aspirations among adolescent girls are widespread (Stoet and Geary 2022). Among younger groups, a national-scale English study finds that 18 percent of 12–13-year-old boys but only 12 percent of girls aspire to science careers (Archer Ker et al. 2013).

Collectively, these findings indicate that by the time students enter the "STEM pipeline"—often considered to begin with secondary school coursework—their occupational orientations are already taking shape. Gender disparities in career choices may thus originate earlier than the pipeline model assumes (Hartung et al. 2005; Maltese and Cooper 2017; Maltese and Tai 2010). Fully understanding the STEM gender gap requires examining the emergence and long-term impacts of gendered career interests at younger ages (Puente et al. 2021; M.-T. Wang et al. 2017).

The Korean Context

As in many developed nations, women in Korea are significantly underrepresented in STEM. In 2020, women comprised only 33.1 percent of bachelor's degree recipients in engineering and the natural sciences, dropping to 23.9 percent in engineering (Ministry of Education 2021). Until recently, Korea's education system enforced rigid field-of-study tracking. At the end of grade 9, students were assigned to either academic or vocational high schools. By grade 10, academic-track students selected between *munka* (liberal arts) and *yika* (natural sciences). The *yika* track emphasized advanced mathematics and science, providing a foundation for STEM study, while *munka* focused on humanities and social sciences. Students chose College Scholastic Ability Test (CSAT) subjects aligned with their track.[5]

College admissions in Korea are typically structured around a student's intended major, with competition among applicants to the same major within an institution. For STEM fields, especially at selective universities, students often need advanced math and science CSAT scores, which are predominantly earned by *yika* students. Most college STEM curricula presuppose a *yika*-level background, making it uncommon for students to transition from a non-STEM track to a STEM major in college. Consequently, occupational plans solidified by 11th grade are expected to strongly predict college major choices.

Data from the 2019 Graduates Occupational Mobility Survey (GOMS)

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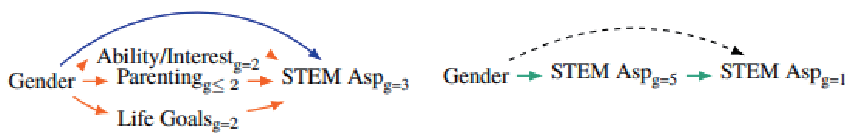
[5] Since the cohort entering college in 2022, the Korean government has implemented significant changes to this tracking system.

bolster this point.[6] Among 2018 four-year college graduates from academic high schools, 84 percent of those majoring in engineering or natural sciences had followed the *yika* track. Put differently, of *yika* students earning four-year degrees, 74 percent majored in engineering or natural sciences, and 12 percent pursued medical or health-related fields. In contrast, only 11 percent of *munka*-track students graduated with a STEM degree, highlighting the profound influence of Korea's tracking system on STEM participation.

Research Questions



(a): Target of Inference in PSKC (b): Target of Inference in KELS

Fig. 1.—Visual Summary of Research Questions.

Each node represents a (set of) variable(s), subscript g denotes the grade level at which the measurement was taken; the directed arrows represent causal effects. The first research question pertains to the sum of blue and orange paths shown in panel (a). The second research question corresponds to the orange paths. The third question corresponds to the green path in panel (b).

Against this backdrop, our study addresses the following research questions (illustrated in Figure 1):

1. Do gender differences in STEM career aspirations emerge among a nationally representative sample of Korean 3rd-grade students?
2. If so, to what extent do factors such as (1) parenting, (2) math ability and interest, or (3) broader life goals help explain these early differences?
3. Are the gender gaps in 11th-grade STEM aspirations linked to the gender differences already observable by 5th grade?

[6] GOMS is an annual survey tracking career outcomes for a nationally representative sample of college graduates; the 2019 survey included 18,163 individuals who graduated in 2018.

Data and Measures

Data

We draw on two surveys, each representative of a complete Korean birth or grade cohort: the Panel Study on Korean Children (PSKC) and the Korean Educational Longitudinal Study 2013 (KELS). The PSKC, initiated in 2008, sampled 2,150 newborns to represent Korea's 2008 birth cohort. Initially focused on parents, the survey expanded annually to include children and their educators. We draw on the first 10 waves (2008–2017); after excluding cases due to attrition and missing data, we obtain a final analytic sample of 1,366. All analyses incorporate PSKC sampling weights to adjust for unequal selection probabilities and panel attrition.

The KELS, launched in 2013, began with 7,324 students in grade 5 from 242 elementary schools nationwide, representing Korea's entire 5th-grade population. We use the first and seventh waves (5th and 11th grades). From the original cohort, 1,112 were lost to attrition; we further restricted to students in academic high schools (excluding vocational or specialized schools), removing 1,216 students, and excluded 462 lacking occupational plans. We reweigh these samples so that observable characteristics align with the baseline target population. Missing data in both datasets are addressed using the random forest algorithm proposed by Stekhoven and Bühlmann (2012).[7] Additional details on data sources, sample construction, weighting schemes, and descriptive statistics are provided in the appendix.

[7] In the final samples, 8 percent of PSKC and 12 percent of KELS respondents had missing data on at least one covariate or mediator. Results remain robust across imputation methods; list-wise deletion produces qualitatively similar findings.

Table 1
Summary of the Core Variables of the Analyses.

Variables	Question(s)/Description	Respondent(s)	Response levels
	A. PSKC (*n* = 1,360)		
Outcome variable			
STEM aspiration (Grade 3)	"Which job does [child's name] want to have? Can you tell us your first and second choices? [Verbatim response]	Child	Classified into: 1) STEM; 2) Medical; 3) Clinical; 4) Non-STEM; 5) Ambiguous
Mediator Set 1:			
Parents' aspirations (Age 5)	"Here is a question about your aspirations about [child's name] as a parent. Please select for each of the categories below that best describes the degree of your aspirations. 1) High earnings; 2) Gaining fame; 3) Achieving high status; 4) Willingness to help others; 5) A happy family; 6) Prioritizing leisure and hobbies over work	Each parent	Bifurcated into: 0 "Doesn't matter at all" and "Doesn't matter 1 "Somewhat aspire to" and "Strongly aspire to"
Parenting styles (Age 3 or 7)	Composite scores from a battery of parental reports on three separate parenting domains: 1) Social; 2) Didactic; 3) Limit-setting (Note: Each dimension is a stand-alone variable)	Each parent (social dimension asked only to mothers)	Composite score (First factor from factor analysis)
Home stimulation (Grade 2)	"Now I'd like to talk with you about [child's name]'s activities with family members. In a typical week, how often do you or any family member do the following things with [child's name]? 1) Read books; 2) Tell stories; 3) Sing songs; 4) Arts and crafts; 5) Household chores, like cooking, cleaning, setting the table, or caring for pets; 6) Play games or do puzzles; 7) Talk about nature or do a science project; 8) Build something or play with construction toys; 9) Play a sport or exercise together; 10) Learn to read and write numbers. (Note: Each component is a stand-alone variable)	Each parent	1 "None 2 1–2 times 3 3–6 times 4 "Every day; Converted to weekly frequencies using midpoints

Variables	Question(s)/Description	Respondent(s)	Response levels
Academic pressure (Grade 2)	Composite score of parental involvement and pressures for academic achievement based on 17 question items (see Table A1 in the Appendix)	Each parent	Composite score (First factor from factor analysis)
Mediator Set 2: Ability and interest			
Cognitive ability (Grade 2)	Multi-Factorial Intelligence Test (M-FIT): 1) Word application ability; 2) Verbal analogy; 3) Graphical representation ability; 4) Numerical ability; 5) Spatial perception; 6) Reasoning ability (Note: Each dimension is a stand-alone variable)		Standardized scores (mean 50; s.d. 10)
Self-assessed school subject interests (Grade 2)	"How much does [child's name] enjoy [Korean/ Math] classes?	Child	Likert scale: 1 "Don't enjoy to 4 "Enjoy a lot
Mediator Set 3: Life goals			
Child's life goal (Grade 2)	"What kind of person do you want to become when you grow up? A person who... 1) Has high earnings; 2) Gains fame; 3) Has a high status within our society; 4) Is willing to help others; 5) Has a happy home; 6) Prioritizes hobbies and leisure over work	Child	Choose one among the six levels
B. KELS (n = 4,533)			
Outcome variable			
STEM aspiration (Grade 11)	"What job do you want when you grow up? Provide us with one detailed answer. [Verbatim response]	Child	Classified into: 1) STEM; 2) Medical; 3) Clinical; 4) Non-STEM; 5) Ambiguous
Mediator variable			
Occupational aspiration (Grade 5)	Same as above	Same as above	Same as above

The original questionnaires were all provided in Korean, and the English translations are our own. Refer to Tables A1 and A2 in the appendix for more detailed information about the measures as well as other variables used in the analysis.

Measures

Outcome Variables. In the PSKC, occupational aspirations were first collected in 3rd grade; in KELS, they were collected every wave. We use 5th- and 11th-grade responses from KELS. Both surveys elicited open-ended (verbatim) occupational answers (see Table 1). KELS respondents were asked to name a single occupation, while PSKC allowed two. For the PSKC mediation analysis, respondents listing a STEM occupation as either choice were classified as STEM-aspiring.

Mediator Variables. Table 1 overviews our mediators (for additional details, see Tables A1 and A2 in the appendix). For the PSKC analysis, we grouped mediators into three sets, treating variables within a set en bloc. The first set captures parental influences: (1) aspirations for the child, (2) parenting styles, (3) home educational stimulation, and (4) academic pressures. These measures attempt to capture gender-biased parenting values and socialization practices emphasized in expectancy-value models (Eccles 1983). For variables collected across multiple waves, we use responses closest in time to, but preceding, the outcome measurement.

The second mediator set centers on cognitive ability—measured via the Multi-Factorial Intelligence Test (M-FIT) in 2nd grade—and self-reported interest in math and Korean, long linked to the STEM gender gap. The M-FIT covers six dimensions (word application, verbal analogy, graphical representation, numerical ability, spatial perception, and reasoning; 20 items each). We standardize and include them as separate variables. Self-reported interest in math and Korean provides an additional measure of academic orientation.

Informed by the literature on the role of work-life preferences (Hakim 2000) and the gendered role of values and identities (Wegemer and Eccles 2019), the third mediator set examines life goals. In 2nd grade, children selected one of six goals (Table 1); each goal, but for one (reference), is represented by a dummy variable. In the KELS analysis, we treat 5th-grade occupational aspirations as a mediator of the relationship between gender and 11th-grade occupational plans.

Adjustment Variables. The PSKC dataset includes 46 variables that serve as either baseline or immediate (i.e., gender-impacted) covariates. These measures span family background, early cognitive and emotional development, and parental characteristics. In KELS, we utilize 43 variables capturing children's test scores, attitudes, family background, and school-level factors. Detailed lists and descriptions of these variables, including corresponding questionnaire items and scales, are provided in the appendix (Tables A1 and A2).

Coding of Occupations. We classified the open-ended occupational responses from both PSKC and KELS into four categories: (1) STEM, (2) professional medical, (3) clinical, and (4) non-STEM fields, following a specified procedure.[8] We map each of the 450 broad occupation groups in the 7th Korean Standard Classification of Occupations (KSCO) to one of these four fields.[9] We consider STEM occupations to be those that require bachelor's degrees with intensive math or science coursework, whereas professional medical careers (e.g., physician, dentist, pharmacist, veterinarian) necessitate professional or extended post-secondary training (at least six years) in Korea. We then assign each verbatim response to the corresponding KSCO category and, thus, to one of the four fields.[10] Lastly, an "ambiguous" category captures responses too vague to classify (e.g., "I don't know," "A well-paying job").

Empirical Approach

Target Parameters

We estimate the gender gap in STEM aspirations with randomized-intervention analog (RIA) estimands (VanderWeele et al. 2014). Let $G = 1$ for girls and $G = 0$ for boys; $Y \in \{0, 1\}$ indicate a STEM aspiration; $\mathbf{M} = (M^{(1)}, ..., M^{(K)})$ denote K candidate mediators; $\mathbf{C}$ collect baseline covariates assumed unaffected by gender (e.g., parental education); and $\mathbf{L} = (L^{(1)}, ..., L^{(J)})$ gender-affected variables that may confound the mediator–outcome relationship (e.g., reading habits). Write $Y\{g, \mathbf{m}\}$ for the potential outcome under gender g and

[8] Following Morgan et al. 2013 and Weeden et al. 2020, we distinguish medical fields from STEM. Finer divisions by math intensity are difficult because many young respondents simply listed broad orientations, such as "a scientist."

[9] KSCO, administered by Statistics Korea, is analogous to the US Standard Occupational Classification System.

[10] Importantly, we categorize each response before conducting our main analyses to ensure objectivity.

mediators **m** and let $\mathbf{M}_{G=g|\mathbf{c}}$ be a random draw from the empirical distribution of **M** among respondents with $G = g$ and $\mathbf{C} = \mathbf{c}$.[11]

Our target presents the portion of the overall gender gap is the RIA version of the average treatment effect (RI-ATE)[12]

$$\text{RI-ATE} = \mathbb{E}\left[Y\left(1, \mathbf{M}_{g=1|\mathbf{c}}\right) - Y\left(0, \mathbf{M}_{g=0|\mathbf{c}}\right)\right],$$

which compares girls with boys while setting the mediators to levels drawn randomly from their own population distributions, given the baseline covariates $\mathbf{C} = \mathbf{c}$.[13]

To assess the explanatory power of the mediators, we decompose RI-ATE into the randomized intervention analog of the natural direct (RI-NDE) and indirect effects (RI-NIE)

$$\text{RI-ATE} = \underbrace{\mathbb{E}\left[Y\left(1, \mathbf{M}_{g=0|\mathbf{c}}\right) - Y\left(0, \mathbf{M}_{g=0|\mathbf{c}}\right)\right]}_{\equiv \text{RI-NDE}} + \underbrace{\mathbb{E}\left[Y\left(1, \mathbf{M}_{g=1|\mathbf{c}}\right) - Y\left(1, \mathbf{M}_{g=0|\mathbf{c}}\right)\right]}_{\equiv \text{RI-NIE}}$$

The RI-NDE is the STEM aspirational gap if both genders had mediator values drawn from the boys' distribution; RI-NIE reflects the additional gap eliminated by shifting girls' mediator distributions to boys'. In our KELS analysis, RI-NDE is the 11th-grade gap persisting after equating 5th-grade aspirations, whereas RI-NIE is eliminated by that equalization.

When finer insights are needed, we split RI-NIE into two subcomponents: the pure indirect effect (RI-PIE) and mediated interaction effect (RI-INT)

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[11] We recognize the ongoing debate over whether non-manipulable traits such as gender may be treated as causes. We adopt the view of (Glymour and Glymour 2014) that immutable traits can serve as causes in an etiological sense, identifying sources of inequity even when no simple policy lever exists. We read $Y(g, \mathbf{m})$ not as the outcome after altering biology, but possibly as the outcome where relevant actors *perceive* the child as gender g (Greiner and Rubin 2011). This accords with Pearl (2018, 2019): in Pearl's structural-causal semantics, $\text{do}(G = g)$ denotes a *minimal* conceptual operation that simply sets G while leaving all other mechanisms untouched, so potential outcomes remain legitimate without a practical toggle for G.

[12] To be precise, since the baseline covariates **C** and gender-impacted covariates **L** are defined for each mediator set (see Tables A1 and A2 in the appendix), the dimensions of J and K, as well as the specific variables within **C**, vary accordingly.

[13] Because RI-ATE depends on the mediator distribution, the "composition" equality $E\left[Y\left(g, M_{G=g|\mathbf{c}}\right) - Y\left(g', M_{G=g'|\mathbf{c}}\right)\right] \neq E\left[Y(g) - Y(g')\right]$ generally fails; hence RI-ATE is specific to each mediator distribution.

$$\text{RI-NIE} = \mathbb{E}[Y\left(0, \mathrm{M}_{g=1|\,\mathrm{c}}\right) - Y\left(0, \mathrm{M}_{g=0|\,\mathrm{c}}\right)$$
$$\underbrace{}_{\equiv\text{RI-PIE}}$$
$$+(\mathbb{E}\left[Y\left(1, \mathrm{M}_{g=1|\,\mathrm{c}}\right) - Y\left(0, \mathrm{M}_{g=1|\,\mathrm{c}}\right)\right] - \mathbb{E}\left[Y\left(1, \mathrm{M}_{g=0|\,\mathrm{c}}\right) - Y\left(0, \mathrm{M}_{g=0|\,\mathrm{c}}\right)\right])$$
$$\underbrace{}_{\equiv\text{RI-INT}}$$

The RI-PIE quantifies the gender effect due exclusively to the mediators, assuming no gender-mediator interaction—the expected difference attributable to the mediators alone if their effects were uniform across genders. The RI-INT captures mediated effects attributable to gender-specific differences in mediator impacts, and is non-zero only when mediator distributions differ between genders and mediator effects on the outcome vary by gender.

Identification and Estimation

All the target parameters are identified under: (i) No unmeasured $G - Y$ confounding; (ii) no unmeasured $M - Y$ confounding; (iii) no unmeasured $G - M$ confounding.[14] Because these are demanding, we treat estimates as the best attainable approximation and discuss potential violations in the results.

Following Wodtke and Zhou (2020), we apply regression-with-residuals to handle gender-affected confounders. We fit

$$\ell^{(j)}\left(\mathbb{E}\left[L^{(j)}|\ G, \mathbf{C}\right]\right) = \gamma_0^{(j)} + \gamma_1^{(j)} G + \gamma_4^{(j)\prime} \tilde{\mathbf{C}}$$
$$\ell^{(k)}\left(\mathbb{E}\left[M^{(k)}|\ G, \mathbf{C}\right]\right) = \theta_0^{(k)} + \theta_1^{(k)} G + \theta_3^{(k)\prime} \tilde{\mathbf{C}}$$
$$\mathbb{E}\left[Y|\ G, \mathbf{C}, \mathbf{L}, \mathbf{M}\right] = \beta_0 + \beta_1 G + \beta_2^{(1)} M^{(1)} + \ldots + \beta_2^{(K)} M^{(K)} + \beta_3^{(1)} G M^{(1)} + \ldots + \beta_3^{(K)} G M^{(K)} + \beta_4^{'} \mathbf{L}^{\perp} + \beta_5^{'} \tilde{\mathbf{C}}$$

where $\ell(\cdot)$ is the canonical link (e.g., the identity link for (quasi-)continuous variables and the logistic link for discrete variables), $\tilde{\mathbf{C}} = \mathbf{C} - \mathbb{E}[\mathbf{C}]$ represents the baseline confounders after mean-centering, and $\mathbf{L}^{\perp} = \mathbf{L} - \mathbb{E}\left[\mathbf{L}|\ \mathbf{C}, G\right]$ is the residualized $\mathbf{M} - Y$ confounders also affected by G.

[14] Formally, i) $Y(g, \mathbf{m}) \perp\!\!\!\perp G \mid \mathbf{C}$; ii) $Y(g, \mathbf{m}) \perp\!\!\!\perp M \mid \mathbf{C}, \mathbf{L}$; iii) $\mathbf{M}(g) \perp\!\!\!\perp G \mid \mathbf{C}$, where $\perp\!\!\!\perp$ denote conditional independence. Specifically, RI-ATE requires only (i). Standard assumptions such as positivity, consistency, and no-interference are implicitly applied (see Morgan and Winship 2015).

Closed-form plug-ins gives

$$\text{RI-NDE} = \beta_1 + \sum_k \beta_3^{(k)} \mathbb{E}\left[M^{(k)} \mid G=0, \mathbf{C}=\mathbf{c}\right],$$

$$\text{RI-PIE} = \sum_k \beta_2^{(k)} \left\{\mathbb{E}\left[M^{(k)} \mid G=1, \mathbf{C}=\mathbf{c}\right] - \mathbb{E}\left[M^{(k)} \mid G=0, \mathbf{C}=\mathbf{c}\right]\right\},$$

$$\text{RI-INT} = \sum_k \beta_3^{(k)} \left\{\mathbb{E}\left[M^{(k)} \mid G=1, \mathbf{C}=\mathbf{c}\right] - \mathbb{E}\left[M^{(k)} \mid G=0, \mathbf{C}=\mathbf{c}\right]\right\},$$

$$\text{RI-NIE} = \sum_k \left(\beta_2^{(k)} + \beta_3^{(k)}\right) \left\{\mathbb{E}\left[M^{(k)} \mid G=1, \mathbf{C}=\mathbf{c}\right] - \mathbb{E}\left[M^{(k)} \mid G=0, \mathbf{C}=\mathbf{c}\right]\right\}$$

All standard errors are computed using the nonparametric bootstrap with 1,000 replications.[15]

Findings

Gender Disparities in Occupational Aspirations

Table 2
Gender Differences in STEM Aspiration in Grades 3, 5, and 11.

	PSKC (Grade 3)						KELS (Grade 5)		KELS (Grade 11)	
	STEM/MED		STEM		1st Choice		STEM		STEM	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Percent selected	49.2	26.9	42.1	7.2	28.6	3.4	22.0	3.2	22.6	9.2
(S.E.)	(2.2)	(1.9)	(2.2)	(1.2)	(2.0)	(0.8)	(1.0)	(0.4)	(1.0)	(0.6)
Absolute disparity (in pp.)	22.3		34.9		25.2		18.8		13.4	
Boys-to-girls ratio	1.8		5.8		8.4		6.7		2.5	
Observations	1,360		1,360		1,360		4,533		4,533	

The first row presents the estimated probability of choosing each type of aspiration, with standard errors in the second row. The third row reports the gender gap (in percentage points), and the fourth row shows the ratio of boys to girls for each aspiration category.

15 Bootstrapped samples are drawn with probability proportional to each respondent's analytical/sampling weight.

Table 2 presents occupational aspirations across grades 3, 5, and 11. In the PSKC 3rd-grade data, 49.2 percent of boys and 26.9 percent of girls express interest in STEM or professional medical occupations—a 22.3 percentage-point gap indicating boys are approximately 1.8 times more likely to aspire to these careers. Separating STEM from medical fields, the differences become more pronounced. As shown in the third and fourth columns, in 3rd grade, 42.1 percent of boys reported an interest in a STEM career compared with only 7.2 percent of girls—a 34.9 percentage-point gap, suggesting boys are nearly six times more inclined toward STEM. Considering only top-choice aspirations (fifth and sixth columns), 28.6 percent of boys versus 3.4 percent of girls select STEM first, making boys over eight times more likely to name a STEM occupation as their primary aspiration.

The KELS data show how these disparities evolve. The seventh and eighth columns reveal that in 5th grade, 22.0 percent of boys aspire to a STEM occupation compared to 3.2 percent of girls, mirroring the PSKC 3rd-grade findings. This consistency across comparable target populations strengthens our confidence in the observed patterns. The final two columns show the aspirations of 11th-grade students who have been assigned to their field-of-study tracks. At this stage, 22.6 percent of boys express an interest in STEM, compared to 9.2 percent of girls. Although the gap narrows, boys remain 2.5 times more likely to pursue STEM.

Overall, these findings highlight pronounced gender differences in career aspirations during the early years of education. In 3rd and 5th grades, only 3 to 7 percent of girls report an interest in STEM, compared to 42 to 49 percent of boys. Notably, girls show a stronger inclination toward professional medical roles, suggesting their limited STEM interest does not reflect a broader lack of career ambition. Although the disparity narrows by 11th grade, boys remain substantially more likely to pursue STEM throughout schooling.

Potential Mechanisms of Early Gender Disparities in STEM Aspirations

We next examine whether the proposed mediators in Table 1 help explain the third-grade gender gap. Before the formal mediation analysis, we first assess the raw gender differences in each mediator.

As an illustration, Figure 2 shows parental aspirations by child's gender. Differences are modest, though fathers emphasize material success ("becoming rich") more for sons, while mothers encourage leisure activities

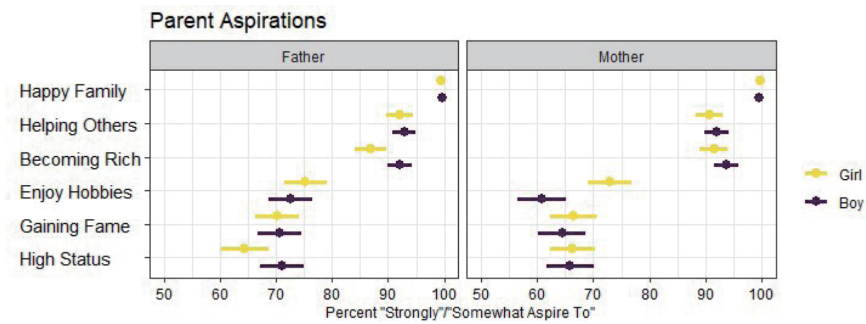

FIG. 2.—PARENTS' ASPIRATIONS ABOUT THE CHILD BY CHILD'S GENDER AND PARENT IN PSKC.

Note: parental aspirations (right panel) were measured when the respondents were five. Vertical bars represent 95-percent confidence intervals (n = 1,360).

("enjoy hobbies") more for daughters. In-home stimulation (results not shown) shows small differences, especially among fathers, who engage more in construction play with sons and storytelling with daughters. Overall, while these parenting measures lack marked gender differences, they could still potentially explain a portion of the 3rd-grade STEM aspiration gap if they substantially influence early STEM aspirations.

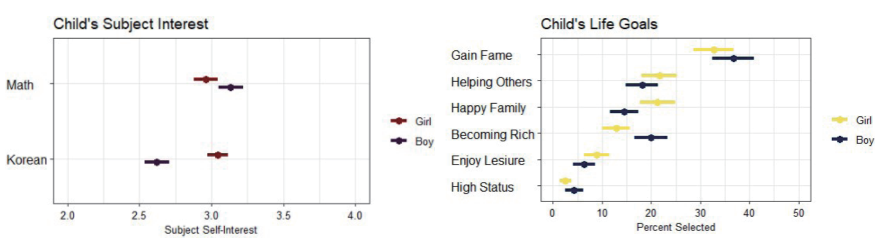

FIG. 3.—SELF-RATED INTEREST IN SCHOOL SUBJECTS AND LIFE GOALS BY GENDER IN PSKC.

Left panel: average interest in each subject (higher = greater interest). Right panel: proportion of children selecting each category as their primary life goal. Vertical bars are 95-percent confidence intervals (n = 1,360).

Figure 3 (left panel) shows gender differences in self-rated subject interest. Girls report 0.4 points higher interest in Korean (on a four-point

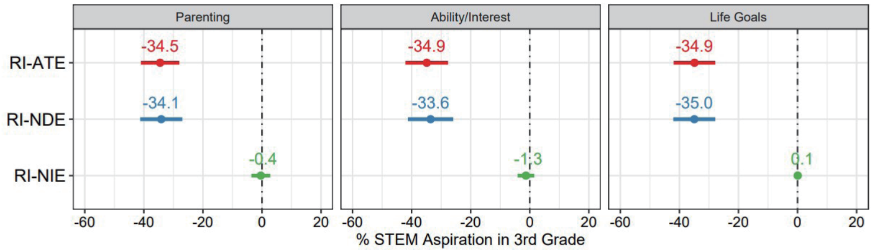

Fig. 4.—Mediation Analysis of 3rd Grade STEM Aspirations.

Vertical bars represent 95-percent confidence intervals (n = 1,360).

scale) but are 0.2 points lower in math. Additional results (not shown), indicate that girls outperform boys verbally, whereas boys outperform girls in numeric, spatial, and reasoning domains—consistent with girls' relative verbal advantage (Breda and Napp 2019). The right panel of Figure 3 presents 2nd-grade life goals: boys are about 7 percentage points more likely to select external achievements ("being rich"), while girls more often value a fulfilling family life.

Do these gendered patterns explain the early STEM aspiration gap? Figure 4 presents our mediation analysis, adjusting for the relevant confounders (listed in Table A1 of the appendix). The binary outcome is 1 if a STEM occupation was among the top two 3rd-grade aspirations, and 0 otherwise. In Figure 4, RI-NIE (green; bottom panel) represents the gap portion explained by a given mediator set, RI-NDE (blue; middle panel) is the remaining gap after mediator equalization, and RI-ATE (red; top panel) is the overall gap, approximately 35 percentage points across models.

The left panel shows that parenting disparities have a negligible impact on the aspiration gap (disparity eliminated ≈ -0.4 percentage points; p = .91). The middle panel reflects cognitive skills and subject interests, yielding a disparity of -1.3 percentage points (95 percent C.I. = [-5.2, 2.6]; p = 0.51), which collectively accounts for under 4 percent of the total disparity (i.e., -1.3/-34.9 ≈ 0.04). The right panel, examining life goals, again shows near-zero mediation (0.1 percentage points; p = .96). In a robustness check, we explored whether overall null effects reflect opposing variable impacts within a mediator set. Grouping only effects sharing the same sign, the disparity reduction is at most 1.9, 1.8, and 0.6 percentage points—none exceeding 10 percent of the total disparity or reaching significance at the 90 percent level.

Overall, given likely positive selection into mediators (e.g., children with higher math interest may possess unobserved traits boosting STEM aspirations), our disparity-eliminated measure should be an upper bound. Even under this favorable assumption, the proposed mediators play a minimal role in explaining the 3rd-grade STEM gender gap.[16]

Continuity of Early STEM Aspirational Gaps to Late Adolescence

Having established significant gender disparities in childhood STEM aspirations, we explore whether these persist into adolescence. Using KELS, Figure 5 displays the joint distribution of career aspirations in 5th and 11th grades by gender. Each cell shows the proportion of 11th-grade aspiration categories within each 5th-grade group (columns sum to 100 percent). For 5th grade, clinical fields are classified as non-STEM due to minimal interest

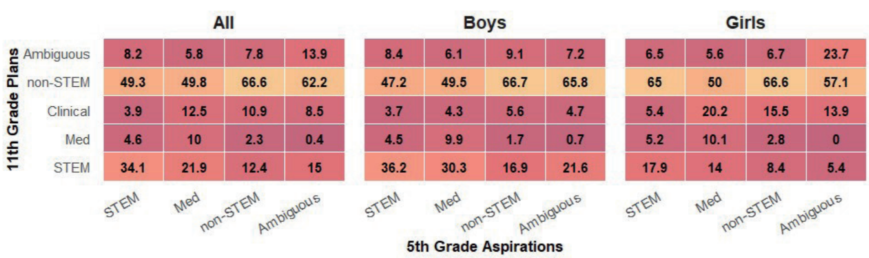

FIG. 5.—THE JOINT DISTRIBUTIONS OF 5TH AND 11TH GRADE CAREER ASPIRATIONS BY GENDER.

Each cell represents the proportion of each 11th-grade aspiration category within each 5th-grade group, where column proportions sum to 100 percent.

among boys (only three indicating a preference).

The middle and right panels reveal considerable fluidity but also notable persistence. Among girls with 5th-grade STEM interests, 17.9 percent maintained them into 11th grade versus 8.4 percent of girls with non-STEM aspirations—more than double. For boys, the pattern is stronger: 36.2 percent

[16] A limitation is that this analysis does not account for likely correlations and causal dependencies among mediator sets. For instance, the ability/interest set may be endogenous with respect to life goals. In that case, the mediation effects of ability/interest variables might be overestimated. Establishing precise causal structure among mediators a priori is extremely challenging (see Daniel et al. 2015). Nonetheless, given consistently small mediating effects, any bias from not modeling these dependencies should have minimal impact on our conclusion.

of those with 5th-grade STEM aspirations continued, versus 16.9 percent with non-STEM goals (a 19.3 percentage-point difference). Overall (left panel), children with 5th-grade STEM aspirations are about three times (21.7 percentage points) more likely to maintain them than those initially aspiring to non-STEM careers.

Mediation Analysis

Table 3
Changes in Gender Disparities in STEM Occupational Plans in the 11th Grade through Equalization of 5th-Grade Occupational Aspirations.

	Estimate		95% CI	% Attributable	p-value
	Effect size	(S.E.)			
Total gap (RI-ATE)	-13.0	(1.8)	[-16.6, -9.4]	-	< .001
Gap remaining (RI-NDE)	-12.1	(2.2)	[-16.4, -7.8]	92.7%	< .001
Gap eliminated (RI-NIE)	-0.9	(1.2)	[-3.3, 1.4]	7.3%	.440
Due to pure mediation (RI-PIE)	-2.9	(0.8)	[-4.5, -1.3]	22.3%	< .001
Due to mediated-interaction (RI-INT)	2.0	(1.4)	[-0.9, 4.8]	-15.0%	.170

All estimates are in percentage-point scales. The percent attributable represents the proportion of the estimated total disparity attributable to each component (n = 4,353).

Although Figure 5 reveals clear patterns, Table 3 provides additional validation via covariate-adjusted mediation analysis. The total disparity (RI-ATE) is -13.0, indicating girls are 13.0 percentage points less likely than boys to have 11th-grade STEM aspirations. The estimated disparity eliminated (RI-NIE) is -0.9 (p = .44), suggesting that equalizing 5th-grade aspirations would reduce the 11th-grade gap by merely 0.9 percentage points.

A closer examination reveals that the negligible overall mediating effect results from two opposing components offsetting each other. As explained, the RI-NIE can be decomposed into a pure mediation component (RI-PIE) and a mediated interaction (RI-INT) component. The pure mediation effect quantifies the potential reduction if girls had boys' 5th-grade aspirations *and* these influenced both genders uniformly. The mediated interaction (RI-INT) captures the mediating effect based on gender-specific impacts of 5th-grade aspirations on later STEM plans.

The pure mediation component is -2.9 percentage points (p < .001).

Under our identification assumptions, if girls' 5th-grade aspirations matched boys' and persisted equally into late adolescence, the 11th-grade gap would narrow to 10.1 percentage points (i.e., −13.0 − (−2.9)), with this component accounting for approximately 22.3 percent of the total gap (i.e.,−2.9 / −13.0 ≈ 0.223). The mediated interaction (2.0 percentage points) suggests boys' STEM aspirations persist more strongly from 5th to 11th grade — consistent with Figure 5 — though this estimate carries considerable uncertainty (s.e. = 1.4; $p = .17$).

In summary, gender disparities in late childhood aspirations may be meaningful precursors to later STEM disparities. Two factors appear to amplify the male advantage: boys are far more inclined toward STEM in early years, and their STEM interests remain more stable into adolescence. Nonetheless, the latter observation should be interpreted cautiously given the limited statistical power associated with the estimate.

Conclusions and Discussion

Despite continued efforts to promote equity, occupational gender segregation remains persistent. Bridging childhood experiences with emerging research, we examined the existence, causes, and consequences of gender disparities in occupational aspirations early in life, using two nationally representative samples of Korean students and analyzing verbatim responses to capture aspirations with greater precision.

Korean boys and girls form markedly distinct occupational preferences from an early age, differences not explained by our measures of parenting, math skills and interests, or work–family values. Although aspirations remain fluid for many, early divergence in STEM career goals persists meaningfully into late adolescence, likely contributing to boys' higher rates of STEM pursuit.

Among 3rd graders, our results echo findings (Archer et al. 2010) distinguishing between "doing" science and "becoming" a scientist (see also Zhao et al. 2024). Although boys and girls demonstrate similar math and science abilities, a substantially larger share of girls reject science careers as "not for me," highlighting gendered occupational norms internalized much earlier than typically captured in population-level research. At the same time, our study does not identify the precise mechanisms driving these early differences. Given likely positive selection, our findings help rule out certain explanations while highlighting the need for deeper inquiry. For example, our parenting measures omit key dimensions such as "science capital" (Archer et al. 2012; DeWitt et al. 2016). Conclusions about the limited role of parenting thus remain tentative; future work should incorporate a broader range of parental and household-level factors.

Another notable pattern is the persistence of aspirational gaps from 5th to 11th grade despite children's limited occupational knowledge. One possibility is that early preferences become entrenched through a path-dependent process, suggesting interventions may be most effective when introduced early. Alternatively, these patterns could reflect unmeasured common causes—such as gendered status beliefs (Ridgeway 2011)—in which case the narrowing of gaps in adolescence may indicate a waning influence of early norms. Still, we caution against overstating early aspirations or treating them as fixed dispositions. Over three-quarters of the adolescent STEM gender gap remains unexplained by early differences, and substantial shifts occur across primary and secondary education. This challenges a linear "pipeline" and points to a more fluid, socially embedded process (Ma 2011). Future research should track these transitions and identify the forces driving them.

Comparatively, the STEM aspiration gap among Korean adolescents mirrors trends in other developed and East Asian countries (Liu 2018; Sikora 2019; Stoet and Geary 2013, 2022; e.g., Weeden et al. 2020). As elsewhere, the gap surpasses commonly cited explanations. Math ability and interest exert only minor influence on occupational preferences, consistent with prior findings (Mann and DiPrete 2013; Morgan et al. 2013; Riegle-Crumb et al. 2011; Xie and Shauman 2003).

However, further cross-national evidence is essential to determine whether our findings hold more broadly. Korea's competitive educational system (Park et al. 2011; Park and Kim 2013), rigid tracking, and dual labor market (Schauer 2018) may accelerate career commitments. Our childhood aspiration gap exceeds that in England's ASPIRES project (Archer Ker et al. 2013), though the adolescent gap aligns with patterns elsewhere (Stoet and Geary 2018). Korea's pronounced gender inequality—reflected in one of the largest OECD gender pay gaps (Ortiz-Ospina and Roser 2018)—may also reinforce these disparities, though the role of societal egalitarianism remains contested (Stoet and Geary 2018; Charles 2017; cf. Mann and DiPrete 2016). Korea also ranks high in international student achievement, linked to increasing STEM aspiration gender gaps (Mann and DiPrete 2016).[17]

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[17] For comparative studies on drivers of gender disparities in early career aspirations, see (Charles

As DiPrete and Buchmann (2013, p. 195) observe, "we do not know when during childhood STEM orientations typically stabilize and produce long-term implications for academic degrees and occupational choices." Significant gaps remain in understanding how the gender composition of STEM fields interacts with early-life experiences. By leveraging unique population data from Korea, our study offers new evidence on a formative yet underexamined stage, shedding light on the origins of gender disparities in STEM aspirations.

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2017; Han 2015, 2016; Mann and DiPrete 2016; Stoet and Geary 2018)

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Appendix

Supplementary Details on Data and Measurement

Panel Study on Korean Children

The Panel Study on Korean Children (PSKC) was initiated in 2008, with a probability sample of 2,150 newborns born in Korea between April and July of the same year to represent its target population of the entire 2008 Korean birth cohort. The initial survey involved the parents of these selected individuals, with subsequent annual interviews that gradually included the children themselves and their educators in childcare and elementary education settings. We utilize data from various survey waves from the first ten waves collected between 2008 and 2017.

From the initial sample of 2,150 respondents, we excluded 552 respondents (i.e., 26 percent of the initial sample) due to unsuccessful follow-up in the tenth survey wave when the study first collected data on occupational aspirations. Among the remaining 1,598 respondents, we further omitted 232 respondents who did not provide information on occupational aspirations. These exclusions resulted in an analytical sample of 1,366 respondents. In all analyses, we employed sampling weights provided in the PSKC, which account for unequal selection probabilities and differential attrition rates.

Korean Educational Longitudinal Study 2013

The Korean Educational Longitudinal Study 2013 (KELS) is a longitudinal study that began with a sample of 7,324 grade 5 students from 242 elementary schools throughout the nation in 2013. The base-year target population is 5th graders in Korea in 2013. Yearly interviews were conducted with the students involved in the study, as well as their parents, teachers, and school principals.

For our research purposes, we employed data from the initial and seventh rounds of KELS, collected when the participants were in the 5th and 11th grades, respectively. Out of the initial 7,324 student participants, we excluded 1,112 respondents (i.e., 15 percent of the initial sample) due to panel attrition. We then refined our sample to include only those attending academic high schools, which resulted in excluding 1,216 participants who were in vocational or specialized schools in arts or sports.[18] We further dropped 462 respondents who failed to provide valid responses concerning their occupational plans during either the 5th or 11th grade. After these exclusions, our final analytical sample consisted of 4,533 students.

To account for panel attrition and endogenous selection bias, we sequentially estimate the probabilities of 1) attending an academic high school and 2) providing valid occupational aspirations in the two survey waves. These probabilities were derived from separate logistic regressions, using the background variables listed in Table A2 of the appendix as predictors. The (multiplicative) inverse of each probability was sequentially multiplied to create an analytical weight, which was then utilized in all subsequent analyses. Hence, while all KELS findings are derived from an analytical sample of academic high school respondents who offered valid occupational aspirations, they are weighted to reflect the baseline target group. We handled any missing data in PSKC and KELS using a random-forest algorithm suggested by Stekhoven and Bühlmann (2012).

Measurement Details for PSKC Variables

Table A1
Description of the Mediator and Adjustment Variables of the Analysis of PSKC.

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Parents' aspirations	Mother	Here is a question about your aspirations for [child's name] as a parent. Please select for each of the categories below that best describe the degree of your aspirations. 1) High earnings; 2) Gaining fame; 3) Achieving high status; 4) Willingness to help others; 5) A happy family; 6) Prioritizing leisure and hobbies over work (Note: Each component is treated as a separate variable)	Bifurcated into 1 Doesn't matter at all Doesn't matter 0 Somewhat aspire to Strongly aspire to	6	NA
	Father	Same as the above	Same as the above	6	NA

18 Despite a considerable college enrollment rate among vocational school students in Korea, less than a quarter enroll in four-year universities, in contrast with about 70 percent among academic high school students (Byun and Park 2017).

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Parenting style: Social (Composite score)	Mother	Here are questions about your parenting practices regarding [child's name]. For each statement, please check the appropriate options. 1) I spend my time playing with my child 2) I immediately and appropriately respond when my child seems uncomfortable 3) I fulfill the tasks (e.g., feeding, washing, dressing) my child needs 4) I express positive, affectionate, and warm attention to my child 5) I am somewhat flexible in my expectations about the child's behavior 6) I understand what my child wants and needs 7) I provide opportunities for my child to gain various social experiences through playgroups or gatherings 8) I spend my time talking with or exchanging a conversation with my child 9) When my child seeks attention, I respond immediately and positively.	Likert scale: 1 Strongly disagree to 5 Strongly agree; Composite score constructed	4	NA
Parenting style: Didactic (Composite score)	Mother	Here are questions about your parenting behavior regarding [child's name]. For each question, please choose the option that best matches your general behavior. 1) I have intimate time with my child 2) I respect my child's views and allow them to be expressed 3) I talk and play with my child 4) I set the family rules together with my child 5) I explain things when my child asks 6) I express my attention to my child's actions and achievements	Likert scale: 1 Strongly disagree to 5 Strongly agree; Composite score constructed	8	NA
	Father	Same as the above	Same as the above	8	NA

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Parenting style: Limit setting (Composite score)	Mother	Here are questions about your parenting behavior regarding [child's name]. For each question, please choose the option that best matches your general behavior. 1) I strictly enforce good manners even if my child is young 2) When my child does something wrong, I always punish and make them reflect on it 3) I make my child obey my words 4) I set the rules and disciplines, and make my child keep to them 5) I restrict my child's behaviors as a way to educate them at home 6) I do not put up with the child's irritability	Likert scale: 1 Strongly disagree to 5 Strongly agree; Composite score constructed	8	NA
	Father	Same as the above	Same as the above	9	NA
Home stimulation and parent–child communication	Mother	Now I'd like to talk with you about [child's name]'s activities with family members. In a typical week, how often do you or any family member do the following things with [child's name]? 1) Read books to [child's name]? 2) Tell stories to [child's name]? 3) Sing songs with [child's name]? 4) Help [child's name] to do arts and crafts? 5) Involve [child's name] in household chores, like cooking, cleaning, setting the table, or caring for pets? 6) Play games or do puzzles with [child's name]? 7) Talk about nature or do science projects with [child's name]? 8) Build something or play with construction toys with [child's name]? 9) Play a sport or exercise together? 10) Learn to read, write, and count numbers with [child's name]? (Note: Each component is a stand-alone variable)	1 None 2 1–2 times 3 3–6 times 4 Everyday; Converted to weekly frequencies using midpoints	9	NA
	Father	Same as the above	Same as the above	9	NA

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Academic pressure (Composite score)	Mother	Regarding [child's name]'s academics, please check the option that best describes how much you are engaged in the following activities. 1) I teach [child's name] myself 2) I constantly monitor [child's name]'s school academics and homework 3) I interact with the parents of [child's name]'s friends to gather information on education or homework 4) I search the internet to gather information on [child's name]'s education or homework 5) I often visit the library with [child's name] to foster an academic atmosphere 6) I often tell [child's name] to study 7) I set an example for [child's name] to have good learning attitudes 8) To buy time for [child's name] to study, I refrain from making them participate in various family events 9) I try not to leave home when [child's name] is present 10) I know well of and monitor [child's name]'s all daily schedules 11) I travel or engage in cultural activities with [child's name] 12) Even if it interferes with studying, when necessary, I make the child run an errand or help with housework 13) I encourage playing a lot with friends to [child's name] cultivate their personality 14) I sometimes tell [child's name] to make be friends with those who are thriving academically 15) I often ask about [child's name]'s close friends' grades or their family background 16) I watch over my child's nutrition and physical health to prevent various supplementary educational activities damaging their health 17) I send my child to cram schools or invite personal tutors so that my child doesn't fall behind others	Likert Scale: 1 Disagree 2 Somewhat disagree 3 Agree 4 Strongly agree; Composite score constructed	9	NA

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Baseline covariates (C)					
Planned birth	Mother	Perceptions of pregnancy and childbirth are unique to everyone. Here is a list of questions about your current pregnancy. Did your couple plan on the current pregnancy?	1 Only myself 2 Only the partner or Planned by both 3 Planned by neither	1	1, 2, 3
Parents' gender preference	Mother	What was your preference for the child's sex during pregnancy?	1 Male 2 Female 3 No preference	1	1, 2, 3
	Mother (Father)	What was the father's preference for the child's sex during pregnancy?	Same as the above	1	1, 2, 3
Pregnancy depression (Composite score)	Mother	How often did you experience the following feelings a month before childbirth? 1) Anxiety? 2) Lethargy? 3) Restlessness? 4) Feeling everything is hard? 5) Worn out from sorrow? 6) Worthlessness?	Likert Scale: 1 Not at all to 5 All the time	1	1, 2, 3
Birth order	Mother (Child)	Birth order of the sampled child		1	1, 2, 3
Parenting knowledge	Mother	The following questions ask about children's normal behavior. Each item describes what a typical child might be like or what could affect the child's growth and behavior. Answer each item based on your knowledge of children in general. 1) Children often will keep using the wrong word for a while, even when they are told the right way to say it. 2) Infants understand only words they can say. 3) If children are shy or fussy in new situations, it means they have an emotional problem. 4) The way a child is brought up has little effect on how smart he (she) will be	1 Agree 2 Disagree 3 Unsure; Sum of the number of correct answers	1	1, 2, 3

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
		5) Kids have little effect on how parents care for them, at least until they get older. 6) A brother or sister may start wetting the bed or thumb sucking when a new baby arrives in the family. 7) Most premature babies end up being abused, neglected, or intellectually disabled. 8) Even healthy babies sometimes spit out food if it's new to them until they get used to it. 9) The child's personality or temperament is set by 6 months of age; it doesn't change much after that. 10) The reaction of parents to their baby within a few months of birth determines whether the baby grows up to be a happy, positive child or a depressed, negative one. 11) Children learn all of their languages by copying what they have heard adults say 12) If it's too noisy, or there are many things to look at, a baby cannot focus on the things around them. 13) Even some normal babies do not like being cradled.			
Education	Primary caregiver (Mother)	Here is a list of questions about [child's name] mother. 1-4) Mother's highest level of completed education	Recoded into: 1) HS or Less 2) Associate degree 3) BA 4) Advanced	5, 8	1, 2, 3
	Primary caregiver (Father)	Here is a list of questions about [child's name] father. 1-4) Father's highest level of completed education	Same as the above	5, 8	1, 2, 3
Occupation	Father	Which company (business) are you currently working in? Please indicate specifically the name of the branch or the factory you are employed in. (Then...) What does the company (business) do? (Then...) What is the main task you perform in the company (business)?	10 Major Occ. Groupings of KSCO; Each treated as dummy	5, 8	1, 2, 3

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
STEM occupation	Father	A binary indicator using the question same as the above	Derived from detailed occupation (5 digit) codes based on the definition of STEM used in this article	5, 8	1, 2, 3
Region	Mother (family)	Region of residence (17 Provincial areas)	17 major provincial/ metropolitan regions	5, 8	1, 2, 3
Region type	Mother (family)	Type of the residential area	1 Metropolitan 2 Small town 3 Rural	5, 8	1, 2, 3
Child age	Primary caregiver (child)	Child's age in months at the time of the interview	Months	5, 8	1, 2, 3
Parents' age	Mother	Mother's age in years at the time of the interview	Years	5, 8	1, 2, 3
	Father	Father's age in years at the time of the interview	Years	5	1
Family structure	Primary caregiver	Child's family structure at the time of the survey	1 Parent + Children; 0 All Other, including Grandparent + Parent + Children	5, 8	1, 2, 3
Treatment-induced confounders (L)					1
Low birth weight	Mother (Child)	Child's birth weight in kilograms	1 If less than 2.5 kg; 0 Otherwise	1	1, 2, 3
Child development 1	Primary caregiver (child)	Denver II Developmental Screening Test (Korean adaptation)	1 Normal; 0 Questionable	1	1, 2, 3
Child development 2	Primary caregiver (child)	Korean-Ages and Stage Questionnaires on the following five skills 1) Communication; 2) Gross Motor; 3) Fin Motor; 4) Problem Solving; 5) Personal and Social	Number of dimensions child's score is 2 std. dev. below average	3	1, 2, 3

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Marital satisfaction (Composite score)	Mother	Please indicate how much you agree with each question regarding your couple. 1) How satisfied are you with your husband as a partner? 2) How satisfied are you with your marriage life? 3) How satisfied are you with your relationship with your husband? 4) How satisfied are you with your husband's role as a father?	Likert scale: 1 Very unsatisfied to 5 Very satisfied; Composite score constructed	4	1
	Father	Analogous to the above	Same as the above	4	1
Child vocabulary	Child	Receptive and Expressive Vocabulary Test	Sum of raw scores on each test dimension	4	1
Parenting stress (Composite score)	Mother	The following are questions about the difficulties associated with raising [child's name]. For each question, please check that best describes your general feelings or thoughts. 1) I am not sure whether I can be a good parent. 2) I am not confident that I can raise the child well. 3) I sometimes feel that my child is falling behind on other children because I am not playing a good role as a parent. 4) Sometimes, I want to run from my child. 5) It feels hard that I should treat the child more warmly and kindly 6) I am confused because there is too much childcaring information out there. 7) My life is not as enjoyable after the child's birth. 8) Childcaring expenses are demanding. 9) I agonize when the child expresses mental instability because it feels like it is my fault.	Likert scale: 1 Strongly disagree to 5 Strongly agree; Composite score constructed	4, 7, 8	1, 2, 3

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
		10) I feel annoyed when the child has a tantrum while I am tired. 11) When going to meetings, I think to myself it will not be fun because of the child.			
	Father	Same as the above		4, 7, 8	1, 2, 3
Parent self-esteem (Composite score)	Mother	Please indicate how much you agree with the following statements. 1) Some of my problems cannot possibly be solved by myself. 2) Sometimes, I feel like some things sway me. 3) I cannot gain control over the things that occur to me. 4) I often feel like I cannot take care of issues in life on my own.	Likert scale: 1 Strongly disagree to 5 Strongly agree; Composite score constructed	4, 7, 8	1, 2, 3
	Father	Same as the above	Same as the above	4, 7, 8	1, 2, 3
Height	Primary caregiver (child)	Child's height in centimeters at the time of the interview	Centimeters	5, 8	1, 2, 3
Weight	Primary caregiver (child)	Child's weight in kilograms at the time of the interview	Kilograms	5, 8	1, 2, 3
Father childcaring participation	Primary caregiver (father)	How many hours on average does your spouse spend caring for the child? 1) On a regular weekday	Hours	5	1, 2, 3
	Primary caregiver (father)	How many hours on average does your spouse spend caring for the child? 2) On a regular weekend	Hours	5	1, 2, 3
Family income	Primary caregiver (family)	Total annual family income from all sources	in Korean Won (logged)	5, 8	1, 2, 3
Net wealth	Primary caregiver (family)	The net wealth of the family (total wealth in all forms - total debt in all forms)	in Korean Won	5, 8	1, 2, 3
Employment status	Primary caregiver	What is your current employment/enrollment status?	1 Employed; 0 Unemployed or In school	5, 8	1, 2, 3

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Division of caregiving duties (composite score)	Mother	Please indicate how much you or your partner are involved in the following activities. 1) Give bath to the child 2) Bringing the child to the kindergarten, daycare center, or the sitter 3) Bringing the child to see the doctor 4) Buying the child toys 5) Preparing the child's meals 6) Dressing the child 7) Waking up in the middle of the night to care for the child 8) Playing with the child 9) Getting the child to bed 10) Scheduling with the kindergarten, daycare center, or the sitter 11) Buying clothes for the child 12) Going outside to play with the child 13) Monitoring the child when a friend comes over to play 14) Caring for the child to play with friends	Likert scale: 0 NA 1 Partner does all to 5 I do all; Composite score constructed	7	2, 3
	Father	Same as the above	Same as the above	7	2, 3
Gender role ideology (composite score)	Mother	Here are questions about women's employment and childrearing. After reading each statement, please indicate how much you agree with it. 1) It is somewhat desirable for mothers to stay home and look after their child when the child is young (before school age) 2) Working is good, but the natural role of women is to raise their child at home 3) A working mother can have just as intimate a relationship with a child as a full-time mother 4) Men and women should share an equal amount of housework and childcare if a woman is also employed 5) A father can also have just as intimate a relationship with a child as a full-time mother 6) Even when a woman is not employed, men and women should share an equal amount of housework and childcare	Likert scale: 1 Don't agree at all to 4 Strongly agree; Composite score constructed	7	2, 3

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
	Father	Same as the above	Same as the above	7	2, 3
Self-esteem (composite score)	Child	The pictorial scale of perceived competence and social acceptance from 24 questions	Composite score constructed	7	2, 3
Parental school involvement	Mother	Following are questions about parental participation in [child's name]'s school. From the following regarding [child's name]'s school, please check all you have participated this year. 0) Did not participate 1) School entrance ceremony (including pre-entrance orientations) 2) School events (e.g., sports day) 3) Volunteer 4) Open classes 5) School programs for parents (e.g., workshops, lectures) 6) Teacher counseling 7) School steering committees/parent meetings (Then...) How often, on average, did you participate in such events?	0 Did not participate 1 Once every 6 months 2 2-3 times every 6 months 3 Once a month 4 2-3 times a month 5 Once a week 6 2-3 times a week 7 Almost every day; Converted to the total number of participations per month in all events	8	2, 3
	Father	Same as the above	Same as the above	8	2, 3
Life satisfaction (composite score)	Child	Now, I [interviewer], will show a couple of images and ask how you think. You just have to tell me which image is the closest to [child's name]. 1) How do you feel when you think about studying? 2) How do you feel about your appearance? 3) How do you feel when you think about family? 4) How do you feel when you think about friends? 5) How do you feel when you think about the current school? 6) How do you feel when you think about everyday life?	Likert scale: 1 Not at all happy to 4 Very happy; Composite score constructed	7,8	2, 3

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales	Wave	Mediator
Mediators (M)					
Reading hours	Primary caregiver (child)	Please answer the questions recalling [child's name]'s typical day during a school semester and differentiating between a weekday and a weekend. How long does your child spend on the following activities? 5) Reading books? (Note: Weekday and weekend hours are each treated as a separate variable)	Hours	8	2, 3
TV exposure	Primary caregiver (child)	From the same battery of questions same as the above.... 6) Watching TV? (Weekday and weekend hours each treated as separate variable)	Hours	8	2, 3
School adjustment	Primary caregiver (child)	Did [child's name] adapt well into elementary school?	Likert scale: 1 Didn't adapt at all to 5 Adapted very well	8	2, 3
Shadow education	Primary caregiver (child)	The total sum of financial investment in shadow education	KRW (logged)	8	2, 3
Subjective class	Primary caregiver	Following are questions about your subjective status. Imagine that the following ladder [picture of a ladder with 10 steps shown] represents the structure of our society. At the top are those who are the most privileged lives. They are wealthy, well-educated, and have jobs that are respected within society. Some live the least privileged lives. They have little wealth, are not well-educated, and hold jobs that nobody wants or respects. If this ladder represents the structure of Korean society, where would you place yourself on it?	Scale from 0 to 10	8	3

The term "wave" denotes the particular survey wave during which the variable was measured, implying that the age of the child at the time of measurement is one less than the survey wave. The term "mediator" refers to the mediator set (refer to Table 1 in the main text), wherein the variables are regarded as adjustment variables. When a variable is measured in multiple waves, we use the measure from the wave closest to the mediator's measurement wave. The questionnaires were originally administered in Korean; our own English translations are provided. In rare instances, some factor variables are simplified into broader categories during the analysis to avoid complete separation in logistic regression models. Unless otherwise noted, all composite scores are derived from the first factor score in a factor analysis.

Measurement Details for KELS Variables

Table A2
Description of the Adjustment Variables of the Analysis of KELS.

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales
Baseline Covariates (C)			
Size of residential area	Primary Caregiver	Size/type of the residential area	1 Seoul 2 Other metropolitan 3 Small town 4 Rural
Parents' age	Primary caregiver (mother)	Age at the time of the interview	in Years
	Primary caregiver (father)	Same as the above	
Parent's education	Primary caregiver (Mother)	What is the child's parents' highest level of completed education?	HS or less Associate degree BA Advanced
	Primary caregiver (Father)	Analogous to above	Same as the above
Grandparent education	Primary caregiver (maternal grandparents)	What is the child's grandparents' highest level of completed education?	HS or less; Associate degree or more
	Primary caregiver (paternal grandparents)	Analogous to above	Same as above
Parent co-residence	Primary caregiver (mother)	"Please check all that co-resides with the child at home 2) Mother	1 Yes; 0 No
	Primary caregiver (father)	"Please check all that co-resides with the child at home 1) Father	1 Yes; 0 No
White-collar occupation	Primary caregiver (mother)	"What is the child's parents' occupation? (Derived from detailed occupation (5 digit) codes. Occupations in "Managers, "Professionals, or "Clerks major-groupings of the KSCO defined as white-collar)	1 Yes; 0 No
	Primary caregiver (father)	Same as above	Same as above

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales
STEM occupation	Primary caregiver (mother)	"What is the child's parents' occupation? (Derived from detailed occupation (5 digit) codes based on the definition of STEM used in this article)	1 Yes; 0 No
	Primary caregiver (father)	Same as above	Same as above
Private school	NA (School)	An indicator of whether the child's elementary school is a private school	1 Yes; 0 No
% Male teachers in school	NA (School)	Percentage of male teachers within each school	Raw percentage
School size	NA (School)	Total number of students enrolled in the child's grade cohort	Raw N
Teacher age	NA (School)	The average age of all teachers teaching in each school	Raw percentage
School gender composition	NA (School)	Percentage of boys among all enrolled students in each grade cohort of a school	Raw percentage
School poverty rate	NA (School)	Percentage of students in each school who are basic livelihood security recipients	Raw percentage
Teacher quality	NA (School)	Percentage of teachers within each school with master's or doctoral degrees	Raw percentage
Treatment-induced Confounders (L)			
Educational aspiration	Child	"How far do you plan to go in your study?	HS or less Associate degree BA MA or Ph.D.; Undecided
Parent's aspiration	Primary caregiver	"How far do you want your child to go in their study? (If the answer was associate degree or above...) "College located in which region do you want your child to attend?	Less than BA BA (non-Seoul) BA (Seoul) BA (abroad) MA/Ph.D.
Shadow education	Primary caregiver (child)	"Has your child participated in any shadow education after entering 5th grade?	Yes; No
Reading habits (composite score)	Child	"Here is a list of statements about reading. Please indicate how much you agree with them. 1) Reading is one of my favorite hobbies 2) I enjoy talking about reading with others 3) I tend to finish the books that I start reading 4) I feel happy when I receive a book as a gift 5) I enjoy going to bookstores or libraries	5-point Likert scale: 1 "Strongly disagree to 5 "Strongly agree

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales
Daily study hours	Child	"Besides classes in school and shadow education, on average, how many hours do you spend studying on your own?	0–9+ Hours
Career maturity (composite score)	Child	"Here is a list of statements about your career goals. Please indicate how much you agree with them. 1) I know the kind of work I am good at 2) I know my strength 3) I know the type of work I enjoy 4) I know what kind of work I like 5) I know my core life values 6) I am conscious of what I need to do now to achieve my future goal 7) I plan to gain various experiences for my future 8) Some of the things I learned in school are valuable for my future goal 9) I regularly think about the things I really enjoy 10) I regularly think about the things I value in life	Likert scale: 1 "Strongly disagree to 5 "Strongly agree
Child-parent relationship (composite score)	Child	Here is a list of statements about your parents. Please indicate how much you agree with them. "My parents... 1) Always make me follow what they've decided on 2) Meddle in even in small matters 3) Allow me to decide on my own matters 4) Encourage me to decide myself on my future	Likert scale: 1 "Strongly disagree to 5 "Strongly agree
Parental involvement (composite score)	Child	Here is a list of statements about your parent's attitudes/behavior toward your schoolwork. Please indicate how much you agree with them. "My parents... 1) Set the study atmosphere at home 2) Check on my school assignments and studies 3) Teach/instruct me themselves 4) Advise on how to study 5) Care about my grades and how to manage them 6) Collect information about tutors or cram schools 7) Spend sparingly on my education 8) Check and manage my daily routines and schedules	Likert scale: 1 "Strongly disagree to 5 "Strongly agree
Family income	Primary caregiver (family)	"What is the average monthly income of your family?	In 10,000 Korean Won (logged)

Variables	Respondent (on behalf of...)	Question(s)/Description	Response Scales
Parenting values (composite score)	Primary caregiver	"What do you think about the following statements about the child's education? 1) Studying is a higher priority than enjoying leisure and hobbies 2) It is more important to be high achieving academically than be popular among schoolmates 3) It is more beneficial to sit and study than to play outdoors 4) It is wise to study hard, even though it may lead to less enjoyable school life 5) It is never too late to seek aptitude and interest after first becoming competent academically	Likert scale: 1 "Strongly disagree to 5 "Strongly agree
Standardized test scores	Child	Standardized scores in: 1) Korean; 2) English; and 3) Math	
School friendship	Teacher	"Does this child get along well with friends in the school?	Likert scale: 1 "Strongly disagree to 5 "Strongly agree
Study motivation	Teacher	"Does this child study hard? "Does this child actively participate in classes? "Does this child concentrate in classes? (Response to each question constitutes a separate variable)	Likert scale: 1 "Strongly disagree to 5 "Strongly agree
Self-rated level of understanding of school subjects	Child	"How much do you think you understand classes in the following subjects? 1) Korean 2) English 3) Math (Response to each question constitutes a separate variable)	1 "Less than 20% 2 21%–40% to 5 81%–100%; converted to percentages using midpoints
Self-rated level of concentration in classes	Child	"For how long do you concentrate in the following classes? 1) Korean 2) English 3) Math (Response to each question constitutes a separate variable)	1 "Less than 10 minutes 2 11–20 minutes to 5 "More than 31 minutes; converted to minutes using midpoints
Educational investment	Primary caregiver	"What is the average amount of money spent monthly on the child's educational expenses (including shadow education)?	KRW

All variables were measured during the first wave of the survey, which was administered when the participants were in the 5th grade. The questionnaires were originally in Korean, and we provide our own translations into English. Unless noted otherwise, all composite scores are generated by extracting the first factor score from a factor analysis.