What can we learn from *A Talent for Tinkering: Developing Talents in Children From Low-Income Households Through Engineering Curriculum*?

Ann Robinson
Kristy Kidd
Jodie Mahony Center for Gifted Education
University of Arkansas at Little Rock
Jill L. Adelson
University of Louisville
Christine M. Cunningham
Museum of Science, Boston

"Thank you, Miss K______ for teaching us custical (sic [acoustical]) engineering." "Thank you for showing that we can engeneer (sic) . . . . I liked listening to the birds (sic) calls and makeing (sic) the sound with representatiens (sic [representations])." Written notes from two children participating in an engineering intervention capture the enthusiasm and demonstrate the learning that took place when young students participated in STEM Starters+, a Jacob K. Javits project funded by the U.S. Department of Education. Children in 39 Grade 1 classrooms across four school districts were provided with engaging experiences in engineering and science. The results were exciting. When compared with the children in the 23 Grade 1 classrooms who did not participate in the program, STEM Starters+ students demonstrated greater gains in science achievement measured by an out-of-level test and greater gains in engineering knowledge. Importantly, no excellence gaps were found when students from low-income households were compared with their more advantaged peers on the pretest or on the post-test of the engineering measure; moreover, STEM Starters+ students regardless of background (i.e., race/ethnicity, family income) scored higher compared to students who did not participate. Finally, STEM Starters+ students also reported high levels of engagement. Finally, STEM Starters+ students also reported high levels of engagement with engineering. (See Figure 1, What Did We Find?). How did we attain these results? How can other schools replicate the STEM Starters+ program and its outcomes? Why is an engineering intervention in the primary grades a promising avenue for spotting and developing the talents of children living in poverty?

What did we do?

The intervention, STEM Starters+, included an engineering unit, a STEM biography, and a professional development component linked to the curricula. 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 form the basis of the curricular intervention. In addition, teachers implementing the intervention were trained in a one-week summer institute and had access throughout the academic year to a STEM specialist with preparation in gifted education. The two curricular components and the companion professional development comprise the Grade 1 STEM Starters+ intervention.

Curriculum. Challenging curriculum can serve as a platform for developing talent. We selected curricula on the basis of 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. Second, the use of biography has a long history as a curricular approach in the field. 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 engineering, primary source research, science, and the visual arts. (See Figure 2 Want to Learn More about the Curriculum Resources used in the STEM Starters+ Program?).

Professional Development. Grade 1 teachers were trained in a week-long summer institute and provided a coaching specialist over the course of the subsequent academic year. The summer institute included information on acknowledging and locating talents among young children from low-income households, science talk moves, specific lessons from the engineering curriculum unit, and specific lessons from the biography teaching guide. During the academic year, coaching was provided 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. The coach demonstrated lessons, provided support through email, telephone calls, and conducted classroom or school visits. These strategies drew from previously effective coaching strategies implemented and evaluated with general elementary teachers.

What are talents for tinkering?

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.

One key feature of engineering for young learners is the opportunity to take things apart and see how they work and to tinker with objects. 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 and the rise of the maker movement have reinforced tinkering as a valuable source of hands-on experimentation and creativity for children. According to advocates, tinkering is 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). Tinkering is positive and can be connected with the creative endeavor of design—a key concept in engineering and engineering education. In a review of the literature, researchers 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." Tinkering and the more formal domain of engineering are a good match for 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 wealthy members of society. Engineering flowered in Great Britain as part of the Industrial Revolution. Among the creative engineers who found a place was Thomas Telford (1757-1834). (See Figure 3 The Case of Thomas Telford). For individuals with engineering talents, the emerging profession became a way out of poverty. Even today, in comparison with professions like medicine and law, engineers often come from families with roots in manual labor. For example, researchers 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.

How can we find engineering role models in a library?

A barrier faced by promising students from low-income households is that they may have little exposure to engineers in their communities. 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 is to incorporate role models from books or other media. Portrayals of engineers in children's fiction are infrequent, generally male, and usually involve cars. Non-fiction 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 been part of gifted education since the 1920s. More recently, biography study has been linked to STEM education as a source for engagement, for teaching specific aspects of STEM practices, to encourage scientific thinking in children, and for presenting role models to students. 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.

Conclusion

Guided by the theoretical framework of curriculum as a platform for talent development, the *Talent for Tinkering* 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 science content achievement, engineering knowledge, and engineering engagement (both behavioral and emotional). The intervention resulted in student achievement on an out-of-level science content assessment 0.28 standard deviations greater than for comparison students and achievement on the engineering knowledge measure 0.66 standard deviations greater. 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. (See Figure 4 What Lessons Did We Learn and Figure 5 Want to Read More about STEM Starters+ and the Scholarship Supporting It?)

Figure 1
What Did We Find?

Grade 1 students who participated in STEM Starters+ achieved more on a rigorous out-of-level science test than students who did not participate.

Grade 1 students who participated in STEM Starters+ gained more engineering knowledge when compared with students who did not participate.

No meaningful or statistical excellence gaps occurred in engineering knowledge when students from low-income households were compared with their more advantaged peers.

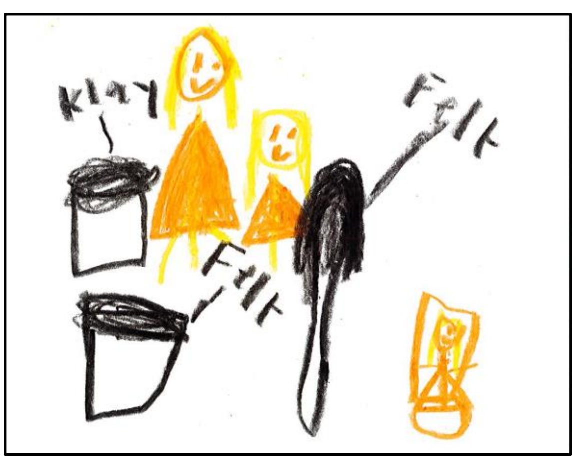
Students reported high engagement levels with engineering following participation in STEM Starters+.

When comparing students from low-income households and those who identify as ethnic minority with their grade-level peers, there were no differences in emotional engagement. Lower levels of behavioral engagement were reported by students from low-income households. Most of the difference in behavioral engagement was attributable to classroom differences rather than to differences between groups of children in the same class.

Teachers "talent-spotted" greater numbers of children from low-income households and from ethnic minority groups after participating in STEM Starters+ professional development.

Figure 2:
Want to learn more about curriculum resources used in the STEM Starters+ program?

Engineering is Elementary (EiE) units are found at https://eie.org-curriculum/curriculum-units. The goals of EiE include introducing children to engineering and technology concepts; integrating the engineering design process into STEM programs; exploring linkages among science, mathematics, and engineering; providing a broad perspective on various engineering fields and the types of work specialist engineers do; and fostering students' engineering identities.



Blueprints for Biography are a series of teaching guides linked to specific trade book biographies. The goals of *Blueprints* are to encourage biography study as a means of talent exploration, to explore the life and work eminent individuals through trade book biographies, to link primary source analyses of various kinds 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 was developed through Jacob K. Javits funding and focuses on the lives of scientists, engineers and inventors. Example *Blueprints* can be found at ualr.edu/gifted/curriculum/stemblueprints.

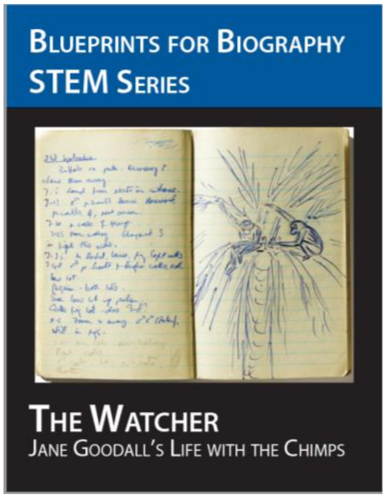


Figure 3:
The Case of Thomas Telford

Thomas Telford is an example of a child born into extreme poverty who grew up to be a famous engineer. His father was a shepherd who died when Thomas was very young. Thomas' mother raised him alone. Working as a mason, he taught himself architecture. He was so innovative that he was promoted to an engineer of bridges, canals, and aqueducts. Many beautiful Telford structures still exist in the U. K. today with one designated a UNESCO World Heritage Site. Here is a stamp commemorating Thomas 250 years after he was born. He is imagining a bridge design. (Royal Mail, The World of Invention stamp issue, Peter Till illustrator)

Figure 4
What Lessons Did We Learn?

Generalist primary teachers can successfully implement engineering interventions that include commercially available units, design challenges, and STEM-focused biographies.

Primary classrooms focus on literacy and numeracy, but the daily schedules of Grade 1 teachers may include 40-minute blocks of time that can be used to implement engineering lessons.

Students are highly engaged during engineering lessons and the creative enrichment activities associated with STEM-focused biographies.

Out-of-level science assessments for primary grade children can be constructed from released National Assessment of Educational Progress (NAEP) and Trends in International Math and Science Study (TIMSS) items that are psychometrically sound.

Engineering knowledge is a promising domain for minimizing excellence gaps between children from low-income households and their more advantaged peers.

Engineering is a promising academic domain for spotting and developing the talents of children from low-income households.

History includes many examples of adult engineers for whom the profession was a "pathway" out of poverty.

Creativity and the engineering design process are a good match.

Figure 5:
Want to read more about STEM Starters+ and the scholarship supporting it?

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