Article

Gifted Child Quarterly
2018, Vol. 62(1) 130–144

DOI: 10.1177/0016986217738049
journals.sagepub.com/home/gcq
SAGE

A Talent for Tinkering: Developing Talents in Children From Low-Income Households Through Engineering Curriculum

Ann Robinson[1], Jill L. Adelson[2], Kristy A. Kidd[1], and Christine M. Cunningham[3]

Abstract

Guided by the theoretical framework of curriculum as a platform for talent development, this quasi-experimental field study investigated an intervention focused on engineering curriculum and curriculum based on a biography of a scientist through a comparative design implemented in low-income schools. Student outcome measures included science content achievement, engineering knowledge, and engineering engagement. The sample comprised 1,387 Grade 1 students across 62 classrooms. Multilevel modeling was used separately for each of the three student outcome measures. The intervention resulted in an effect size of 0.28 on an out-of-level science content assessment and effect size of 0.66 for the engineering knowledge measure. Students in the intervention group reported a high level of engineering engagement. General education teachers were trained to implement the curricula through a summer institute and received coaching throughout the subsequent academic year. Evidence suggests the intervention functioned as a talent-spotting tool as teachers reported they would nominate a substantial portion of low-income and culturally diverse students for subsequent gifted and talented services. Discussion focused on the match between the needs and preferences of students from low-income households for hands-on design experiences and the curricular affordances in the engineering domain as a talent development pathway for young, poor children.

Keywords

biography, curriculum, engineering, poverty, talent development, talent spotting

Poverty drops a screen over talent. The underrepresentation of students living in poverty in the highest achievement quartiles has been documented for the college age cohort (Wyner, Bridgeland, & Diiulio, 2007) and for students in K-12 education (Plucker, Hardesty, & Burroughs, 2013). Although the overall percentage of U.S. children living in poverty has remained steady at approximately 20% from 1958 to 2013, there are significant pockets of poverty entangled with geography, race, and the key demographic of single mother households (Child Trends, n.d.). The problems associated with child poverty are widespread, recalcitrant, and demand a call to action (Burney & Beilke, 2008; VanTassel-Baska & Stambaugh, 2007; Wai & Worrell, 2015). Childhood poverty affects health, educational outcomes, and life chances. General achievement and school readiness gaps begin early and close erratically at a slow rate (Morgan, Farkas, Hillemeier, & Maczuga, 2016; Reardon & Portilla, 2016). Who will stand in the gap between undiscovered potential and the opportunity to achieve for low-income children? In what innovative educational ways can academic talents among children in poverty be spotted and nurtured?

Review of the Literature

Challenging Curriculum and the Development of Talent

Despite the challenges of poverty, resilient children develop their talents and can achieve at high levels (Borland & Wright, 1994; Swanson, 2006). With respect to low-income learners, one theoretical framework focuses on the use of rigorous curriculum designed for high-ability learners to encourage talents to emerge in children (Gallagher & Gallagher, 2013; Little, 2012; Robinson, Bradley, & Stanley, 1990; VanTassel-Baska & Stambaugh, 2006). The essence of the curricular approach to developing talent is exposing all

[1]University of Arkansas - Little Rock, Little Rock, AR, USA
[2]University of Louisville, Louisville, KY, USA
[3]Museum of Science, Boston, MA, USA

Corresponding Author:
Ann Robinson, Jodie Mahony Center for Gifted Education, University of Arkansas, 2801 South University, Little Rock, AR 72204, USA.
Email: aerobinson@ualr.edu

students to enriched and accelerated curriculum and then observing student engagement and performance indicative of advanced learners. Known variously as front-loading (Briggs, Reis, & Sullivan, 2008) or talent spotting (Robinson, 2017a), the goal is to provide subsequent services at an appropriate level of challenge. The curricular approach to talent development has been recommended for a variety of underrepresented groups including children from low-income homes (Olszewski-Kubilius & Clarenbach, 2012; Stambaugh, 2007) and/or children from traditionally underrepresented cultural groups (Briggs et al., 2008). It has been investigated in core academic domains such as mathematics (Gavin, Casa, Firmender, & Carroll, 2013) and language arts/reading (Swanson, 2006; VanTassel-Baska & Stambaugh, 2006). In addition to the dominant curricular foci of primary schools, literacy and numeracy, providing rigorous science curriculum as a platform for talent development with low-income students has also been recommended and investigated (Cotabish, Dailey, Robinson, & Hughes, 2013; Kim et al., 2012; Robinson, 2017b).

Engineering Curriculum and Promising Students from Low-Income Households

The arrival of the Next Generation Science standards with their focus on engineering practices has opened a new academic domain once thought the purview of college-age students and practicing professionals; the salience of engineering in the elementary school has increased (Anning, 1994; Cunningham & Carlsen, 2014; Cunningham & Hester, 2007; Miaoulis, 2014). Mann, Mann, Strutz, Duncan, and Yoon (2011) noted the similarities between gifted education and engineering education which share interests in creativity, innovation, problem solving, and the visualization of solutions. More specifically, engineering provides an engaging curricular platform for the development of talents in young, promising learners from low-income households (Robinson, 2017b; Robinson & Kidd, 2017). We suggest that the conditions of poverty where young children learn early that they must "make-do" and solve problems of everyday challenges such as broken household items, dilapidated or missing school backpacks, or a lack of traditional toys may allow children of poverty to develop early "talents for tinkering"—the very talents and habits of mind that adult engineers put to use in the practice of their profession, and that prompt teachers to spot these talents in contexts with everyday objects (Brophy & Mann, 2008).

One key feature of engineering for young learners is the opportunity to take things apart and see how they work (Royal Academy of Engineering, 2014) and to tinker with objects (Vossoughi & Bevan, 2014). A definition of tinkering from standard dictionaries often includes the meaning, "to attempt to improve or repair something in a desultory way." In at least one dictionary, a synonym for the verb, "tinker," is "bungle." In contrast to these negative connotations, the increased calls for emphasis on engineering in the Pre-K-12 school curriculum (Brophy, Klein, Portsmore, & Rogers, 2008; Katehi, Pearson, & Feder, 2009; Royal Academy of Engineering, 2014) and the rise of the maker movement have reinforced tinkering as a valuable source of hands-on experimentation and creativity for children. Martinez and Stager (2013) described tinkering as a mind-set that involves a playful approach to solving problems. Resnick (2011) emphasized tinkering as technology with a low floor (accessible and easy to get started), a high ceiling (supportive of creating sophisticated projects), and wide walls (inclusive of many different types of hands-on projects). Resnick and Rosenbaum's (2013) conceptualization of tinkering is positive and connected with the creative endeavor of design—a key concept in engineering and engineering education. In a review of the literature, Vossoughi and Bevan (2014) emphasized the value of tinkering as an activity that may promote equity as it focuses on everyday objects and processes that have "low barriers to participation" (p. 4). Resnick (2011) noted that tinkering and the more formal domain of engineering are a good match for low-income children whose life circumstances have presented them with the need to dismantle, redesign, and repair everyday objects or to improve processes that are necessary for day-to-day living within the constraints of scarce resources.

In the history of engineering, early engineers were not necessarily associated with elite or wealthy members of society. According to Rae and Volti (2001), engineering in a modern sense flowered in Great Britain as part of the Industrial Revolution. Among the creative engineers who found careers were James Brindly (1716-1772), John Metcalf (1717-1810), Thomas Telford (1757-1834), and George Stephenson (1781-1848)—all individuals who came from farming or mining families of very modest or impoverished means. Rae and Volti (2001) noted that for individuals with engineering talents, the emerging profession became a way out of poverty. Even today, they assert that in comparison with professions like medicine and law, engineers often come from families with roots in manual labor. American universities adopted the French approach to an engineering curriculum that focuses on mathematics and abstract study rather than practical application, but changing practices in engineering education have begun to find a balance that once again establishes the importance of hands-on experiences and an appreciation for the craft of executing design. For example, Smith and Lucena (2015) studied engineering students from low-income backgrounds attending the Colorado School of Mines and explored the ways in which these college-age students leveraged their working-class experiences with manual labor and "make-do" problem-solving strategies into professional strengths. The students noted that their practical experience with machinery, appreciation of skilled craftsmen and women, and understanding of the constraints of materials and costs made them more effective engineers. Evidence is also emerging from younger samples. A recent qualitative study of two elementary classrooms of gifted students in low-income schools examined the emergence of engineering identity in children over time as it evolved from identification with child characters in storybooks to the development of identities as engineers through personal engagement in design challenges (Kelly, Cunningham, & Ricketts, 2016).

STEM Biography and Advanced Learners

A challenge faced by promising students from low-income households is that they may have little exposure to engineers in their communities (Capobianco, Yu, & French, 2015). With the positive influence of role models on talent development, interventions that include them are important. In terms of curricular interventions, one means of introducing role models systematically in the classroom is to incorporate role models from books or other media. Holbrook, Panozza, and Prieto (2008) reviewed the portrayals of engineers in children's fiction and reported that the appearance of engineers as fictional characters is infrequent, generally male, and usually involves cars. Although they concluded that the potential for fictional mentors is considerable, current literary selections do not provide much information on typical engineering activities. Nonfiction texts may provide more details of the ways engineers, inventors, and scientists engage with their professions and, therefore, can serve the function of role models when low-income families, neighborhoods, or schools may not have convenient access to practicing professionals. The intervention investigated in this study capitalizes on the "role model in a book" specifically through STEM biographies.

The use of biography across the curriculum has a long history in the education of gifted children through the work of Leta Hollingworth (1936). She integrated biography study into the school day through reading clubs managed by children. After 2 years of study, Hollingworth concluded that even very bright students required adult guidance in the selection of biographies to read and recommended 40 minutes of discussion twice a week as optimal. More recently, biography study has been linked to STEM education as a source for engagement (Robinson, Kidd, & Deitz, 2016), for teaching specific aspects of STEM practices (Fairweather & Fairweather, 2010), to encourage scientific thinking in children (Fingon & Fingon, 2009), and for presenting role models to students (Daugher & Ford, 2005; Robinson et al., 2016). Research on biography in the curriculum has also been used to examine the use of STEM biographies in gifted and talented elementary programs and services through teachers' perceptions of gifted children's engagement and identification with scientists, inventors, and engineers (Deitz, 2012).

Purpose

The purpose of this study is to investigate the performance of children from low-income schools exposed to an enriched engineering curriculum during Grade 1. Does the opportunity for curriculum focused on problem solving in science, engineering design processes, and STEM biography encourage the development of academic talents? The central claim of this study is that the intervention is related to the student outcomes of science achievement and engineering knowledge and engagement.

The research questions for the study include the following:

Research Question 1: What are the differences by gender, meal subsidy status, and underrepresented minority status on science content achievement, knowledge of engineers, and behavioral and emotional engagement in engineering?

Research Question 2: How does the intervention affect first graders' science content achievement and knowledge of engineers?

Research Question 3: After a year of the intervention, what does the pool of students that general education teachers would nominate for gifted programs and services look like in terms of demographics? Do the students that teachers *would* nominate differ on the outcome measures from students who teachers *would not* nominate?

Method

Design

The design of the study is quasi-experimental with a control group design with dependent pretest and posttest measures (Shadish, Cook, & Campbell, 2002). In consultation with the researchers and to ensure that students from low-income households were represented, districts selected schools with similar characteristics to assign to intervention and comparison groups. Nine schools were included in the intervention group. Nine schools were included in the comparison group. The number of schools invited to participate in the study was determined with a power analysis conducted in Optimal Design.

Participants

Grade 1 students in 18 schools across four districts were included in the intervention study. The sample comprised 1,387 students who participated in at least one of the preassessments or postassessments. They were in 62 different classes, with an average of 22 students per class (SD = 2.26, range = 16-31). There was an average of 3 classes per school (SD = 0.92, range = 1-5). Table 1 summarizes the demographics of student participants in the first year of implementation.

Intervention

The intervention, STEM Starters+, included an engineering unit, a STEM biography, and a professional development

Table 1. Demographics for Grade 1 in Year 1 Implementation.

	Total sample (N = 1,387)	Intervention group (n = 765)	Comparison group (n = 622)
Sex			
Male	699 (50.4)	401 (52.4)	298 (47.9)
Female	622 (44.8)	329 (43.0)	293 (47.1)
Ethnicity			
White	638 (46.0)	337 (44.1)	301 (48.4)
Asian/Pacific Islander	36 (2.6)	14 (1.8)	22 (3.5)
Black	573 (41.3)	321 (42.0)	252 (40.5)
Hispanic	64 (4.6)	54 (7.1)	10 (1.6)
Native American	17 (1.2)	4 (0.5)	13 (2.1)
Two or more races	19 (1.4)	9 (1.2)	10 (1.6)
Other	8 (0.6)	4 (0.5)	4 (0.6)
Lunch status			
Full pay	609 (43.9)	349 (45.6)	260 (41.8)
Receive subsidy	745 (53.7)	394 (51.5)	351 (56.4)

Note. Table provides *n* (%). Percentages do not add up to 100 due to missing demographic data.

component linked to the curriculum as a platform for spotting talent in young children from low-income and/or culturally diverse households. Specifically, an acoustical engineering unit, *Sounds Like Fun: Seeing Animal Sounds*, developed by the Museum of Science, Boston, and a *Blueprint for Biography* based on *The Watcher: Jane Goodall's Life with the Chimps*, developed at the Jodie Mahony Center for the STEM Starters+ project form the basis of the curricular intervention. In addition, teachers implementing the intervention were trained in a 1-week summer institute and had access throughout the academic year to a science and engineering specialist with preparation in gifted education. The curricular components and the companion professional development comprise the Grade 1 STEM Starters+ intervention and are described in the subsequent sections.

Given the theoretical framework guiding this study, challenging curriculum can serve as a platform for developing talent, we selected curricula based on its suitability for meeting the educational needs of advanced learners. First, engineering is not a content area generally available to primary grade students and, therefore, provides an enrichment opportunity for differentiation. Given that engineering is also viewed as a content domain accessible to college majors, the implementation of engineering curriculum in the primary grades differentiates by acceleration. In addition, the engineering design process at the center of engineering curricula has been linked to the development of creativity—a goal espoused in the field of gifted education (Mann et al., 2011). Second, the use of biography has a long history as a curricular approach in gifted education (Hollingworth, 1925; Robinson, 2009). Biography provides advanced learners an opportunity to explore talents in the lives of eminent individuals and to identify with them. The biography curriculum materials focus on talent exploration and provide students with the opportunity to participate in creative and analytical processes used by practicing professionals in the fields of engineering, primary source research, science, and the visual arts.

Engineering Curriculum. Developed by the Museum of Science, Boston, the Engineering is Elementary (EiE) curriculum series focuses on the engineering design process within a variety of engineering specialties such as acoustical engineering, agricultural engineering, electrical engineering, materials engineering, and mechanical engineering. Example units are found at https://eie.org/eie-curriculum/curriculum-units. The goals of the curriculum include introducing children to engineering and technology concepts, providing a broad perspective on various engineering fields and the types of work specialist engineers do, exploring linkages among science, mathematics, and engineering, and integrating the engineering design process into STEM programs. Units are introduced through a story that features a child presented with a problem to solve. For example, the acoustical engineering unit, *Sounds Like Fun: Seeing Animal Sounds*, introduces Kwame, a child from Ghana, who is given the challenge of representing sounds to his cousin who cannot hear them because he lives far away. In other words, the students must develop a visual representation of sounds—a form of coding.

After reading the storybook in Lesson 1, the students participate in three additional lessons characterized by the developers as follows: Lesson 2, A Broader View of an Engineering Field; Lesson 3, How Scientific Data Inform Engineering; and Lesson 4, Engineering Design Challenge. The unit also includes a preparatory lesson to introduce children to the concept that engineers use technology to solve problems. The EiE website also includes extension lessons for each unit. The STEM Starters+ application of this unit, *Sounds Like Fun*, also incorporated an extension lesson on coding bird sounds.

Blueprints for Biography Curriculum. Developed at the Jodie Mahony Center for Gifted Education, *Blueprints for Biography* are a series of teaching guides linked to specific trade book biographies. The goals of the curriculum materials are to encourage biography study as a means of talent exploration, to explore the life and work of eminent individuals through trade book biographies, to link primary source analyses of various types of documents to the methods of research used by biographers, and to provide a window into the habits and methods used by practicing professionals in specific fields. The STEM series of the Blueprints was developed through Jacob K. Javits funding and focuses on the lives of scientists, engineers, and inventors to engage young learners in the STEM fields (Deitz & Robinson, 2016; Robinson, 2017b). Example Blueprints can be found at http://ualr.edu/gifted/curriculum/stemblueprints. Blueprints include questions that set the context for the biography (Before the Book), questions that require close reading of text and illustrations (By the Book), and questions that explore talent development and investigations outside the text of the trade biography (Beyond the Book).

Four extension lessons are included in the Blueprints teaching guides: Portrait Analysis, Persuasive Writing Prompts, Primary Source Analysis, and Point of View Analysis. Prior to implementation in STEM Starters+, the Blueprints model was field tested by teachers with preparation in gifted education (Deitz, 2012). The Blueprint developed for the Jane Goodall biography provided students with a childhood photographic portrait of Jane Goodall and guided them through the analysis of the portrait with a graphic organizer through group discussion (Kidd, Deitz, & Robinson, 2016). The graphic, FACE, incorporates strategies recommended by curators at the National Portrait Gallery in London (Morris, 1994). For the Persuasive Writing Prompts, students were given the choice to write a speech convincing people not to cut down the forests of Gombe or a letter convincing their teacher to support a Jane Goodall Roots and Shoots project in the classroom. In terms of Primary Source Analysis, students were given an excerpt from one of Jane's typewritten field notebooks that included chimpanzee vocalizations and were asked to analyze the document using strategies modified from the National Archives. Finally, in point of view analysis, students were asked to consider both Jane's and Jane's mother's point of view about the dangers Jane might encounter living alone in the rainforest for an extended period.

The combined instructional time for the EiE Unit and the Blueprint for Biography was approximately 5 to 6 hours. Most teachers delivered the engineering unit and the biography study over a 4- to 5-week period. Teachers were permitted to begin the curricular intervention with the Blueprint for Biography, with the EiE unit, or to alternate lessons from either set of curricular materials as their daily teaching schedule allowed.

Teacher Professional Development. To support fidelity of implementation, Grade 1 teachers were trained in a week-long summer institute and provided a coaching specialist with expertise in STEM and gifted education over the course of the subsequent academic year. The summer institute included information on acknowledging and locating talents among low-income young children, science talk moves, specific lessons from the EiE curriculum unit, and specific lessons from the Blueprint teaching guide. Summer institute sessions were provided by two STEM professional development specialists with credentials in gifted education and by a university faculty member with expertise in curriculum differentiation and underrepresentation. All three individuals provide professional development nationally. During the academic year, coaching was provided by the full-time STEM professional development specialist on an individual basis depending on teacher need established informally through direct contact with the teachers, individual school visits by the coach, and requests for assistance from principals and/or gifted and talented coordinators in participating districts. With respect to the coaching model for the intervention, the coach demonstrated lessons, provided support through e-mail, telephone calls, and conducted classroom or school visits. These strategies drew from previously effective coaching strategies implemented and evaluated with general elementary teachers (Dailey & Robinson, 2017; Robinson, Dailey, Hughes, & Cotabish, 2014) and are representative of factors incorporated into fidelity of implementation frameworks (Century, Rudnick, & Freeman, 2010; O'Donnell, 2008). In addition to training and coaching on specific curricular materials and on the characteristics and needs of promising learners from low-income households, fidelity of implementation was checked through classroom visits and frequent contacts by the coaching specialist, the collection of student work samples, and through on-site visits and interviews conducted by the project external evaluator (Robinson, Kidd, Adelson, Deitz, & Meadows, 2017; Ruiz-Primo, 2006).

Instrumentation

Three instruments were used to assess student performance and engagement outcomes: *What is an Engineer?* (a 20-item measure of young student knowledge of engineering practices developed by the Museum of Science, Boston), the *Science Content Test* (constructed of eight released TIMSS [Trends in International Math and Science Study] and NAEP [National Assessment of Educational Progress] items), and the *STEM Engagement Scale (SES): Engineering* (developed for the project).

What is an Engineer? includes 19 yes/no questions to which students respond focused on what an engineer "could do at work" (in addition to one open-ended question, not analyzed for this study). Example "yes" stems include "develop better bubblegum" and "design ways to clean polluted air." Example "no" stems include "repair cars" and "put roofs on buildings." Students score a proportion correct. The internal consistency reliability for *What is an Engineer?* was good (α = .781; Lachapelle, personal communication, September 8, 2017).

The *Science Content Test* includes six single-part questions and two two-part questions that were developed for and released from TIMSS and NAEP assessments. TIMSS releases items as a service for its member nations; NAEP releases items regularly for educational and research purposes. All released items meet standards of sound psychometric properties; TIMSS and NAEP have procedures to ensure that the items produce reliable scores and are developed with a focus on validity so that appropriate inferences can be drawn from the results of the items. A science and engineering educator and the external evaluator reviewed released items from TIMSS and NAEP and selected items that aligned with the objectives stated for the curriculum unit. A test blueprint detailed the scope-and-sequence of the designed test and how the items aligned with the objectives. (Note that the external evaluator was unaware of the specific curriculum, so items were chosen specifically to match the objectives from the curriculum, not the curriculum itself.) A third researcher reviewed the final assessment decisions to check alignment. Each part was worth one point, with no partial credit, for a total possible score of 10 points. Because neither TIMSS nor NAEP assess Grade 1 students in science, the *Science Content Test* is an out-of-level test.

The *SES: Engineering* is a parallel assessment to the *SES: Mathematics* and *SES: Science* scales (Cash, Adelson, & Robinson, 2016; Robinson, Kidd, & Adelson, 2017). It includes 15 items, 6 of which measure Emotional Engagement (such as "I enjoy learning new things in engineering") and 9 of which measure Behavioral Engagement (such as "I pay attention during engineering lessons"). Students rate the items on a 5-point Likert-type scale ranging from *not at all like me* to *a lot like me*. For the primary grade version used in this study, each Likert response has a corresponding picture of a face (from sad to happy). Scores on each scale are averaged. Reliabilities for the scales were adequate (α = .70 for Emotional Engagement, α = .77 for behavioral engagement). Because schools were not explicitly conducting engineering lessons with first graders prior to the implementation of this project or at any point in the comparison schools, we were unable to assess engineering engagement at pretest or in the comparison schools. At pretest in both cohorts and at posttest in the comparison group, students were simply not able to report engagement in engineering because no engineering opportunities were systematically or explicitly presented to them. Thus, there was no opportunity to be engaged.

Finally, we used a teacher nomination form to learn which students general education teachers would nominate for gifted and talented services. We gave each teacher a form with his or her class roster on it. For each student, teachers were asked two questions: "Would you consider this student to have high academic potential?" and "Would you nominate this student for gifted and talented services?" For this study, we focused on the responses to the question regarding nominating students for gifted and talented services.

Data Analysis

The data in this study violate the assumption of independence of observations. Students are nested together in the same class, taught by the same teacher. Multiple teachers/classrooms are within the same school, with the school being the unit that was randomized to intervention or comparison. Thus, we used multilevel modeling to appropriately adjust the standard errors and to allow us to examine cross-level interactions (McCoach & Adelson, 2010), using HLM 7 (Raudenbush & Bryk, 2002). We conducted a series of models, beginning with an unconditional model with no predictors and building to our full contextual model, as recommended by Raudenbush and Bryk (2002). This was done separately for each of the three outcome measures.

To answer the third research question, we examined descriptively the student sample that teachers indicated they would nominate for gifted programs and services, particularly focusing on traditionally underrepresented students. Then we compared the students teachers would nominate with those they would not nominate using t tests.

Results

Descriptive statistics for the three assessments at each wave for the full sample, for the intervention group, and for the comparison group are included in Table 2. As indicated by both the range and the mean, the content test was sufficiently difficult; there was no evidence of a ceiling effect. The average scores on *What is an Engineer?* also suggest an adequate ceiling, although some students (n = 9) in the intervention group did answer all questions correctly on the posttest. Overall, 20 students (2.24%) scored above 90% and 53 students (5.93%) scored above 80% on the posttest.

Science Content Test

First, we estimated an unconditional model of the average score on the content assessment and calculated the proportion of variance at each of the three levels (between students within classes, between classes within schools, and between schools). On average, students scored 2.96 (out of a possible score of 9) on the posttest, which was statistically significantly different from 0 ($t_{17} = 19.60$, $p < .001$). As expected, most variability (85%) was between students within classes. However, 7% of the variability in content assessment scores was between classes within schools, and 8% of the variability

Table 2. Descriptive Statistics for Assessments.

	Full sample		Intervention group		Comparison group	
Assessment	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)
Content						
Pre	0-6	1.45 (1.21)	0-6	1.39 (1.22)	0-6	1.53 (1.20)
Post	0-9	2.98 (1.80)	0-9	3.20 (1.90)	0-8	2.69 (1.63)
What is an Engineer?						
Pre	5.26-94.74	42.89 (13.40)	10.53-94.74	42.88 (13.76)	5.26-84.21	42.89 (13.05)
Post	10.53-100.00	48.47 (18.13)	10.53-100.00	54.17 (19.07)	10.53-84.21	41.18 (13.76)
Emotional. engagement[a]	—	—	1.00-5.00	3.89 (0.85)	—	—
Beh. engagement[a]	—	—	1.00-5.00	4.10 (0.73)	—	—

[a]The Emotional and Behavioral Engagement scales were not administered at pretest or to the comparison group because engineering was not taught explicitly in either group except during the project, meaning that at pretest for both groups and at posttest for the comparison group students were simply not engaged in engineering.

was between schools. There was significant variability at both Level 2 (between classes) and Level 3 (between schools).

Next, we added the content pretest as a predictor of the posttest (grand-mean centered). For every 1-unit higher students scored on the pretest, they were expected to score 0.29 points higher on the posttest (t_{17} = 3.99, p < .001). This relationship did not vary significantly between classes (τ_π = 0.002, χ^2_{33} = 22.38, p > .500), so we fixed the Level 2 random effect. This relationship did vary between schools (τ_β = 0.04, χ^2_{16} = 32.56, p = .009). The pretest explained 6.16% of the variability between students, 13.04% of the variability between classes, and 11.54% of the variability between schools, with variability remaining to be explained at each level.

To answer Research Question 1, what differences exist by gender, lunch subsidy status, and underrepresented minority status, we next added those three student characteristics to the model. We eliminated any random effects that did not randomly vary (p > .10), one at a time. For random effects that had a significance between .05 and .10, we also conducted a chi-square difference test and eliminated them if they did not significantly improve the model fit. The relationship between gender, lunch subsidy status, and underrepresented minority status and the outcome variable (content assessment score) did not vary between classes or between schools. As shown in Table 3, gender (coded 0 = male, 1 = female), lunch subsidy status (coded 0 = full pay, 1 = receives subsidy), and underrepresented minority status (coded 0 = not Black or Hispanic, 1 = Black or Hispanic) were all related to the outcome. On average, girls scored 0.27 points higher than boys, students receiving a lunch subsidy scored 0.51 points lower than those who do not, and students who are from an underrepresented minority group scored 0.32 points lower than those who are not. These student characteristics explain only 5.41% of the variability between students within classes. Although student characteristics did not explain any variability between classes, they did explain 26.09% of the variability between schools.

To answer Research Question 2, examining the effects of the intervention, we entered group (coded 0 = comparison, 1 = intervention) as a predictor of the intercept. As shown in Table 3, students in the intervention group scored 0.50 points higher than those in the comparison group scored. Although the p value for this parameter estimate was .050, the effect size was rather large. Whether a school was in the intervention group or not explained 41.18% of the variability in content assessment scores between schools. As another measure of effect size, we divided the parameter estimate by the square root of the variance components from the null model (i.e., the standard deviation for the outcome), resulting in d = 0.28, indicating that students receiving the intervention scored 0.28 standard deviations higher on an out-of-level science content test than those in comparison schools.

What is an Engineer?

First, we estimated an unconditional model of the average score on *What is an Engineer?* (i.e., proportion of correct responses) and to calculate the proportion of variance at each of the three levels (between students within classes, between classes within schools, and between schools). On average, students scored 48.04% on the posttest, which was statistically significantly different from 0 (t_{17} = 31.28, p < .001). As expected, much of the variability (65%) was between students within classes. Much more of the variability in this measure was at Levels 2 and 3 than in the content assessment; 14% of the variability in *What is an Engineer?* scores was between classes within schools, and 22% of the variability was between schools. There was significant variability at both Level 2 (between classes) and Level 3 (between schools).

Next, we added the *What is an Engineer?* pretest as a predictor of the posttest (grand-mean centered). For every 1% higher students scored on the pretest, they were expected to score 0.21% higher on the posttest (t_{544} = 4.75, p < .001). This relationship did not vary significantly between classes

Table 3. Results of Final 3-Level Models: Intervention Group Comparisons on Achievement.

	Science content test			*What is an Engineer?*		
Fixed effect	Coefficient (*SE*)	*t* (*df*)	*p*	Coefficient (*SE*)	*t* (*df*)	*p*
Model for outcome score (π_0)						
Intercept (γ_{000})	2.89 (0.20)	14.29 (16)	<.001	43.63 (11.75)	22.01 (16)	<.001
Group (γ_{001})[a]	0.50 (0.23)	2.12 (16)	.050	11.75 (2.52)	4.66 (16)	<.001
Model for gender slope (π_1)						
Intercept (γ_{100})	0.27 (0.12)	2.26 (636)	.024	0.21 (1.19)	0.18 (518)	.858
Model for lunch subsidy slope (π_2)						
Intercept (γ_{200})	−0.51 (0.13)	−3.96 (636)	<.001	−2.01 (1.32)	−1.53 (518)	.126
Model for underrepresented minority slope (π_3)						
Intercept (γ_{300})	−0.32 (0.14)	−2.23 (636)	.026	−2.77 (1.47)	−1.89 (518)	.059
Model for pretest slope (π_4)						
Intercept (γ_{400})	0.28 (0.07)	3.80 (17)	.001	0.20 (0.05)	4.42 (518)	<.001
Random effect	Variance	χ^2(*df*)	*p*	Variance	χ^2(*df*)	*p*
Level 1 (students within classes)						
Variance between students (e_{tij})	2.45			206.92		
Level 2 (classes within schools)						
Variance in class means (r_{0ij})	0.21	77.04 (37)	<.001	20.76	79.18 (30)	<.001
Level 3 (schools)						
Variance in school means (u_{00j})	0.10	29.97 (15)	.012	10.10	27.40 (14)	.017
Variance in pretest slope (u_{40j})	0.04	31.46 (16)	.012	—	—	—

Note. df = degrees of freedom; *SE* = standard error.
[a]Group was coded as 0 (comparison group) and 1 (intervention group).

(τ_π = 0.02, χ^2_{28} = 0.13, p = .150) or between schools (τ_β = 0.0006, χ^2_{15} = 14.91, p > .500), so we fixed the Level 2 and Level 3 random effects. The pretest explained almost no variability between students within classes (0.27%), but it explained 44.97% of variability between classes within schools and 37.91% of variability between schools.

To answer Research Question 1, what differences exist by gender, lunch subsidy status, and underrepresented minority status, we next added those three student characteristics to the model. We eliminated any random effects that did not randomly vary (p > .10), one at a time. The relationship between gender, lunch subsidy status, and underrepresented minority status and the outcome variable (proportion correct on *What is an Engineer?*) did not vary between classes or between schools. As shown in Table 3, gender (coded 0 = male, 1 = female), lunch subsidy status (coded 0 = full pay, 1 = receives subsidy), and underrepresented minority status (coded 0 = not Black or Hispanic, 1 = Black or Hispanic) were not related to the outcome. On average, girls and boys, students receiving a meal subsidy and those not, and students identifying as an underrepresented minority and those not, did not statistically significantly differ in the proportion of items they answered correctly on *What is an Engineer?*

To answer Research Question 2, examining the effects of the intervention, we entered group (coded 0 = comparison, 1 = intervention) as a predictor of the intercept. As shown in Table 3, students in the intervention group averaged 11.75% more correct than those in the comparison group. Whether a school was in the intervention group or not explained 74.19% of the variability in *What is an Engineer?* scores between schools. As another measure of effect size, we divided the parameter estimate by the square root of the variance components from the null model (i.e., the standard deviation for the outcome), resulting in d = 0.66, indicating that students receiving the intervention scored 0.66 standard deviations higher than those in comparison schools.

Engineering Engagement: Emotional Engagement

Because the *STEM Engagement Scale: Engineering* was administered only to students in the intervention schools, nine schools provided data on this instrument. We ran this analysis as a 2-level model using full information maximum likelihood. After running the full model, we reran it to include eight dummy codes to control for differences in the schools, but the results were robust.

First, we estimated an unconditional model of the average score (on a Likert-type scale 1 to 5) and to calculate the proportion of variance between classes (vs. within classes). On average, students scored 3.89, which was statistically significantly different from 0 (t_{31} = 74.81, p < .001). As expected, the majority of variability (94%) was between students within classes, with 6% of variability in student engagement being between classes.

Table 4. Results of Final 3-Level Models: Engineering Engagement.

	Emotional engagement			Behavioral engagement		
Fixed effect	Coefficient (*SE*)	*t* (*df*)	*p*	Coefficient (*SE*)	*t* (*df*)	*p*
Model for outcome score (β_0)						
Intercept (γ_{00})	3.95 (0.08)	49.83 (31)	<.001	4.19 (0.07)	63.99 (31)	<.001
Model for gender slope (β_1)						
Intercept (γ_{10})	0.06 (0.07)	0.84 (469)	.401	0.06 (0.06)	0.96 (469)	.337
Model for lunch subsidy slope (β_2)						
Intercept (γ_{20})	−0.07 (0.08)	−0.90 (469)	.367	−0.18 (0.07)	−2.69 (469)	.007
Model for underrepresented minority slope (π_3)						
Intercept (γ_{300})	−0.10 (0.09)	−1.17 (469)	.242	−0.04 (0.07)	−0.61 (469)	.545
Random effect	Variance	χ^2(*df*)	*p*	Variance	χ^2(*df*)	*p*
Level 1 (students within classes)						
Variance between students (r_{ij})	0.67			0.49		
Level 2 (classes)						
Variance in class means (u_{0j})	0.04	59.40 (31)	.002	0.02	53.66 (31)	.007

Note. df = degrees of freedom; *SE* = standard error.

To answer Research Question 1, what differences exist by gender, lunch subsidy status, and underrepresented minority status, we added those three student characteristics to the model. We eliminated any random effects that did not randomly vary ($p > .10$), one at a time. The relationship between gender, lunch subsidy status, and underrepresented minority status and the outcome variable (emotional engagement) did not vary between classes. As shown in Table 4, gender (coded 0 = male, 1 = female), lunch subsidy status (coded 0 = full pay, 1 = receives subsidy), and underrepresented minority status (coded 0 = not Black or Hispanic, 1 = Black or Hispanic) were not related to the outcome. On average, girls and boys, students receiving a meal subsidy and those not, and students identifying as an underrepresented minority and those not, did not statistically significantly differ in their emotional engagement in engineering.

Engineering Engagement: Behavioral Engagement

As with the emotional engagement scale, we analyzed the behavioral engagement data using a 2-level model and full information maximum likelihood. After running the full model, we again reran it to include eight dummy codes to control for differences in the schools, but the results were robust.

First, we estimated an unconditional model of the average score and to calculate the proportion of variance between classes (vs. within classes). On average, students scored 4.09 (on a Likert-type scale from 1 to 5), which was statistically significantly different from 0 ($t_{31} = 96.91$, $p < .001$). As expected and like emotional engagement, the majority of variability (95%) was between students within classes, with 5% of variability in student engagement being between classes.

To answer Research Question 1, what differences exist by gender, lunch subsidy status, and underrepresented minority status, we added those three student characteristics to the model. We eliminated any random effects that did not randomly vary ($p > .10$), one at a time. The relationship between gender, lunch subsidy status, and underrepresented minority status and the outcome variable (behavioral engagement) did not vary between classes. As shown in Table 4, gender (coded 0 = male, 1 = female) and underrepresented minority status (coded 0 = not Black or Hispanic, 1 = Black or Hispanic) were not related to the outcome. On average, girls and boys, students identifying as an underrepresented minority and those not, did not statistically significantly differ in their engagement in engineering. However, lunch subsidy status (coded 0 = full pay, 1 = receives subsidy) was negatively related to behavioral engagement, indicating that students receiving a lunch subsidy reported being less behaviorally engaged in engineering class than students who did not receive a lunch subsidy. To assess the effect size of this relationship, we ran a model with gender and underrepresented minority status and compared the variance between these two models to see what proportion of variance lunch subsidy status explained above and beyond the other student characteristics. Interestingly, meal subsidy status explained less than 1% of variability in engagement between students within the same class. However, it explained about 19% of variability between classes. As another measure of effect size, we divided the parameter estimate by the square root of the variance components from the null model (i.e., the standard deviation for the outcome), resulting in $d = 0.25$, indicating that students receiving a lunch subsidy scored 0.25 standard deviations lower on behavioral engagement than those who did not receive a lunch subsidy. Significant variability remained to be explained.

Table 5. First Graders Teachers Indicated They Would Nominate for Services After STEM Starters+ Year 1 Implementation.

School	Total nominated	Black, *n* (%)	Hispanic, *n* (%)	Subsidized Lunch, *n* (%)
1	41	10 (24)	0 (0)	18 (44)
2	17	5 (29)	0 (0)	7 (41)
3	11	8 (73)	0 (0)	5 (45)
4	22	21 (95)	1 (5)	13 (59)
5	7	6 (86)	1 (14)	6 (86)
6	32	4 (13)	1 (3)	6 (19)
7	38	5 (13)	1 (3)	8 (21)

Talent Spotting

To answer Research Question 3, we examined what the nomination pool for gifted programming and services looked like after a year of implementing the intervention curriculum in Grade 1. We were particularly interested in whether teachers were nominating students who received a meal subsidy or who identified as Black or Hispanic. We asked the Grade 1 teachers which of their students they would nominate to be identified as gifted and talented as an indicator of talent spotting. As shown in Table 5, most teachers nominated a substantial proportion of students who received a subsidized lunch or who identified as either Black or Hispanic. In School 5, which had no second graders identified the prior 2 years, the teachers indicated they would nominate seven students, all minority students and almost all receiving a meal subsidy. Similarly, in School 2, no second graders had been identified the prior year, but the teacher would nominate 17 students after implementing STEM Starters+. In Schools 1 and 7, although no minority children had been identified the prior year, the teachers indicated they would nominate 10 minority students and 6 minority students, respectively. The diversity of students nominated by general education teachers who were provided with professional development on talent spotting among children from low-income households is a heartening finding.

To examine the validity of the nominations, we compared the posttest scores for students nominated and those not nominated on the science content test, *What is an Engineer?*, and the two engineering engagement scales. On all four measures, the students nominated by their Grade 1 teachers scored statistically significantly higher, as shown in Table 6. Thus, teachers were spotting more academically promising students.

Discussion

The discussion is organized in two sections: (a) Implications for Practice and (b) Recommendations for Future Research.

Implications for Practice

First, Grade 1 children attending low-income schools can and do learn science when time is provided in the daily schedule for curriculum that addresses science embedded in engineering contexts. In STEM Starters+, science content was taught using an engineering unit anchored in the science of sound and through a biography that explored the scientific process of careful observation. Given the emphasis on engineering concepts and design challenges in the Next Generation Science Standards, the STEM Starters+ curricular intervention supports the nascent body of literature on the efficacy of engineering taught at grades much earlier than has been general practice. The results reported in this study are strengthened by the rigorous measure used to assess science content, an out-of-level test constructed from released TIMSS and NAEP items. Creative enrichment and design challenges linked to out-of-level testing provide a practical means of fostering and documenting advanced performance in science.

Second, exposure to engineering design challenges and high-interest biographies provide rich curricular opportunities to engage promising learners in low-income schools. Young students improved both their knowledge of engineers and their reported engagement in engineering activities. Our findings are strengthened by the absence of baseline differences and by comparable postintervention outcomes on the measure of engineering knowledge achieved both by children from low-income households and by more advantaged students. Given the frequently reported gaps between the performance of students from low-income households and their more advantaged peers on many academic measures, engineering experiences at the early grades provide a creative and rigorous curricular platform for advanced performance across income levels. Although it remains speculative to link the historical pattern of engineering as a pathway out of poverty to the current achievement and engagement of children, we suspect that young children from low-income environments may be well matched to the more active and practical problem-solving approach of engineering. Having had to “make-do” with limited resources, a constraint frequently imposed in real-world engineering design, children from low-income households may have relevant experience in stretching resources to make things work. The combination of engineering curricula and an inspiring children’s biography can foster the development of academic talent.

Table 6. Comparison of First Graders Teachers Would Nominate as Gifted With First Graders Teachers Would Not Nominate.

Test	Nominated? (*n*)	*M* (*SD*)	*t* (*df*)	*p*
Science content	No (237)	2.81 (1.68)	8.26 (381)	<.001
	Yes (146)	4.34 (1.88)		
What is an Engineer?	No (226)	53.31 (19.50)	4.26 (365)	<.001
	Yes (141)	62.26 (19.74)		
Emotional engagement	No (237)	3.78 (0.83)	3.78 (382)	<.001
	Yes (147)	4.10 (0.82)		
Behavioral engagement	No (237)	4.02 (0.73)	2.98 (382)	.003
	Yes (147)	4.24 (0.66)		

Note. df = degrees of freedom.

Third, engineering demonstrated its usefulness as a talent-spotting platform in a domain generally reserved for older students or adult learners. Although this study focused on students, their elementary generalist teachers could stimulate and observe advanced performance as young children interacted with hands-on materials, manipulated objects, and adopted the mind-set of tinkering to solve practical problems. Given that Grade 1 classrooms emphasize vocabulary, reading fluency, and basic numeracy, engineering in the curriculum brought other talents to teachers' attention. Many of the children teachers chose to nominate for further services were from low-income households/or and culturally underrepresented groups; this finding indicates that underrepresentation can be addressed early and in innovative ways that tap the talents and life experiences of children from these groups. The increased numbers of children from low-income households and culturally diverse groups who were "talent-spotted" and whose achievement gains were related to participation in the STEM Starters+ intervention is evidence for the practice of encouraging primary teachers to look for talent systematically and to provide advanced students with appropriate curricular interventions. By enriching first and observing advanced performance second to plan and provide more intensive interventions, the current study supports the use of challenging curriculum as a framework for talent development.

Recommendations for Future Research

In terms of future research, the current study sets the stage for subsequent investigations. Studies that examine the lower developmental bound of engineering talent spotting will add to the literature. Do engineering design interventions work with kindergarteners or with preschoolers to increase science content achievement, knowledge of engineering, and engagement with engineering?

Turning our attention to the other end of the talent pipeline, what are the longitudinal effects of early engineering exposure to maintaining interest beyond elementary grades into middle and high school and ultimately to collegiate engineering majors? Future studies should measure science achievement, engineering knowledge, or engineering engagement across multiple years to investigate issues of educational dosage and longitudinal effects.

With respect to the use of biography as a curricular intervention, are some elements of the *Blueprints for Biography* model more effective than other elements in providing role-models-in-a-book for children from low-income households? Studies that vary the use of the Beyond-the-Book discussion questions and the enrichment extensions would add to the historically interesting, but limited empirical literature on the efficacy of using biography with talented learners.

Finer grained studies of componential interventions such as STEM Starters+ are needed. The STEM Starters+ intervention includes three components: *Engineering is Elementary* curriculum, *Blueprints for Biography* curricular materials, and professional development to support these curricula and their companion practice of talent spotting. In the current study, the intervention was investigated holistically. In the future, implementing one or both curricular components across two conditions, with and without professional development, would permit a nuanced understanding of the relative contributions of the individual components to the overall efficacy of the intervention.

Finally, the recognition of spatial ability as an important contributor to engineering talent in older individuals suggests that future research with young children who may display spatial talents early could inform the field (Wai, Lubinski, & Benbow, 2009; Wai & Worrell, 2015). Although the contributions of spatial ability to engineering performance have been conducted, existing studies tend to measure the construct during adolescence and with talent search participants rather than with a younger cohort. Can spatial ability be measured validly and reliably among much younger students, particularly among children from low-income households? If the skills of visualization associated with adult engineers and valued as problem-solving strategies in both gifted and engineering education are measurable among young children, engineering could provide an elementary curricular platform to locate talent among young children whose life circumstances have presented them with the need to "tinker, design, and improvise."

Limitations of the Study

Measuring engineering engagement in young children presented challenges in both instrumentation and research design. Children are exposed to activities related to engineering such as building with blocks or creating containers to carry their toys, but these activities are not generally or formally identified as engineering. If asked about their engagement in engineering, Grade 1 children who have not had the opportunity to learn the vocabulary of engineering or to participate in engineering curricula in the classroom could be confused by engineering engagement questions. Thus, we were unable to pretest intervention children nor to compare children who participated in the intervention with those who had not on the engineering engagement measure.

Characterizing the "business as usual" condition in comparison classrooms presented challenges because STEM opportunities in the comparison classrooms are heterogeneous. Some Grade 1 comparison teachers provide science opportunities by reading a story about a science topic or by offering occasional engineering-type activities such as constructing pinwheels; others provide little or no science or engineering instruction. Thus, the observed gains cannot be attributed to distinct differences among STEM curricula, but rather to one distinct science and engineering intervention, STEM Starters+ versus a spectrum of curricular opportunities that may or may not include science, engineering, or STEM biography.

Inferences from curriculum interventions are strengthened by multiple direct and indirect measures of fidelity of implementation. This study monitored fidelity, but did not request individual teacher logs or provide multiple observers in all intervention classrooms. The current study relied on classroom visits with informal observations by the professional development coach, collection of student work samples, and both face-to-face and electronic interviews conducted by the external evaluator with teachers, gifted and talented coordinators, and principals. Thus, an individual teacher may have failed to implement an activity in the curriculum without our knowledge.

Conclusions

Guided by the theoretical framework of curriculum as a platform for talent development, this quasi-experimental field study investigated an intervention focused on engineering curriculum and curriculum based on a biography of a scientist. Implemented in Grade 1 classrooms in low-income schools, STEM Starters+ was examined through a comparative design. Student outcome measures included the following: science content achievement, engineering knowledge, and engineering engagement (both behavioral and emotional). The intervention resulted in gains with a *Cohen's d* type effect size of 0.28 on an out-of-level science content assessment constructed from released NAEP and TIMSS items and an effect size of 0.66 for the engineering knowledge measure. Students in the intervention group also reported a high level of engineering engagement. Evidence suggests the intervention functioned as a talent-spotting tool as teachers reported they would nominate a substantial portion of low-income and culturally diverse students for subsequent gifted and talented services; these students performed at higher levels on the outcome measures than students who were not "talent-spotted" by their teachers. Engineering, with linkages to a design process emphasizing investigation and creativity as curricular goals, provides a match between the needs and preferences of students from low-income households for hands-on design experiences. The curricular affordances in the engineering domain are a promising talent development pathway for young, poor children.

Acknowledgments

The authors wish to thank Keila Moreno Navarette and Kathleen Cash for their invaluable data collection and data management contributions to the study and Becky Rogers for her diligence in reading the text for clarity and errant punctuation.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This project is supported under the Javits Gifted and Talented Students Education Grant Program PR Award Number S206A140006-16 as administered by the Office of Elementary and Secondary Education U.S. Department of Education.

References

Anning, A. (1994). Dilemmas and opportunities of a new curriculum: Design and technology with young children. *International Journal of Technology and Design Education*, *4*, 155-177. doi:10.1007/BF01204545

Borland, J. H., & Wright, L. (1994). Identifying young, potentially gifted economically disadvantaged students. *Gifted Child Quarterly*, *38*, 164-171. doi:10.1177/001698629403800402

Briggs, C. J., Reis, S. M., & Sullivan, E. E. (2008). A national view of promising programs and practices for culturally, linguistically, and ethnically diverse gifted and talented students. *Gifted Child Quarterly*, *52*, 131-145. doi:10.1177/0016986208316037

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, *97*, 369-387. doi:10.1002/j.2168-9830.2008.tb00985.x

Brophy, S. P., & Mann, G. (2008, June). *Teachers' noticing engineering in everyday objects and processes*. Paper presented at the Annual Conference of the American Society of Engineering Education, Pittsburgh, PA.

Burney, V. H., & Beilke, J. R. (2008). The constraints of poverty on high achievement. *Journal for the Education of the Gifted*, *31*, 171-197. doi:10.4219/jeg-2008-771

Capobianco, B. M., Yu, J. H., & French, B. F. (2015). Effects of engineering design-based science on elementary school science students' engineering identity development across gender and grade. *Research in Science Education*, *45*, 275-292. doi:10.1007/s11165-014-9422-1

Cash, K. M., Adelson, J. L., & Robinson, A. (2016, April). *Development of the Science and Math Engagement Scale*. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, DC.

Century, J., Rudnick, M., & Freeman, C. (2010). A framework for measuring fidelity of implementation: A foundation for shared language and accumulation of knowledge. *American Journal of Evaluation*, *31*, 199-218. doi:10.1177/1098214010366173

Child Trends. (n.d.). *Child poverty* [Data file]. Retrieved from http://www.childtrends.org/databank/

Cotabish, A., Dailey, D., Robinson, A., & Hughes, G. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics*, *113*, 215-226. doi:10.1111/ssm.12023

Cunningham, C. M., & Carlsen, W. S. (2014). Teaching engineering practices. *Journal of Science Teacher Education*, *24*, 197-210. doi:10.1007/s10972-014-9380-5

Cunningham, C. M., & Hester, K. (2007). *Engineering is elementary: An engineering and technology curriculum for children*. Retrieved from https://eie.org/sites/default/files/research_article/research_file/ac2007full8.pdf

Dailey, D., & Robinson, A. (2017). Improving and sustaining elementary teachers' science teaching perceptions and process skills: A postintervention study. *Journal of Science Teacher Education*, *28*, 169-185. doi:10.1111/ssm.12023

Daugher, A. R., & Ford, D. J. (2005). How are scientists portrayed in children's science biographies? *Science & Education*, *14*, 377-393. doi:10.1007/s11191-004-7933-2

Deitz, M. C. (2012). *Gifted education teachers' perceptions on implementation of Blueprints for Biography: STEM Starters* (Unpublished doctoral dissertation). University of Arkansas at Little Rock, Little Rock.

Deitz, M. C., & Robinson, A. (2016, April). *Using biography and biographical methods in the classroom: Lives that teach*. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, DC.

Fairweather, E., & Fairweather, T. (2010). A method for understanding their method: Discovering scientific inquiry through biographies of famous scientists. *Science Scope*, *33*(9), 23-30.

Fingon, J., & Fingon, S. (2009). What about Albert Einstein? Using biographies to promote students' scientific thinking. *Science Scope*, *32*(7), 51-55.

Gallagher, S. A., & Gallagher, J. J. (2013). Using problem-based learning to explore unseen academic potential. *Interdisciplinary Journal of Problem-Based Learning*, *7*(1), 111-131. doi:10.7771/1541-5015.1322

Gavin, M. K., Casa, T. M., Firmender, J. M., & Carroll, S. R. (2013). The impact of advanced geometry and measurement curriculum units on the mathematics achievement of first-grade students. *Gifted Child Quarterly*, *57*, 71-84. doi:10.1177/0016986213479564

Holbrook, A., Panozza, L., & Prieto, E. (2008). Engineering in children's fiction—not a good story? *International Journal of Science and Mathematics Education*, *7*, 723-740. doi:10.1007/s10763-008-9129-8

Hollingworth, L. S. (1925). Introduction to biography for young children who test above 150 I.Q. *Teachers College Record*, *2*, 277-287. doi:10.1007/s10763-008-9129-8

Hollingworth, L. S. (1936). The Terman classes at Public School 500. *Journal of Educational Sociology*, *10*, 86-90. doi:10.2307/2262039

Katehi, L., Pearson, G., & Feder, M. A. (Eds.). (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press. doi:10.17226/12635

Kelly, G. J., Cunningham, C. M., & Ricketts, A. (2016, April). *Emergence of an engineering identity in elementary students*. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, DC.

Kidd, K. A., Deitz, M. C., & Robinson, A. (2016). *The watcher: Jane Goodall's life with the chimps* (Blueprints for Biography: STEM Starters Series). Little Rock: Jodie Mahony Center for Gifted Education, University of Arkansas at Little Rock.

Kim, K., VanTassel-Baska, J., Bracken, B., Feng, A., Stambaugh, T., & Bland, L. (2012). Project Clarion: Three years of science instruction in Title I schools among K-third grade students. *Research in Science Education*, *42*, 813-829. doi:10.1007/s11165-011-9218-5

Little, C. A. (2012). Curriculum as motivation for gifted students. *Psychology in the Schools*, *49*, 695-705. doi:10.1002/pits.21621

Mann, E. L., Mann, R. L., Strutz, M. L., Duncan, D., & Yoon, S. Y. (2011). Integrating engineering into K-6 curriculum: Developing talent in the STEM disciplines. *Journal of Advanced Academics*, *22*, 639-658. doi:10.1177/1932202X11415007

Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

McCoach, D. B., & Adelson, J. L. (2010). Dealing with dependence (Part I): Understanding the effects of clustered data. *Gifted Child Quarterly*, *54*, 152-155. doi:10.1177/0016986210363076

Miaoulis, I. (2014). K-12 engineering: The missing core discipline. In S. Purzer, J. Stroebel, & M. E. Cardella (Eds.), *Engineering in pre-college setting: Synthesizing research, policy, and practices* (pp. 21-34). West Lafayette, IN: Purdue University Press.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher*, *45*, 18-35. doi:10.3102/0013189X16633182

Morris, S. (1994). *A teachers' guide to using portraits*. Colchester, England: English Heritage.

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K-12 curriculum intervention research. *Review of Educational Research*, *78*, 33-84. doi:10.3102/0034654307313793

Olszewski-Kubilius, P., & Clarenbach, J. (2012). *Unlocking emergent talent. Supporting high achievement of low-income, high-ability students*. Retrieved from http://www.nagc.org/sites/default/files/key%20reports/Unlocking%20Emergent%20Talent%20%28final%29.pdf

Plucker, J. A., Hardesty, J., & Burroughs, N. (2013). *Talent on the sidelines: Excellence gaps and America's persistent talent underclass*. Storrs: Center for Education Policy Analysis, Neag School of Education, University of Connecticut.

Rae, J. B., & Volti, R. (2001). *The engineer in history* (2nd ed.). New York, NY: Peter Lang.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Thousand Oaks, CA: Sage.

Reardon, S. F., & Portilla, X. A. (2016). Recent trends in income, racial and ethnic school readiness gaps at kindergarten entry. *AERA Open*, *2*(3). Advance online publication. doi:10.1177/2332858416657343

Resnick, M. (2011). *Scratching the surface with Mitch Resnick*. Retrieved from http://www.hightechinthehub.com/2011/02/scratching-the-surface-with-mitchel-resnick/

Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 163-181). New York, NY: Routledge.

Robinson, A. (2009). Biography, eminence, and talent development: The lure of lives. In B. D. MacFarlane & T. Stambaugh (Eds.), *Leading change: The festschrift of Dr. Joyce VanTassel-Baska* (pp. 427-442). Waco, TX: Prufrock Press.

Robinson, A. (2017a). Conceptual frameworks in gifted education as the foundation for services. In J. L. Roberts, T. F. Inman, & J. H. Robins (Eds.), *Introduction to gifted education* (pp. 5-15). Waco, TX; Prufrock Press.

Robinson, A. (2017b). Developing STEM talent in the early school years: STEM Starters and its Next Generation scale up. In K. S. Taber, M. Sumida, & L. McClure (Eds.), *Teaching gifted learners in STEM subjects: Developing talent in science, technology, engineering and mathematics* (pp. 45-56). London, England: Routledge.

Robinson, A., Bradley, R. H., & Stanley, T. D. (1990). Opportunity to achieve: Identifying mathematically gifted black students. *Contemporary Educational Psychology*, *15*, 1-12. doi:10.1016/0361-476X(90)90001-H

Robinson, A., Dailey, D., Hughes, G., & Cotabish, A. (2014). The effects of a science-focused STEM intervention on gifted elementary students' science knowledge and skills. *Journal of Advanced Academics*, *25*, 189-213. doi:10.1177/1932202X14533799

Robinson, A., & Kidd, K. A. (2017). Engineering is elementary: Considerations when implementing for high ability learners (Appendix B: Engineering in formal and informal environments). In D. Dailey & A. Cotabish (Eds.), *Engineering instruction for high-ability learners in K-8 classrooms* (pp. 207-208). Waco, TX: Prufrock Press.

Robinson, A., Kidd, K. A., & Adelson, J. L. (2017). Assessments for K-8 engineering: What is available and advisable for talented students? In D. Dailey & A. Cotabish (Eds.), *Engineering instruction for high-ability learners in K-8 classrooms* (pp. 165-178). Waco, TX: Prufrock Press.

Robinson, A., Kidd, K. A., Adelson, J. L., Deitz, M. C., & Meadows, M. (2017, November). *Teacher perceptions of developing engineering talent in low-income, young children through evidence-based curriculum*. Paper presented at the Annual Meeting of the American Educational Research Association, San Antonio, TX.

Robinson, A., Kidd, K. A., & Deitz, M. C. (2016). Biography builds STEM understanding for talented learners. In B. D. MacFarlane (Ed.), *STEM education for high-ability learners: Designing and implementing programs* (pp. 171-186). Waco, TX: Prufrock Press.

Royal Academy of Engineering. (2014). *Thinking like an engineer: Implications for the education system*. Retrieved from http://www.raeng.org.uk/thinkinglikeanengineer

Ruiz-Primo, M. A. (2006). *A multi-method and multi-source approach for studying fidelity of implementation*. Los Angeles: CA: National Center for Research on Evaluation, Standards, and Student Testing.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental design for generalized causal inference*. Boston, MA: Houghton-Mifflin.

Smith, J. M., & Lucena, J. C. (2015). Invisible innovators: How low-income, first-generation students use their funds of knowledge to belong in engineering. *Journal of Engineering Studies*, *8*, 1-26. doi:10.1080/19378629.2016.1155593

Stambaugh, T. (2007). Next steps: Priorities for action. In J. VanTassel-Baska & T. Stambaugh (Eds.), *Overlooked gems: A national perspective on low-income promising learners: Conference proceedings from the National Leadership Conference on Low-Income Promising Learners* (pp. 83-88). Washington, DC: National Association for Gifted Children.

Swanson, J. D. (2006). Breaking through assumptions about low-income, minority gifted students. *Gifted Child Quarterly*, *50*, 11-25. doi:10.1177/001698620605000103

VanTassel-Baska, J., & Stambaugh, T. (2006). Project Athena: A pathway to advanced literacy development for children of poverty. *Gifted Child Today*, *29*, 58-65. doi:10.4219/gct-2006-202

VanTassel-Baska, J., & Stambaugh, T. (Eds.). (2007). *Overlooked gems: A national perspective on low-income promising learners: Conference proceedings from the National Leadership Conference on Low-Income Promising Learners*. Washington, DC: National Association for Gifted Children.

Vossoughi, S., & Bevan, B. (2014). *Making and tinkering: A review of the literature*. Retrieved from http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_089888.pdf

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*, 817-835. doi:10.1037/a0016127

Wai, J., & Worrell, F. C. (2015). Helping disadvantaged and spatially talented students fulfill their potential: Related and neglected national resources. *Policy Insights from the Behavioral and Brain Sciences*, *3*, 122-128. doi:10.1177/2372732215621310

Wyner, J. S., Bridgeland, J. M., & Diiulio, J. J., Jr. (2008). *Achievement trap: How America is failing millions of high-achieving students from lower-income families*. Lansdowne, VA: Jack Kent Cooke Foundation.

Author Biographies

Ann Robinson is professor of educational psychology and founding director of the Jodie Mahony Center for Gifted Education at the University of Arkansas—Little Rock. She is past president of the National Association for Gifted Children (NAGC), a former editor of the *Gifted Child Quarterly*, and has been honored by NAGC as Early Scholar, Early Leader, Distinguished Scholar and for Distinguished Service to the association. She developed five Jacob K. Javits projects including two STEM research and demonstration programs for elementary students and teachers. She is the lead author on the best-selling *Best Practices in Gifted Education: An*

Evidence-Based Guide and coeditor of *A Century of Contributions to Gifted Education: Illuminating Lives.* Her *Blueprints for Biography* curriculum guides provide teachers with strategies for differentiating nonfiction reading for talented students.

Jill L. Adelson is an associate professor in the educational psychology, measurement, and evaluation program at the University of Louisville. She currently is serving on three Javits grants: Project SPARK, STEM Starters+, and Project RAP. She is the coauthor of *Letting Go of Perfect: Overcoming Perfectionism in Kids*. As a translational methodologist, her research involves bridging the gap between advanced methods and applied research. She is particularly interested in applications of advanced methods to examine the effects of gifted programming and mathematics talent development.

Kristy A. Kidd is the STEM Starters+ program director, a Jacob K. Javits research and demonstration project, at the University of Arkansas—Little Rock. She has 21 years of experience teaching elementary and middle school science in the Little Rock Public Schools. She also served as a gifted and talented facilitator for the Little Rock Schools, an adjunct professor of early childhood science methods for the University of Arkansas—Little Rock, and as the K-12 math and science specialist for the eStem Public Charter Schools. She is the recipient of the Milken National Educator Award which honors top educators around the country for their achievements in education.

Christine M. Cunningham is a vice president at the Museum of Science, Boston where she works to make engineering and science more relevant, accessible, and understandable, especially for underserved and underrepresented populations. As the founding director of the groundbreaking Engineering is Elementary (EiE) project, she has developed engineering curricula for preschool through middle-school students and professional development for their teachers. As of July 2017, EiE has served 13.3 million children and 150,000 educators nationwide. She is a fellow of the American Society for Engineering Education (ASEE). In 2017, her work was recognized with the prestigious Harold W. McGraw Jr. Prize in Education. She holds BA and MA degrees in biology from Yale and a PhD in Science Education from Cornell University.