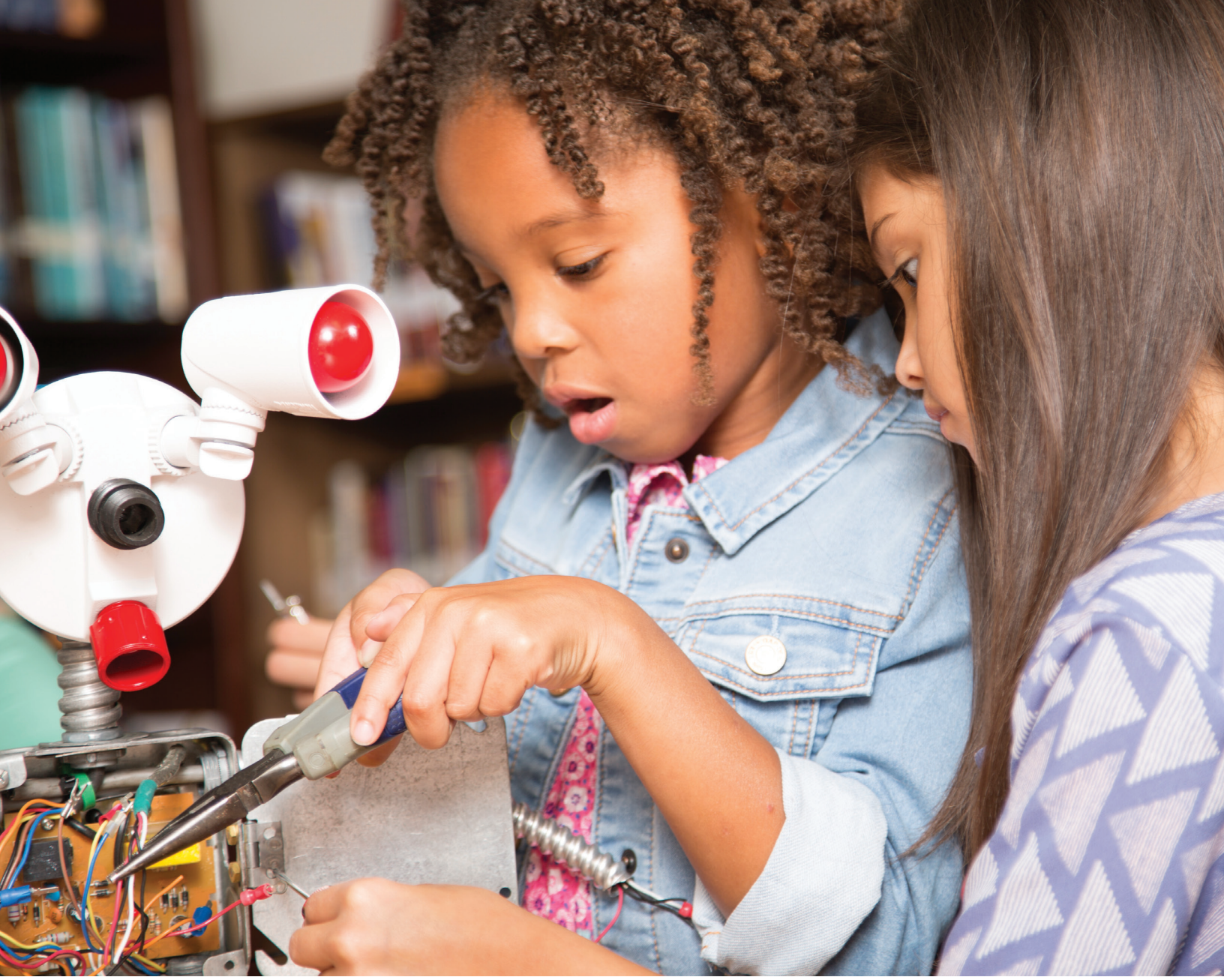

WHAT THE RESEARCH SAYS ABOUT STEM EDUCATION FOR STUDENTS WITH GIFTS AND TALENTS

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Science, technology, engineering, and mathematics (STEM) equip students with critical thinking and problem-solving skills for success in the current workplace, in jobs yet to be created, and in their everyday lives (Dailey et al., 2018; Milano, 2013; Office of Science and Technology Policy, 2019). The importance of STEM education is apparent at both the federal and state levels. At the national level, the Committee on STEM Education has developed a strategic plan focusing on

three goals: (a) building a strong foundation for STEM literacy; (b) increasing the diversity, equity, and inclusion in STEM; and (c) preparing the STEM workforce for the future (Office of Science and Technology Policy, 2019). Moreover, to foster expanded opportunities in high-demand STEM fields, the U.S. Department of Education has invested $540 million to support STEM education in the 2019–2020 year through discretionary and research grants (Committee on STEM Education of the National Science and Technology Council, 2018). Among other areas, these funds will be used to prepare STEM teachers, increase the number of low-income students who are prepared to enter and succeed in postsecondary education, design interventions that help students transition between high school and higher education and careers, and implement programs showing evidence that they are likely to improve STEM learning and engagement. At the state level, the Texas Education Agency offers STEM as a career cluster and provides support for T-STEM campuses offering dual credit, rigorous instruction, and accelerated courses.

Given the push in education toward STEM and more transdisciplinary learning (e.g., infusing math, technology, and engineering into science instruction), what gifted education programs and curricula are effective in encouraging the development of students with gifts and talents in STEM fields? How might STEM opportunities be provided at the elementary level when students have the most favorable attitudes toward science? This review will focus on these important questions.

To identify potential articles related to STEM with gifted students, five gifted education journals were searched: *Gifted Child Quarterly*, *Gifted Child Today*, *Journal of Advanced Academics*, *Journal for the Education of the Gifted*, and *Roeper Review*. We initially identified 84 articles published within the past 10 years that related to STEM. These articles examined topics such as characteristics of students with talent, characteristics of students who pursue STEM careers, identification of students with high potential in STEM, characteristics of programs and instruction, effects of specific programs and different types of curriculum, parents' perceptions and their influence, and professional learning. Because of the large number of articles related to STEM, we decided to focus this article on the effectiveness of specific curricula and programming options only. To be considered for inclusion, articles must also have been empirical studies (i.e., have methods, results, and discussion sections) and have been published within the past 10 years (2009–2019). Empirical studies were excluded if they were conducted outside of the United States or if the research did not primarily focus on the effectiveness of STEM curriculum or programs with gifted and/or high-achieving students. Using these criteria, 28 articles were identified and summarized. Twenty-four articles used quantitative research methods, two articles reported on qualitative research, and two reported on mixed methods.

EFFECTS OF STEM PROGRAMS

Most of the programs described in the literature focused on areas related to STEM; no research described the effects of programs that integrated the arts with STEM. The delivery of STEM programs occurred (a) within the school day, (b) beyond the normal school day on school district or university campuses, (c) within competitions, (d) in online courses, or (e) in early entrance college programs.

IN-SCHOOL STEM PROGRAMS

Three studies examined the effects of various STEM and gifted programs within the school setting. Studying the effects of New York City's selective specialized public high schools, Sloan (2018) discovered that more of these students attended honors colleges and graduated with STEM degrees than students who did not attend specialized schools. She concluded that the challenging curriculum and environment with like-minded peers benefitted the gifted students academically and socially.

Two of the studies used large databases to examine the effects of gifted programs on STEM. Using the National Assessment of Educational Progress (NAEP) database, Young et al., (2017) reported that fourth-grade Black girls who received gifted instruction outperformed Black girls not receiving gifted instruction in mathematics and science on NAEP. Wai and Allen (2019) used the ACT database and examined 482,418 students who took the ACT in the seventh grade and again in high school. Overall, they found that high growth was associated with participation in STEM elective high school courses, advanced programs, and accelerated and honors courses, but not for all groups, such as those from low-income backgrounds. They did report that participating in service organizations, instrumental music, debate, religious organizations, and racial/ethnic organizations was also related to higher academic growth.

OUT-OF-SCHOOL ENRICHMENT

The majority of the studies that focused on programming examined out-of-school enrichment opportunities and their effects on STEM performance. Participants in these studies ranged from primary age through high school with most from underrepresented groups. Programs were offered on the school or university campuses.

In one study, 220 primary age students (K–2) from 10 school districts participated in a summer program addressing math, specifically geometry, which was differentiated for

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high-potential students from underserved populations. Teachers from participating districts were trained to teach the curriculum. Students who participated in the summer program made larger gains from spring testing to fall testing in their mathematics achievement compared to students who did not participate. Importantly, students from economically disadvantaged backgrounds made gains similar to those of their more economically advantaged peers (Little et al., 2017).

Several studies examined the effects of enrichment programs on older elementary students. In one study, 84 students in grades 3–5 participated in a 4-day engineering academy on a university campus (Dailey et al., 2018). Teachers who were seeking a gifted and talented add-on license cotaught the project-based units with engineers in the field. Students and teachers demonstrated growth on pre- and post-engineering assessments, with teachers increasing their knowledge and confidence for teaching engineering, and students making gains in their content knowledge, knowledge of engineering practices, and application of the engineering design process. The other study, which also included middle school students in addition to elementary students, offered a Saturday Enrichment Program (SEP) on a university campus that explored challenging math topics not typically taught in school (Mun & Hertzog, 2018). Although the students did not change significantly in how they viewed mathematicians or how they felt about math, they were less interested in what they were learning in their school math classes after participating in SEP. The authors concluded students enjoyed the SEP learning environment, which encouraged students to look at their solutions from different perspectives, have fun in taking risks and making mistakes, and having "playful" discussions.

At the middle school level, 11 rural school districts participated in STEM Excellence, which engaged 151 students in 96 hours of challenging curriculum in mathematics and science out of school (Ihrig et al., 2018). Students met 4 hours per week after school with their math and science teachers throughout the year. Survey results showed that both teachers and students benefited from their participation by thinking more creatively and critically about their work, expressing satisfaction, and indicating they wanted to continue in the program.

Three studies examined the effects of Project EXCITE, a collaboration between Northwestern University's Center for Talent Development, Evanston/Skokie School District 65, and Evanston Township High School (ETHS) District 202. Project EXCITE's goals are to nurture minority students' interest and talent in math and science by offering math and/or science courses during the summer and on Saturdays so that participants will eventually pursue higher education. Students enter the program in third grade and may remain until they graduate from high school. The researchers' longitudinal studies reported these results: participants qualified for prealgebra in grade 6, mastered district-level math assessments, earned A's and B's in math and science, exceeded math and science standards on the state test, increased their participation in advanced courses in high school, and reduced the math and science achievement gap between disadvantaged high-potential minority and high-achieving majority students (Olszewski-Kubilius et al., 2004; Olszewski-Kubilius et al., 2017). Rising ninth-grade minority students who participated over a 6-year period also noted that the program not only prepared them academically, but also extended social networks with other high-ability minority peers, enhanced social support, and increased their confidence to compete academically (Lee et al., 2009).

Another out-of-school enrichment program in this literature review focused on 29 high school students from ethnic minorities who worked with graduate and postdoctoral students in a laboratory setting during the summer (Fraleigh-Lohrfink et al., 2013). The Center Scholars program collaborated with the Johns Hopkins University Center for Talented Youth in developing the program with the goal of discovering students with an interest in science early. When comparing the Center Scholars to other Talent Search participants, the researchers reported that the Scholars were more likely to indicate that they planned to pursue a career in science research, planned to take advantage of research opportunities in high school, and rated themselves more highly on scientific competency.

A final study examined the overall relationship between out-of-school enrichment and Black student participation in advanced science (Young & Young, 2018). Analyzing the High School Longitudinal Study database,

the researchers reported that Black students who participated in outside-of-school STEM activities such as science competitions and science tutoring tended to participate in more advanced science coursework. They noted that overall participation was low, with only 11.73% of participants participating in at least one outside-of-school activity.

COMPETITIONS

Two studies examined the effects of competitions. Coxon (2012) reported that male students who participated in the FIRST LEGO League (FLL), which incorporates science and technology, made significant gains in spatial ability; however, female students did not make the same gains. The second study examined the long-term effects of students who had participated in the Olympiad, a competition focusing on math, chemistry, and physics (Campbell & Walberg, 2011). These adults graduated from elite universities and completed more doctoral degrees than a comparison group and produced a total of 8,269 publications.

ONLINE COURSES

Only one study examined the effects of online courses in STEM. The course was developed by faculty, staff, and graduate students at the University of Virginia and incorporated videos of lectures, animated simulations, and case-based problems in environmental science (Missett et al., 2010). The 138 self-identified students, ages 12–17, enrolled in the course. The students learned scientific facts and vocabulary, and engaged in higher level thinking and thinking as a scientist, with 72% receiving high or middle school credit. The authors noted that students who were independent learners with strong management skills and were more active on the discussion boards had the most success with the course.

EARLY ENTRANCE INTO COLLEGE

One study examined the effects of early college entrance into the Texas Academy of Mathematics and Science at the University of North Texas (Boazman & Sayler, 2011). In this study, participants displayed a more powerful sense of efficacy and expressed greater satisfaction than similar-age peers with current achievements, their personal safety, and their prospects for their future security. They also found close friendships and reported characteristics related to positive personal well-being.

EFFECTS OF STEM CURRICULUM

Eleven articles reported on the effects associated with specific STEM curriculum. Most of the curriculum development and research was funded by specific grants.

PROJECT M^3 AND PROJECT M^2

Funded initially in part by a federal Jacob K. Javits grant, the goal of Project M^3: Mentoring Mathematical Minds was to develop advanced elementary math curriculum to engage students with mathematical promise from diverse backgrounds and to address the shortage of challenging, research-based math materials for young students (Gavin et al., 2009). Jointly developed by mathematicians, experts in the field of gifted education and mathematics education, in the first phase, 12 Project M^3 units were written and field-tested with grades 3–5. These accelerated units covered the National Council of Teachers of Mathematics (NCTM) standards and addressed four content strands: algebra, data analysis/probability, geometry/measurement, and numbers and operations.

Multiple quasi-experimental studies compared the math achievement of students in intervention classrooms to students in control classrooms that used the approved district math or science curriculum. For example, third- to fifth-grade students demonstrated higher math achievement on the Iowa Tests of Basic Skills (ITBS) math subtest and on the open-response assessment measuring mathematical reasoning (Gavin et al., 2009). In subsequent research, students at various ability levels responded differently to the curriculum, with high-achieving students demonstrating the most gains in achievement (McCoach et al., 2014). In Cho et al.'s (2015) study, mathematically promising third-grade English language learners (ELLs) were randomly placed in a control or M^3 afterschool math program. After the intervention, the treatment group scored significantly higher on the ITBS math subtest compared to the control group.

Project M^2, funded by the National Science Foundation, was created using the same pedagogy and philosophy of Project M^3. The primary aim of Project M^2, however, was to develop challenging measurement and geometry curriculum for all primary students and help them understand higher level creative and critical mathematical thinking and embrace "the role of a practicing mathematician" (Gavin et al., 2013, p. 72). Gavin et al. (2013) reported that ITBS math achievement scores were similar in the treatment and control groups, but the M^2 students scored significantly higher on mathematical reasoning in geometry as demonstrated on the open-ended assessment. In the quasi-experimental research with kindergarten students, the M^2 intervention group scored significantly higher on math achievement and math reasoning assessments (Casa et al., 2017).

The relationship between teachers' instructional practices of teachers utilizing the M^2 curriculum and the math achievement of early elementary students was examined (Firmender et al., 2014). Teacher encouragement

to use mathematical language and engagement of students in verbal communication was moderately correlated (r = .5). Greater use of both instructional practices predicted higher gains from the pretest to the posttest on the open-response mathematical reasoning assessment.

THE INTEGRATED CURRICULUM MODEL

Project Clarion was another grant funded by the U.S. Department of Education Javits Grant to take previously developed science curriculum using the Integrated Curriculum Model for high-ability learners and implement it in Title I schools (Kim et al., 2014). The results of the quasi-experimental study demonstrated that students in the treatment group significantly outperformed their grade 1–3 peer students in the comparison group on a matched achievement test and a test of critical thinking. Furthermore, statistical growth modeling suggested that the curriculum was effective for enhancing science content and science concept knowledge for students at all ability levels.

The Integrated Curriculum Model was also the foundation for a fractions unit for fourth- and fifth-grade students, *The Tale of the Monarchs* (Coxon et al., 2018). This unit is a product of a curriculum design and evaluation project—children using robotics for engineering, science, technology, and mathematics (CREST-M). This curriculum, funded by the Monsanto Fund grant, integrates math and storytelling. After a one-week summer intervention, students demonstrated a statistically and practically significant gain in math achievement. Students from traditionally underrepresented also drew pictures of scientists that were more complex and more reflective of their own personal characteristics.

STEM Starters and STEM Starters+ were additional projects funded by the Jacob K. Javits grant. Both combine biographies of scien-

tists (Blueprints for Biography STEM Series) with William & Mary curriculum units. The purpose of STEM Starters was to develop the STEM talent of elementary students by integrating engineering and math concepts (Robinson et al., 2014). Problem-based curriculum units for students in grades 2– 5 and professional development funding were priorities of this project. For example, teachers received 120 hours of peer coaching, follow-up support, and explicit instructions on teaching practices during the intervention. The science curriculum used problem-based learning in which students utilized critical thinking to address real-world problems. In Robinson et al.'s (2014) study at Title I schools, gifted students in the STEM Starters group performed significantly higher on assessments measuring scientific process, science content, and science concept knowledge compared to gifted students in the district-adopted science curriculum group.

Theorizing that curriculum can be used as a platform to recognize and develop diverse talent, Robinson et al.'s (2018) study investigated the impact of implementing a STEM curriculum, STEM Starters+, in low-income schools. First-grade students in the treatment group, on average, scored statistically higher on engineering content and a self-reported engineering engagement compared to the comparison group. This research also suggests that general education teachers became better equipped to spot talent in low-income and culturally diverse students, and were more likely to nominate these students for gifted and talented services.

TIERED LESSONS IN MATHEMATICS

Pierce et al. (2011) provided professional development and tiered mathematics lessons in algebra and geometry to third- through fifth-grade teachers in cluster classrooms. The authors provided math replacement units that covered the topics of algebra and geometry to augment the standard third-grade math curriculum. Tiering consisted of versions of the curriculum for students who were performing below grade level, for students at grade level, and for students above grade level. The teacher's guide also included problem-solving experiences and "menu activities," which could be used as anchoring activities. Comparing pre- and posttest results, the researchers found that students who were in cluster classrooms where teachers fully implemented the curriculum performed higher on math posttests than the comparison group.

SUMMARY AND CONCLUSIONS

Overall, the researchers reported positive effects related to curriculum and programming in gifted education. Most of the research pertained to curriculum focused on two models: Mentoring Mathematical Minds and the Integrated Curriculum Model. Both of these models had positive results on achievement for gifted and for general education students of all ability levels. In addition, tiered mathematics lessons were equally effective. However, in all cases, effectiveness was dependent on the full implementation of the curriculum. Similarly, participants in both in-school and out-of-school enrichment programs, as well as online and early entrance options, were influenced positively in both academic, social, and emotional areas. However, the type and characteristics of the program do matter. Using a large database, Adelson et al., (2012) found that gifted students who participated in gifted programs in mathematics and reading were similar to students who didn't participate in terms of their achievement and academic attitudes. They concluded that policymakers, educators, and parents must seek research-based practices to obtain program goals.

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Dailey, D., Cotabish, A., & Jackson, N. (2018). Increasing early opportunities in engineering for advanced learners in elementary classrooms: A review of recent literature. *Journal for the Education of the Gifted, 41*(1), 93–105. https://doi.org/10.1177/0162353217745157

Milano, M. (2013). The Next Generation Science Standards and engineering for young learners: Beyond bridges and egg drops. *Science & Children, 51*(2), 10–16.

Office of Science and Technology Policy. (2019). *Progress report on the federal implementation of the STEM education strategic plan*. https://www.whitehouse.gov/wp-content/uploads/2019/10/Progress-Report-on-the-Federal-Implementation-of-the-STEM-Education-Strategic-Plan.pdf

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Adelson, J. L., McCoach, D. B., & Gavin, M. K. (2012). Examining the effects of gifted programming in mathematics and reading using the ECLS-K. *Gifted Child Quarterly, 56*(1), 25–39. https://doi.org/10.1177/0016986211431487

This study examined the average effects of schools' third- through fifth-grade gifted programming policy in mathematics and reading on overall school achievement and on gifted and nongifted students' achievement and academic attitudes. The sample was from a national data set—the Early Childhood Longitudinal Study, Kindergarten Class of 1988–1989, which contains repeated observations of students and their families over time. The researchers found that providing a gifted mathematics program did not have a significant effect on gifted and nongifted students' mathematics achievement. Similar results were found for gifted and nongifted students' attitudes toward mathematics. The authors concluded that providing gifted programming does not have a detrimental effect on other students. However, specific types of gifted programming were not analyzed nor characteristics of the services. They suggested more rigorous research regarding the types of programs and curriculum that improve gifted students' achievement.

Boazman, J., & Sayler, M. (2011). Personal well-being of gifted students following participation in an early college-entrance program. *Roeper Review, 33*(2), 76–85. https://doi.org/10.1080/02783193.2011.554153

This descriptive study examined early college entrants' personal well-being, cheerfulness, and perceived self-efficacy. The participants were former students (2001–2005) of the Texas Academy of Mathematics and Science, which allows high school-aged students to accelerate their education 2 or more years by attending the University of North Texas and studying science, medicine, mathematics, or engineering. Data were gathered via an online survey instrument. Results indicated that the early college-entrance participants had above-average well-being and expressed greater satisfaction than similar-age peers as a whole with their current achievements in life, their personal safety, and their prospects for their future security. They displayed a powerful sense of efficacy in comparison to same-age young adults and were more serious toward work and play. The authors concluded that these results should encourage parents, educators, and gifted students who are considering early college entrance and have concerns about its effects.

Campbell, J. R., & Walberg, H. J. (2011). Olympiad studies: Competitions provide alternatives to developing talents that serve national interests. *Roeper Review, 33*(1), 8–17. https://doi.org/10.1080/02783193.2011.530202

The top Mathematics, Chemistry, and Physics Olympiad students are identified and assembled into national teams that compete against other teams from around the world. The researchers examined data from 345 adult Olympians to examine their contributions to society. They reported that the Olympians graduated from elite universities with 52% completing or in the process of completing doctoral degrees. They also found that 40% selected careers in academia, 34% in careers outside of academia, and 20% in science, engineering, and computers. The 345 Olympians also produced a total of 8,269 publications. The authors concluded competitions are needed to challenge students, particularly because many schools do not have a differentiated curriculum.

Casa, T. M., Firmender, J. M., Gavin, M. K., & Carroll, S. R. (2017). Kindergarteners' achievement on geometry and measurement units that incorporate a gifted education approach. *Gifted Child Quarterly, 61*(1), 52–72. https://doi.org/10.1177/0016986216671806

The purpose of this study was to examine the effects of a newly developed Project M^2 curriculum for heterogeneous kindergarten students. This article provides results of one of the studies regarding the implementation Project M^2 mathematical curriculum (see introduction). Specifically, this study investigated if kindergarten students' math achievement increased after a 12-week Project M^2 intervention using HLM. Pairs of teachers from 11 schools participated in this study; one teacher from each school was randomly assigned as the M^2 treatment group, and the other teacher's class served as the control group. In addition to a 4-day summer training institute, teachers in the treatment group attended two 1-day Project M^2 trainings: before the geometry unit and before the measurement unit. The results from this quasi-experimental study demonstrated that after controlling for pretest scores, the Project M^2 kindergarten students (n = 210) scored significantly higher on both measures of math achievement compared to the control group (n = 196): the Iowa Tests of Basic Skills (ITBS) kindergarten math subtest (d = 0.25, small effect) and the open-response assessment which measured students' written mathematical reasoning in geometry and measurement (d = 2.68, very large effect). Although these findings suggest that early childhood math curriculum can largely impact student math knowledge, the researchers acknowledged limitations, including that the comparison group may not have been taught to explain

their mathematical reasoning in writing nor have spent as much time on geometry and measurement concepts. The research suggests that curriculum and methods based on best practices with gifted students may also be effectual with general education students in math.

Cho, S., Yang, J., & Mandracchia, M. (2015). Effects of M³ curriculum on mathematics and English proficiency achievement of mathematically promising English language learners. *Journal of Advanced Academics, 26*(2), 112–142. https://doi.org/10.1177/1932202X15577205

Researchers examined math achievement of mathematically promising third-grade English language learners (ELLs) who were also economically disadvantaged. Six urban elementary schools from one district agreed to participate. First, a pool of ELLs who scored at least at an intermediate English proficiency level was identified. Consistent with a developmental view of giftedness, the top 50% from each school were chosen based on local norms and multiple measures (e.g., teacher Likert scaled math ratings, peer nominations, students' English grades, and math grades). Participants were randomly placed in the control (n = 85) or the M³ intervention group (n = 86), which met after school on 3 days per week for about 20 hours per semester. The seven teachers providing the intervention attended 3 days of professional development in the summer and a 1-day training in the fall and spring semesters. The results from this quasi-experimental study using HLM demonstrated that the intervention students scored significantly higher (d = 0.63, medium effect) on the Iowa Tests of Basic Skills (ITBS) math subtest compared to the control students.

Coxon, S. V. (2012). The malleability of spatial ability under treatment of a FIRST LEGO league-based robotics simulation. *Journal for the Education of the Gifted, 35*(3), 291–316. https://doi.org/10.1177/0162353212451788

The For Inspiration and Recognition in Science and Technology (FIRST) foundation supports innovative programs that encourage young people to pursue education and career opportunities in STEM, including the LEGO league described in this article. The author studied the effects of a FIRST LEGO League (FLL) competition on 75 students' spatial ability. The author suggested that spatial ability is important to STEM majors in higher education, career choices, and innovations. The participating students, between the ages of 9 and 14 from 29 school districts, were randomly divided into four subgroups of 10 participants each (i.e., a FIRST LEGO team). The experimental groups participated in a simulation based on the FLL competition, whereas the control group did not receive any intervention. There were significant gains in spatial ability for the male participants but not the females who participated in the FLL. The author concluded that LEGO robotics is beneficial in spatial talent development. More research is needed to determine the different effects between males and females.

Coxon, S. V., Dohrman, R. L., & Nadler, D. R. (2018). Children using robotics for engineering, science, technology, and math (CREST-M): The development and evaluation of an engaging math curriculum. *Roeper Review, 40*(2), 86–96. https://doi.org/10.1080/02783193.2018.1434711

Children using robotics for engineering, science, technology, and mathematics (CREST-M) is another curriculum designed to engage traditionally underrepresented students in STEM fields. Developed using the Integrated Curriculum Model (ICM), this curriculum is appropriate for all students of ability levels (including the gifted). The unit, *The Tale of the Monarchs*, incorporated storytelling, the building and programming of LEGO robots, and utilization of the scientific method to solve real-world problems. Using a mixed-methods design, researchers collected pre-post qualitative data on mental models of a scientist and pre-post quantitative achievement data from fourth- and fifth-grade students (n = 25 male; n = 20 female) after a 1-week enrichment program. The results from paired sample t-tests indicated significant student gains on a test aligned with Common Core State Standards for Mathematics for fourth- and fifth-grade fractions (d = 0.72, indicating a large effect). These gains did not differ based on ethnicity, gender, socioeconomic status, or cognitive ability. From a qualitative comparison of the pre- and post-Draw-a-Scientist tests, two themes emerged from these drawings. Greater personal identification as a scientist was demonstrated by post-intervention drawings of people who resembled the student. Students also demonstrated a deeper understanding of the complexity of a scientist with drawings that included more scientific equipment and reflected more accurate depictions of what a scientist might do.

Dailey, D., Jackson, N., Cotabish, A., & Trumble, J. (2018). STEMulate engineering academy: Engaging students and teachers in engineering practices. *Roeper Review, 40*(2), 97–197. https://doi.org/10.1080/02783193.2018.1434709

The researchers designed a university-based day camp, STEMulate Engineering Academy, to provide children engineering opportunities and offer teachers a professional development experience. The purpose of this study was to investigate the impact of the camp experiences on students' knowledge of engineering practices,

their application of the engineering design processes during the camp, and teachers' attitudes about integrating engineering into their classrooms. Over a 2-year period, 121 children in grades 3–5 and 29 teachers attended the Academy. Based on observations and student assessments, the authors found significant increases in student knowledge and engagement in brainstorming and planning. The majority of students also displayed enthusiasm and determination to complete the project. Teachers also increased their knowledge and improved their confidence and self-efficacy for teaching engineering.

Firmender, J. M., Gavin, M. K., & McCoach, D. B. (2014). Examining the relationship between teachers' instructional practices and students' mathematics achievement. *Journal of Advanced Academics, 25*(3), 214–236. https://doi.org/10.1177/1932202X14538032

The objective of this study was to investigate the extent that specific instructional practices utilized in the M^2 curriculum were related to kindergarten, first-grade, and second-grade students' geometry and measurement achievement. Teachers were observed an average of 10 times by a trained observer, who used checklists to indicate the absence or presence of specific instructional practices: verbal engagement in math (nine checklist items) and encouraging the use of mathematical language (three checklist items). A moderate correlation (r = .5) between the two instructional practices was found. The results of the HLM indicated that a greater use of mathematical language and of verbal engagement in math predicted higher scores on the students' open-response assessments.

Fraleigh-Lohrfink, K. J., Schneider, V., Whittington, D., & Feinberg, A. P. (2013). Increase in science research commitment in a didactic and laboratory-based program targeted to gifted minority high-school students. *Roeper Review, 35*(1), 18–26. https://doi.org/10.1080/02783193.2013.740599

This study examined the effects of the Center Scholars Program (CSP), a 3-week summer course in genome science for talented minorities in high school offered through Johns Hopkins University Center for Talented Youth (CTY). Those students who complete the course along with another course in genetics and high school biology were provided opportunities to work with graduate and postdoctoral students at varying stages in their research careers in a laboratory setting. Using a survey, the researchers collected information from 29 students from minority backgrounds who completed the CSP program and a comparison group of students who participated in CTY science courses and were similar demographically. Although there were no differences in science as a career choice, the Center Scholars showed significantly higher and better-defined career aspirations, higher degree-level aspirations, more interest in pursuing science research, and more competence in research techniques and skills than the comparison group. The authors concluded that high school enrichment programs had a substantial impact on minority participation in science and research fields.

Gavin, M. K., Casa, T. M., Adelson, J. L., Carroll, S. R., & Sheffield, L. J. (2009). The impact of advanced curriculum on the achievement of mathematically promising elementary students. *Gifted Child Quarterly, 53*(3), 188–202. https://doi.org/10.1177/0016986209334964

Twelve Project M^3 units were originally designed and field-tested for grades 3–5 (four per grade level). Eleven urban and suburban schools participated in this study for 4 years. Using a quasi-experimental design, researchers compared the math performance of two cohorts of Project M^3 treatment groups to a similar-ability comparison group. Students with mathematical potential were identified using local norms on multiple measures (e.g., NNAT, Mathematical Scales for Rating Superior Students, and teacher recommendations). Intervention teachers were not randomized because they needed to attend a 2-week training during the summer before implementation. The results from this HLM demonstrated that after controlling for pretest scores, the Project M^3 students from Cohort 1 (n = 526) and Cohort 2 (n = 474) in every grade scored significantly higher on both measures of math achievement compared to the comparison group (n = 538). The effect size on the Iowa Tests of Basic Skills (ITBS) concepts and estimation items (d = 0.29 to 0.59) represented a small to medium effect, and the effect size on the open-response assessment (d = 0.69 to 0.97) demonstrated a medium to large effect. These results provide evidence that the curriculum positively affected the achievement of mathematically promising students.

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*(2), 71–84. https://doi.org/10.1177/0016986213479564

This is one of the studies regarding the implementation of Project M^2 mathematical curriculum (see introduction). In this quasi-experimental study, researchers investigated if first-grade students' math achievement increased after a 12-week Project M^2 intervention. Pairs of teachers from 12 schools participated in this study; one teacher's class from each school was randomly assigned as the M^2 inter-

vention group, and the other teacher's class served as the control group. In addition to a 4-day summer training institute, teachers in the treatment group attended a one-day Project M^2 training in the fall and the spring. Hierarchical linear modeling (HLM) results demonstrated that after controlling for pretest scores, there was no statistically significant difference on the Iowa Tests of Basic Skills (ITBS) grade 1 math subtest between the Project M^2 grade 1 students (n = 186) compared to the control group (n = 174). The intervention group, however, scored significantly higher on an open-response assessment that measured students' written mathematical reasoning in geometry and measurement (d = 1.88, very large effect). Given the large effect size on the open-ended assessment, this research supports that the M^2 geometry and measurement curriculum is equally effective in developing mathematical problem solving and more effective in helping young learners to describe their mathematical reasoning. The ability to use and explain one's mathematical thinking is essential, according to the National Council of Teacher Mathematics and the Common Core State Standards for Mathematics.

Ihrig, L. M., Lane, R., Mahatmya, D., & Assouline, S. G. (2018). STEM excellence and leadership program: Increasing the level of STEM challenge and engagement for high-achieving students in economically disadvantaged rural communities. *Journal for the Education of the Gifted, 41*(1), 24–42. https://doi.org/10.1177/0162353217745158

The purpose of this study was to evaluate the experiences of 78 high-achieving, middle school (grades 6–8) students and their 32 teachers from 11 rural school districts who participated in an extracurricular, school-based STEM talent development program. Selection of the districts was based on their commitment to the program, location, and free and reduced-price lunch status. Students who participated in the STEM Excellence and Leadership program performed at the 85th percentile on the Iowa Assessments and engaged in 96 hours of challenging curriculum in mathematics and science out of school. On average, students met 4 hours per week after school with their math and science teachers over a 24-week period throughout the academic year for 48 hours of mathematics instruction and 48 hours of science instruction. Data were collected using an open-ended survey and a focus group interview. Results indicated that from the educators' perspectives students increased their awareness of different academic, career, and social opportunities. Educators also broadened their understanding about the needs of high-achieving students and the need for more differentiation in their classrooms. The majority of students who responded to the survey indicated a sense of satisfaction with the program, enjoyed studying with other students more than in their regular classes, believed that they experienced new ways of learning science, and would attend again. They also indicated that the program supported their creativity, their ability to think critically, and to deal with academic challenges.

Kim, K. H., VanTassel-Baska, J., Bracken, B. A., Feng, A., & Stambaugh, T. (2014). Assessing science reasoning and conceptual understanding in the primary grades using standardized and performance-based assessments. *Journal of Advanced Academics, 25*(2), 47–66. https://doi.org/10.1177/1932202X14520946

Although originally developed for high-ability learners, researchers investigated the efficacy of the Project Clarion curriculum units for students from low-income homes. First- to third-grade teachers from three Virginia Title I districts were randomly assigned to the treatment or comparison group for this quasi-experimental study. Students in the treatment group classroom, on average, significantly outperformed the students taught using district curriculum on a reasoning skill assessment, the Test of Critical Thinking (d = 0.35), and on both Year 1 and Year 2 Metropolitan Achievement Test science achievement assessments (d = 0.22, d = 0.33). Growth in science concepts and science content was also assessed using pre- and post-curriculum problem-based assessments (PBA). Latent curve growth modeling indicated that pre-intervention ability level did not significantly influence student growth, suggesting the curriculum is effective for students of all abilities.

Lee, S.-Y., Olszewski-Kubilius, P., & Peternel, G. (2009). Follow-up with students after 6 years of participation in Project EXCITE. *Gifted Child Quarterly,* 53(1), 137–156. https://doi.org/10.1177/0016986208330562

The authors examined the experiences and perceptions of 14 minority students who were rising ninth graders and who had participated in Project EXCITE, a collaborative program of Northwestern University's Center for Talent Development and Evanston school district, and their parents. The students in the study invested more than 400 hours of their time over a 6-year period by attending out-of-school classes that emphasized enhancing their interest and performance in math and science. Through interviews, the students reported that the program was fun and challenging, increased the desire for placement in advanced academic settings, better prepared them for schoolwork in high school, extended their social networks with other high-ability minority peers, enhanced social support for high achievement, and increased their con-

fidence to compete academically with peers. Balancing academic work and social interaction with peers outside the program was a major concern. The parents perceived the program as increasing their children's interest, confidence, and motivation for schoolwork, and enhancing their own interest and involvement in their children's academic achievement. To summarize the results of their study, the authors provide a model of influences (i.e., academic, social, affective) that result in effects on children and parents.

Little, C. A., Adelson, J. L., Kearney, K. L., Cash, K., & O'Brien, R. (2018). Early opportunities to strengthen academic readiness: Effects of summer learning on mathematics achievement. *Gifted Child Quarterly, 62*(1), 83–95. https://doi.org/10.1177/0016986217738052

The authors examined the effects of Project SPARK on mathematics achievement of high-potential students from underserved populations. Project SPARK is a summer program that focuses on mathematics content and discourse, specifically Project M^2: Mentoring Young Mathematicians, a successful model of advanced mathematics curriculum for primary grade students. A total of 85 primary age students from 10 schools across two school districts participated in the summer program, with 36 of these students qualifying for free/reduced lunch (FRL). The researchers collected pretest and post-achievement test measures for the experimental and comparison groups. Students who participated in the summer program made moderately larger mathematics gains over the summer than students who did not participate. Similar gains were found for summer participants who were eligible for FRL compared to their more economically advantaged peers. In their discussion, the authors concluded positive effects resulted from a summer program that offered a curriculum unit with more advanced content in mathematics, instructional time, and opportunities for like-ability students to work together.

McCoach, D. B., Gubbins, E. J., Foreman, J., Rubenstein, L. D., & Rambo-Hernandez, K. E. (2014). Evaluating the efficacy of using predifferentiated and enriched mathematics curricula for grade 3 students: A multisite cluster-randomized trial. *Gifted Child Quarterly, 58*(4), 272–286. https://doi.org/10.1177/0016986214547631

This article provides results of research of grade 3 students (N = 2,290) of all ability levels regarding the implementation Project M^3 mathematical curriculum (see introduction). Teachers from 43 schools in 12 states were assigned to the intervention group (n = 84) or the control group (n = 57). Specifically, this quasi-experimental study investigated grade 3 students' math achievement after a 16-week Project M^2 intervention compared to students taught using the district's traditional math curriculum. Although there was no statistically significant difference overall between treatment and control groups, the results of the HLM predicting the Iowa Tests of Basic Skills (ITBS) Math Problem Solving and Data Interpretation subtest suggested effects for differing ability students that was moderated by the school-level achievement. In other words, different outcomes were predicted based on participant ability and overall school ability. Based on students' pretest scores, students and schools were subgrouped into one of the four following groups: low, low-average, high-average, and high. At low-achieving schools, the curriculum appeared to be most effective for high-achieving students, whereas the traditional curriculum was more effective for low-achieving students. At high-achieving schools, the intervention was more effective for low-achieving students. The effect of treatment was least clear for average students. Practically speaking, on average, students at most ability levels performance on the ITBS was similar; however, the largest effect was demonstrated for high-achieving students (d = 0.41, small to medium effect). These results suggest that the curriculum may be most effective with high achievers.

Missett, T. C., Reed, C. B., Scot, T. P., Callahan, C. M., & Slade, M. (2010). Describing learning in an advanced online case-based course in environmental science. *Journal of Advanced Academics, 22*(1), 10–50. https://doi.org/10.1177/1932202x1002200102

This qualitative study investigated the learning outcomes for 138 students enrolled in an advanced online, problem-based, and case-based course in environmental science that were aligned with best practices in science pedagogy (see article for specific cases used in the course). Faculty, staff, and graduate students at the University of Virginia designed the course. The 138 self-identified participants for the course came from 14 states and ranged in age from 12 to 17 years old. The 16 instructors for the course had doctoral or master's degrees in a science field and a background in science education. To examine the effects, the researchers analyzed student online discussion boards, case resolutions, student grades, end-of-course student and parent surveys, e-mails, and Advanced Placement examination results to examine the course's effects. Effects included learning scientific facts and vocabulary, engaging in higher level thinking, and thinking as a scientist by using the rules, language, and analytical tools of the discipline of science to demonstrate learning. Of the 138 students, 100 finished by passing the course and received high or middle school credit; however, few chose to take the AP Environmental

Science exam and only 30% earned a score of 3 or higher. The authors concluded that the online course was not an online AP course but provided a viable learning alternative to traditional AP environmental science courses for many, but not all, of the students. For those students who did not complete the course, the authors suggested more support and scaffolding for students who are not independent learners.

Mun, R. U., & Hertzog, N. B. (2018). Teaching and learning in STEM enrichment spaces: From doing math to thinking mathematically. *Roeper Review, 40*(2), 121–129. https://doi.org/10.1080/02783193.2018.1434713

The purpose of this study was to examine the effects of a 9-week Saturday Enrichment Program (SEP) that explored challenging math topics not typically taught in schools. Participants included 40 students in grades 4–8, with the majority (57.1%) in gifted programs. Information was gathered from pre- and post-questionnaires of student interest, video and audio documentation of classes, field notes, classroom-based assessments, student work, problem sets, and other curricular artifacts. Results from pretests and posttests indicated that students were less interested in the content of their school math classes after participating in SEP because they reported the enrichment program provided a more appropriate pace, challenge, and fun. Analysis of video data indicated that teachers used four major strategies in the SEP: fostering a supportive and collaborative environment through student-centered and individualized activities, developing a positive identity of a mathematician, using open-ended questions for conceptual exploration, and emphasizing the exploration of math through play.

Olszewski-Kubilius, P., Lee, S.-Y., Ngoi, M., & Ngoi, D. (2004). Addressing the achievement gap between minority and nonminority children by increasing access to gifted programs. *Journal for the Education of the Gifted, 28(2),* 127–158. https://doi.org/10.1177/016235320402800202

Project EXCITE was created to address the achievement gap between minority and nonminority students in advanced math and science programs in the high school. The key components of the program included parent education and support, peer support, academic enrichment beginning in grade 3, individualized support, and evaluation activities. The purpose of this article was to assess students' academic progress and achievement and the overall success of Project EXCITE. Participants were students in grades 4–6 who participated in the program from 2001 to 2003 (n = 55). Data included students' retention rate, students' performance in Saturday enrichment classes, students' qualification for prealgebra in grade 6, end-of-year teacher evaluation reports on students, students' scores on the Illinois Standards Achievement Tests, and parental efforts to access additional resources for their child. Results over the 3-year period indicated that nearly 80% of the students were retained in the program, 100% participated in Saturday classes, 63% qualified for placement in prealgebra from Cohort 1, 80% of Cohort 1 mastered the district-level math assessment at the end of fifth grade, more than 80% of students earned A's or B's in math and 70% earned A's and B's in science during the academic year, teachers perceived that EXCITE students had a substantial interest and enthusiasm for science, and 100% of the students met or exceeded standards of math and science performance on the state test. The authors did express concerns related to some decline in school performance, perhaps related to transition to middle school and peer influence, and parent involvement, particularly with the use of technology. Project EXCITE staff addressed these areas by offering evening and Saturday classes for parents and cluster grouping Project EXCITE students in school.

Olszewski-Kubilius, P., Steenbergen-Hu, S., Thomson, D., & Rosen, R. (2017). Minority achievement gaps in STEM: Findings of a longitudinal study of Project EXCITE. *Gifted Child Quarterly, 61*(1), 20–39. https://doi.org/10.1177/0016986216673449

This study examined the academic outcomes of the first stage of Project EXCITE (2000–2013). The key components of the program included parent education and support, peer support, academic enrichment beginning in grade 3, individualized support, and evaluation activities. The participants consisted of 361 students from five elementary schools who participated in Cohorts 1 to 14. All third-grade minority students who performed at the 75th percentile on an aptitude test and an achievement test or who had strong, positive recommendations from the teacher were invited to attend the Project. Students were compared with students in their home district who did not attend. Results indicated that Project EXCITE reduced the math and science achievement gap between disadvantaged high-potential minority and high-achieving majority students, prepared them for above-grade-level placement in math, and improved their representation and participating in advanced courses in high school. Throughout the program, Project EXCITE students made larger achievement gains in science, reading, and math. The authors concluded that Project EXCITE suggests that front-loading program can be useful for nurturing and identifying the talents of high-potential minority students and increasing their overall representation in advanced courses.

Pierce, R. L., Cassady, J. C., Adams, C. M., Speirs Neumeister, K. L., Dixon, F. A., & Cross, T. L. (2011). The effects of clustering and curriculum on the development of gifted learners' math achievement. *Journal for the Education of the Gifted, 34*(4), 569–594. https://doi.org/10.1177/016235321103400403

This study examined the effects of using cluster grouping and a specific mathematics curriculum on gifted students. Participants were 133 third-grade gifted students (Year 1) and 92 gifted students (Year 2) in an urban school district. Their teachers were involved in Project Clue, a Javits grant, and participated in a summer institute and professional development days throughout the year to learn how to effectively teach high-ability learners and implement the mathematics curriculum. Using a repeated measures design, the researchers examined student growth across time periods. Gifted students who were clustered in teachers' classrooms who fully implemented the curriculum performed higher than the comparison groups of gifted students who were clustered in nonimplementing classrooms. Moreover, in cluster classrooms all students experienced gains because the curriculum was tiered. The authors concluded that all students benefited from cluster grouping and a mathematics curriculum designed to support learning at varied ability levels, but the teachers needed extensive support in lesson development to promote quality instruction for gifted learners.

Robinson, A., Adelson, J. L., Kidd, K. A., & Cunningham, C. M. (2018). A talent for tinkering: Developing talents in children from low-income households through engineering curriculum. *Gifted Child Quarterly, 62*(1), 130–144. https://doi.org/10.1177/0016986217738049

In this study, a quasi-experimental design was used to examine the performance of grade 1 (n = 1,387) students in 62 classrooms from low-income schools. Pairs of schools were within each district and were randomized as the intervention group or the control group. Students in the intervention group (n = 765) were exposed to an enriched curriculum, STEM Starters+, which included a scientist biography and an engineering unit anchored in the science of sound. Although the students' science content knowledge gains were similar for the intervention and control groups, a practical significance for the intervention (d = 0.28) indicated a small effect. A self-reported engineering content measure, however, demonstrated statistical significance and a large practical significance (d = 0.66). Emotional engineering engagement did not differ between gender, socioeconomic status, or ethnicity. Although behavioral engineering engagement did not differ based on gender or ethnicity, students who received subsidized lunch reported less engagement (d = -.25, small negative effect) compared to students who were not financially eligible for subsidized lunch. After this engineering intervention, general education teachers participating in this study planned to nominate a greater diversity of students compared to the previous year, including, Black, Hispanic, and participants receiving subsidized lunch. Engineering topics can be especially appropriate for fostering talent in high-potential students from low-income homes within the context of tinkering with everyday objects. Furthermore, engineering topics also provides an enrichment opportunity for advanced students that can be differentiated.

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*(3), 189–213. https://doi.org/10.1177/1932202X14533799

A Javits grant funded the development and this research regarding a problem-based STEM curriculum, STEM Starters (a William & Mary curriculum unit). Specifically, researchers wanted to know the impact of the curriculum on gifted students' knowledge of science processes, science concepts, and science content. Seventy Arkansas teachers of grades 2–5 from five low-income schools were randomized as treatment or control (used district curriculum), with most classes having only one to three identified gifted students. Teachers in the intervention group attended two weeklong summer institutes and 60 hours of weekly peer coaching over 2 years focused on inquiry-based instruction, science content, and differentiation. Gifted students in the intervention group scored significantly higher than gifted students in the comparison group in scientific process (designing an experiment when given a research question), scientific concepts, and the science content knowledge.

Sloan, P. J. (2018). NYC selective specialized public high schools and honors college STEM degrees: A previously unexplored relationship. *Journal of Advanced Academics, 29*(4), 304–320. https://doi.org/10.1177/1932202X18778816

This study examined the relationship between attending one of the nine New York City (NYC) selective specialized public high schools and graduating from an honors college with a STEM degree, compared with honors college graduates who attended any other high school. The participants consisted of 1,647 graduates from seven honors colleges, from 2011 to 2015, in the northeastern United States. A causal-comparative study design was applied. Of the 1,647 graduates, 482 students graduated from NYC selec-

tive specialized public high schools and 1,165 students graduated from other high schools. A significantly larger percentage of NYC selective specialized public high schools graduated with a STEM degree from an honors college (32.4%) than students from other high schools (26.8%). There was also a lower percentage (67.6%) of NYC specialized public high schools who earned a non-STEM degree from an honors college than graduates of other high school attendees who earned a non-STEM degree (73.2%).

Wai, J., & Allen, J. (2019). What boosts talent development? Examining predictors of academic growth in secondary school among academically advanced youth across 21 years. *Gifted Child Quarterly, 63*(4), 253–272. https://doi.org/10.1177/0016986219869042

The researchers examined 482,418 academically advanced students who took the ACT in seventh grade and again in 11th or 12th grade to examine academic growth trends from 1996 to 2017. Predictors of academic growth included sociodemographic variables, interests, high school characteristics, high school coursework and GPA, and extracurricular activities. Although growth occurred for most students, growth for Hispanic students and those from low-income and non-English speaking backgrounds was stagnant. Catholic and private school students had the highest growth; homeschooled, rural, and high-poverty public school students had the lowest. High growth was associated with STEM elective high school courses and advanced AP, accelerated, and honors courses. Students with higher science and technology vocational interest scores (i.e., investigative personality types) had higher growth. Those with more hands-on mechanical and spatial interests (i.e., realistic personality types) had lower academic growth. Participating in school or community service organizations, instrumental music, debate, religious organizations or racial or ethnic organizations was related to higher academic growth; however, participating in social clubs and radio/TV was negatively related. The authors conclude by suggesting some potential areas for educational interventions.

Young, J., & Young, J. (2018). The structural relationship between out-of-school time enrichment and Black student participating in advanced science. *Journal for the Education of the Gifted, 41*(1), 43–59. https://doi.org/10.1177/0162353217745381

The authors examined the relationship between Black student engagement in out-of-school science enrichment, such as clubs, competitions, tutoring, and camps, and participation in advanced science courses in high school. The participants were 3,173 ninth-grade students, ages 14 to 16 years, who participated in the High School Longitudinal Study from 2009–22012. Only 11.73% of the participants participated in at least one out-of-school activity. Results indicated that Black students who were engaged in more out-of-school science activities participated in more advanced science high school courses, with significantly more Black females participating than male peers. Socioeconomic status also influenced participation in advanced science courses. The authors concluded that parents and educational stakeholders should strongly encourage Black students in particular to participate in outside of school science activities.

Young, J. L., Young, J. R., & Ford, D. Y. (2017). Standing in the gaps: Examining the effects of early gifted education on Black girl achievement in STEM. *Journal of Advanced Academics, 28*(4), 290–312. https://doi.org/10.1177/1932202X17730549

In this study, achievement scores in mathematics and science as measured by the National Assessment of Educational Progress (NAEP) were compared for fourth-grade girls receiving gifted instruction and girls not receiving gifted instruction (N = 13,868). The authors found that girls receiving gifted instruction outperformed girls not receiving gifted instruction. Moreover, Black girls who participated in gifted education statistically significantly outperformed Black girls in the comparison group. White girls, regardless of access to gifted education, significantly outperformed Black girls in science. The authors conclude that educational interventions are needed to support the mathematics and science learning of gifted Black girls.

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