Testimony of

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Chairman Lipinski, Ranking Member Ehlers, and distinguished members of the Subcommittee on Research and Science Education, thank you for inviting me to participate in this hearing on "*Engineering in K-12 Education*". I am Dr. Thomas Peterson, Assistant Director for Engineering at the National Science Foundation.

Today I will address the challenges we face in attracting and retaining talented students in engineering education as well as your questions focusing on: (1) How engineering education is incorporated into NSF's K-12 STEM education programs; (2) What the current state of research on engineering education is at the K-12 level; (3) What the current level of support and scope of NSF-funded research on K-12 engineering education is; and, (4) What metrics and methodologies exist for evaluation and assessment of K-12 engineering education.

The Challenge We Face

Every student who takes either the SAT[1] or ACT college entrance examination is asked to indicate the discipline of study that they intend to pursue after graduation from high school. An analysis of this data reveals that the fraction of total test takers (both SAT and ACT) who intend to pursue engineering declined from 7.7% in 1994 to 4.6% in 2006. In absolute numbers, Almost 150,000 test takers expressed a preference for engineering in 1994 compared to fewer than 120,000 in 2006. In 1983 about 1.9 percent of all four-year baccalaureate degrees received by women were in engineering. Twenty years later, 1.7 percent of female baccalaureate recipients were engineers.

As a former Engineering Dean I, along with my colleagues Dr. Katehi and Dr. Miaoulis, also both former Engineering Deans, have first-hand experience in dealing with the challenges of finding a diverse and qualified pipeline of domestic students interested in pursuing the study of engineering. There are many extenuating factors that contribute to this situation, but I personally believe that the absence of introducing basic engineering concepts in pre-college curricula, even down to the elementary and middle school levels, is a dominant factor in this situation. Not only will the profession of engineering benefit, but so will society as a whole, if a much larger fraction of our general populace understands the basic elements of the highly technological society in which we all live.

I believe that the presence of engineering education in the K-12 curriculum holds promise to encourage student learning in the fundamental science and mathematics subjects, to raise the level of understanding and awareness of engineering and what engineers do, to stimulate interest in a rapidly changing demographic population to pursue careers in engineering, and to increase the basic technological literacy for all of our citizens. In other words, far from being an additional burden that must be shouldered by the already challenged curriculum, engineering education in the K12 environment should be viewed as an enabler for motivating students to learn other aspects in the curriculum as well.

Engineering Education at the K-12 level – Influence of Early Exposure

Engineering in the K-12 curriculum provides instruction in numerous basic areas, but the key to inclusion of engineering concepts is the emphasis on engineering design. Previously, the standard engineering curriculum at a university culminated in a year-long course in the concepts and practice of engineering design. Undergraduate engineering students would see little, if any of the basic elements of engineering design until they reached that course in the senior year. Engineering design, after all, is that element, more than any other that separates and distinguishes engineering from the basic sciences. More recently, however, Engineering, both the profession and the academic discipline, has come to realize that this approach of postponing the introduction of design principles until the last possible moment in one's educational career is counterproductive and frustrating for many students. After all, in this previous approach students never really truly understood the basis for engineering, the joy of discovery and creative endeavor, until they had almost completed their studies. As a consequence, a large fraction of students who would otherwise become productive practicing engineers left the field in favor of other pursuits.

The modern engineering curriculum, while still maintaining a capstone design experience, now begins the engineering curriculum with an introduction to the basic concepts of design. Why? Because this structure allows us to demonstrate to students very early on what engineering is all about.

For exactly this same reason, the inclusion of engineering design principles within the K-12 education system could not only increase the level of understanding of what engineering is, but it can also provide a motivation to students for learning basic concepts in science and mathematics, which will always be the foundational building blocks of engineering. Obviously, engineering design in its complete implementation by a professional engineer is an elaborate and complex process. Nonetheless, there are many elements of the design process that can easily be illustrated even at elementary school levels. Design is an iterative process, it is illustrative of the concept that more than one solution to a problem may exist, and that the major challenge is to find the best, or optimum solution. Finally, it illustrates the importance and application of basic science and mathematics principles.

Engineering design also stimulates creativity within students. It encourages them to work in partnership with other students because design is fundamentally a team-based activity. It helps to develop communication skills as students work together and describe their work to each other, and even provides a platform for the consideration of important social, environmental and ethical issues.

Support and Scope of NSF-funded research on K-12 Engineering Education

The National Science Foundation plays an important role in encouraging the development and dissemination of materials for engineering education in the K-12 environment. In addition to support provided by the Education and Human Resources (EHR) directorate, the Engineering directorate, through our division of Engineering Education and Centers (or EEC), has supported numerous engineering education programs, the primary purpose of many being to introduce engineering education into the K-12 curriculum. For example, the Innovations in Engineering Education, Curriculum, and Infrastructure (IEECI) program supports research which addresses three basic issues related to engineering education: (1) how students learn, (2) how to attract a more talented and diverse student body, and (3), how to evaluate and assess successful teaching, advising, and mentoring. One of the project areas we directly solicited ideas for was “Strategic Supply-Chain Partnerships for Engineering”, where we strongly encouraged the establishment of “leadership partners” between Engineering Deans and K-12 school district Superintendents and Principals. Such partnerships could improve guidance and cooperation on developing pre-engineering curricula, career opportunities for students, K-12 faculty development, and, importantly, provide a stronger image of engineering in local communities.

Just this past summer, EEC supported an Engineering Education Summit here in Washington, where we brought together the thought leaders from those key universities (such as Purdue, Virginia Tech, Clemson and Utah State) focusing directly on engineering education. While much of their focus was on improving the engineering curriculum in universities, these engineering education programs are leading the profession in establishing partnerships with Colleges of Education to include engineering content in elementary, middle and high school teacher preparation. Just as Education colleges turn to colleges of Science for content preparation in chemistry, physics and biology, we want them to turn to colleges of engineering for content preparation in engineering.

Engineering Education and NSF STEM Education programs

The Engineering and EHR directorates have partnered on numerous K-12 activities. For example, we have teamed to support a GK-12 Fellowship program at the University of Colorado, Boulder. These Fellows are working with Skyline High School (SHS) in Longmont to bring highly interactive, hands-on projects into the classroom. The projects are targeted at moderately at-risk students and allow them to receive high school credit. SHS has a large Hispanic student population and is a school where 49% of the students qualify for free and reduced lunches. SHS also has the largest English Language Learners program in the District.

As a direct result of the funding, the initial new STEM course offerings introduced include “WIRED” (a technology-based course designed for all 9th grade students), Exploration in STEM, Engineering Design I, Introduction to Computer Programming, AP Computer Science, and AP Chemistry. The enrollment demographics in these courses are encouraging. 40% of students accepted into the academies are minority and 33% are female.

Another EHR/ENG partnership supports *Design Squad,* a PBS reality competition series-with an accompanying outreach campaign and Web site designed to inspire a new generation of engineers. Over 10 weeks, six high school and college-aged kids learn to think smart, build fast, and contend with a wild array of engineering challenges-all for real-life clients. Targeted to 9- to 12-year-olds and fun for people of all ages, this fast-paced TV series is the fuel behind a national, multimedia initiative designed to attract kids to engineering.

The series is making a special effort to reach out to girls and minorities, groups that are critically underrepresented-comprising just 11% and 21% of engineers, respectively. By casting teens from a range of racial, ethnic, and socio-economic backgrounds (50% of the Season I and II cast are female and 56% minority), Design Squad provides positive, diverse role models for younger viewers. These casting decisions have a measurable impact. 16% of the Design Squad audience is comprised of Black or African American households and 27% is comprised of Hispanic households.

Since its premiere in 2007, Design Squad has conducted 71 trainings for 3,479 engineers and educators, and engaged 89,453 kids and families with hands-on engineering activities through 263 events and workshops across the country. 64 engineering and education organizations have become formal partners, and 2,700 programs have used Design Squad's educational materials, which include six educators' guides (containing step-by-step directions and leaders notes for 30 activities) targeted to afterschool providers, engineers, and teachers. Recent data estimates that approximately 500,000 viewers watch Design Squad each week. A selected list of current K-12 Engineering projects supported by EHR is found in the Appendix.

Finally, it is noteworthy, and reassuring, that interest and support in expanding opportunities in engineering among K-12 students extends beyond government-related programs. In 1992, FIRST Robotics, an extra-curricular program, was launched in New Hampshire under the visionary leadership of Dean Kamen. Dean received support from NSF in the early stages of his national robotics competition. FIRST Robotics is now supported in over 2000 high schools in the U.S. and a significant number of FIRST alumni are now studying in engineering colleges. Another program, Project Lead the Way, started in New York State in the early 1990s, is a curricular program with engineering-based courses now embedded in about 3000 schools and boasts student participation of upwards of 300,000 students. Programs like this (and several others) will hopefully motivate boys and girls of all ethnicities to become the innovative engineers of the future.

Evaluation and Assessment

Assessment for success in such programs is absolutely critical. Much of our assessment analysis to date has been anecdotal, and true successful assessment metrics can only be defined over a fairly long time horizon. For example, how many students who experience the excitement of discovery and creativity through simple engineering projects in the third and fourth grades end up pursuing academic studies and professional careers in engineering? Obviously longitudinal analyses over decades are required to quantitatively answer that question. But we must begin collecting that information now.

The Engineering and Education and Human Resources directorates held a joint retreat this past summer, for the purpose of delineating the many opportunities for continued and future collaborations on engineering education issues of particular interest to both of us. One topic of discussion was precisely this question of developing better metrics for assessment and evaluation. Suggested metrics and measures for evaluating our investments in K12 engineering education included:

- Number of K-12 development intensive projects that employ appropriate methods to evaluate efficacy and that apply them rigorously

- Number of teachers and students who engage in the capacity building efforts, including increasing awareness, interests, and skills in K-12 engineering education

Summary

The National Science Foundation continues to play a role in this important task of educating future engineers and society decision makers. Moreover, an equally important responsibility is to provide the intellectual rationale and framework for developing educational tools that will give all our citizens the basic engineering and technological skills to live in this complex society. But we must also engage local school districts and the Department of Education in this endeavor. The Boston Museum of Science, which received support from NSF for technological literacy, directs the National Center for Technological Literacy and is, I believe, one good example of an approach to take in this regard.

The NSF is not about providing long-term and sustained funding for programs. We provide the support for new ideas, new curricula, new approaches to engineering education and educational pedagogy. We provide that support for targeted programs in schools and institutions with new and creative ideas. The real challenge is twofold. First, we must find the support to continue programs developed under NSF Sponsorship once NSF support is no longer available. Second, and equally important, is to find the means to financially support the dissemination of the best ideas developed through NSF support to a much broader range of institutions and schools. For this, we must rely on individual school districts throughout our country. I believe that the Skyline High School in Longmont, Colorado, mentioned above, is one example that shows promise in this regard.

Mr. Chairman, this concludes my remarks and I would be happy to answer any questions at this time.

[1] Source: Derived from data provided by the College Board.
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APPENDIX

Active Engineering Education projects
In the
Education and Human Resources Directorate
National Science Foundation

- **UTeachEngineering: Training Secondary Teachers to Deliver Design-Based Engineering Instruction** (MSP, 0831811, University of Texas at Austin)

The University of Texas at Austin's Cockrell School of Engineering is partnering with the successful UTeach Natural Sciences program and the Austin Independent School District to develop and deliver UTeachEngineering, an innovative, design- and challenge-based curriculum for preparing secondary teachers of engineering. To meet the growing need for engineering teachers in Texas, and to serve as a model in engineering education across the nation, UTeachEngineering has the following four professional development pathways to teacher preparedness, two for in-service teachers and two for pre-service teachers: UTeach Master of Arts in Science and Engineering Education (MASEE); Engineering Summer Institutes for Teachers (ESIT); Engineering Certification Track for Physics Majors; and Teacher Preparation Track for Engineering Majors. UTeachEngineering anticipates reaching 650 teachers (80 pre-service and 570 in-service) over the first five years. In the future, it is expected that UTeachEngineering will be sustained as a vital program at the University of Texas at Austin. UTeachEngineering is firmly rooted in current research in the field of engineering education and affords a much-needed opportunity to study the teaching and learning of engineering. While the focused goal of UTeachEngineering is to train a cadre of secondary teachers, the project's vision is that all students are "engineering enabled," acquiring the design and interaction skills that would enable them to be successful in an engineering career should they choose one, while enhancing their lives and participation as global citizens even if they do not become engineers.

- **Partnership for Student Success in Science** (MSP, 0315041, Palo Alto Unified School District)

The Partnership consisting of nine Silicon Valley school districts and San Jose State University's (SJSU) Colleges of Engineering and Education is taking a regional approach to improving science education by building institutional capacity, instructional quality, and student achievement in a major urban region and providing preservice preparation, new teacher induction, on-going inservice and leadership development for over 1300 preservice students and inservice teachers. Elementary and middle school students experience exemplary inquiry and laboratory-based lessons linked appropriately to math, literacy, and technology resulting in higher achievement. Engineering faculty devote time as consultants in middle schools. While they contribute scholarship and content background they also learn by viewing the variety of teaching strategies that serve diverse student needs. Undergraduate engineering education is improved through close collaboration between engineers and teachers.

- **GK-12 - Engineering in Practice for a Sustainable Future** (GK-12, 0538655, University of Oklahoma-Norman Campus)

This project builds upon two awards: The Authentic Teaching Alliance (ATA); and the Adventure Engineering (AE). The outcomes from the first two grants include: (1) a dual degree program in engineering education; (2) greater than 50% of the undergraduate Fellows were accepted into STEM graduate programs; (3) four competitive grants were awarded to the ATA teachers and Fellows; (4) over 100 teaching and learning modules were developed of which 30 are available through the Internet on the ATA website; and (5) improvements in the Fellows communications and teaching skills. The current work focuses on the integration of the 100 units referenced to include more utilization of the engineering processes; conducting summer engineering academies (SEA) that would serve to disseminate the material and be professional development opportunities for the teachers; and preparing Future Faculty through a proposed dual STEM education degree between the Colleges of Engineering and Education. .

- **NJ Alliance for Engineering Education** (GK-12, 0742462, Stevens Institute of Technology)

The objective of the New Jersey Alliance for Engineering Education (NJAEE) is to create a partnership that promotes the integration of problem-solving, innovation and inventiveness within mainstream high school STEM curricula, while fostering the cross-fertilization of innovative teaching methods across K-12 and university level education. A cohort of graduate engineering students (Fellows) is collaborating with engineering professors, education professionals, and high school STEM teachers to design, develop, and implement innovative and motivating educational modules based on the Fellows' research areas. The modules will be aligned with the NJ science curriculum requirements and will incorporate themes of engineering design, innovation and inventiveness within the STEM curriculum. Stevens Institute of Technology (SIT) faculty, education professionals and Lawrence Hall of Science staff will collaborate in the creation of a new course "Communicating Engineering", which all Fellows will experience. While completing their engineering studies, Fellows will also complete a 9 credit graduate certificate in education from SIT. NJAEE will enhance STEM learning for approximately 11,700 high school students, will provide considerable professional development opportunities to 130 participating K-12 teachers, and will immerse the next generation of engineering professors in innovative teaching methodologies.

- **Transforming Elementary Science Learning through LEGO(TM) Engineering Design** (REESE, 0633952, Tufts University)

This project involves development, implementation, and evaluation of innovative engineering-based science curriculum for grades 3-5. A major activity is to measure what and how students learn from engineering design challenges tailored to standards-based science concepts. Another aim is to establish best practices for designing engineering curricula that are more effective at promoting students' fundamental understanding of and interest in science content. The third objective is to determine whether engineering contexts improve elementary teachers' practice of science instruction. The research team seeks to advance theory, design, and practice in the emerging field of elementary school engineering education, which they believe can motivate and deepen the learning of science. To accomplish the project goals, researchers are collaborating closely with participating Boston-area teachers to develop a series of curriculum modules that pose engineering design challenges whose solutions require understanding of specific science content. The learning objectives of these modules will be aligned with the National Science Education Standards (NSES) for grades K-4 and the Massachusetts Science and Technology/Engineering Curriculum Frameworks for grades 3-5. The instruction and assessments will be designed according to three sets of requirements: (1) the concerns and experience of the collaborating classroom teachers, (2) the Project 2061 criteria for science curriculum set forth by the American Association for the Advancement of Science, and (3) the analytical, creative, and practical domains of Sternberg's Triarchic Theory of Intelligence. The curriculum will use the LEGO(TM) MINDSTORMS toolset for prototype construction and ROBOLAB (TM) software for algorithm development. These instructional materials have been proven to be engaging and authentic tools for children's engineering. The data from teacher and student studies will be analyzed to answer the following three driving research questions: (1) Does engineering-based science instruction improve 3rd-5th grade students' analytical, creative, practical abilities related to science content, as well as their memory of science content? (2) How are the attitude, engagement, and self-efficacy of both teachers and students affected by the use of engineering design problems to teach science? (3) Does the efficacy of engineering based science instruction depend on demographic characteristics of the students? The primary intellectual merit of the proposed activity includes (1) the contribution of needed systematic research on the efficacy of elementary-level engineering education for science instruction, and (2) the development of new and potentially more effective methods for engineering-based science instruction.

- **Exploring Content Standards for Engineering Education in K-12** (Discovery Research K-12, 0733584, National Academy of Sciences) and

  National Symposium on K-12 Engineering Education (Discovery Research K-12, 0935879. National Academy of Sciences)

The National Academy of Sciences is assessing the potential value and feasibility of developing and implementing K-12 content standards for engineering education. The specific objectives of this exploratory project, to be carried out by the National Academy of Engineering (NAE), are (1) to review existing efforts to define what K-12 students should know, (2) to identify elements of existing standards documents for K-12 science, mathematics, and technology that could link to engineering, (3) to consider how the various possible purposes for K-12 engineering education might affect the content and implementation of standards, and (4) to suggest what changes to educational policies, programs, and practices at the national and state levels might be needed to develop and implement K-12 engineering standards. To accomplish these objectives, the project will conduct literature reviews, two commissioned background papers, three meetings of the project committee, and a two-day workshop to solicit expert views on the subject. The principal product of the project will be a peer-reviewed workshop summary report, which will be distributed to key stakeholders and presented in various professional meetings. This report is expected to set the stage for discussions and future actions related to the establishment of engineering standards.

The National Academy of Engineering and the National Research Council will hold a workshop to disseminate the findings of a privately-funded, two-year study of the status and nature of efforts to teach engineering to U.S. K-12 students. The symposium and other dissemination activities inform key stakeholders about the role and potential of engineering as an element of K-12 STEM education and also inform the programmatic activities of organizations and individuals concerned about engineering education. The report provides a brief history of engineering, reviews the evidence for the benefits of K-12 engineering education, discusses a large number of curriculum projects and associated teacher professional development efforts, summarizes the cognitive science literature related to how students learn engineering concepts and practices, and concludes with the committee's findings and recommendations. The report is of special interest to individuals and groups interested in improving the quality of K-12 STEM education in the U.S.: engineering educators, policy makers, employers, and those concerned with development of the technical workforce, as well as those working to boost technological literacy of the general public. For educational researchers and for cognitive scientists, the report exposes a rich set of questions related to how and under what conditions students come to understand engineering and design thinking.

- **Family Engineering for Parents and Elementary-Aged Children** (ISE, 0741709, Michigan Technological University)

  Michigan Technological University is collaborating with David Heil and Associates to implement the Family Engineering Program, working in conjunction with student chapters of engineering societies such as the American Society for Engineering Education (ASEE), the Society of Hispanic Professionals (SHP) and a host of youth and community organizations. The Family Engineering Program is designed to increase technological literacy by introducing children ages 5-12 and their parents/caregivers to the field of engineering using the principles of design. The project will reach socio-economically diverse audiences in the upper peninsula of Michigan including Native American, Hispanic, Asian, and African American families. The secondary audience includes university STEM majors, informal science educators, and STEM professionals that are trained to deliver the program to families. A well-researched five step engineering design process utilized in the school-based Engineering is Elementary curriculum will be incorporated into mini design challenges and activities based in a variety of fields such as agricultural, chemical, environmental, and biomedical engineering. Deliverables include the Family Engineering event model, Family Engineering Activity Guide, Family Engineering Nights, project website, and facilitator training workshops. It is anticipated that 300 facilitators and 7,000-10,000 parents and children will be directly impacted by this effort, while facilitator training may result in more than 27,000 program participants.

- **A Comprehensive Pathway for K-Gray Engineering Education** (NSDL, 0532684, Colorado School of Mines)

The K-Gray Engineering Education Pathway is the engineering "wing" of the National Science Digital Library (NSDL). It provides a comprehensive engineering portal for high-quality teaching and learning resources in engineering, computer science, information technology and engineering technology. Project goals are to: 1) merge NEEDS and TeachEngineering into a unified K-Gray engineering educational digital library, 2) significantly grow high quality resources in the NSDL Engineering Pathway in a sustainable way, 3) align the unified curricular materials with appropriate undergraduate and K-12 educational standards, 4) grow the participation of content providers and users, 5) enhance quality control and review protocols for Engineering Pathway content, and 6) create a nonprofit strategy and partnership for the sustainability of the Engineering Pathway. This project also expands the Pathway's gender equity and ethnic diversity components by cataloging and reviewing curricular resources created by female-centric and minority-serving organizations. The K-Gray Engineering Education Pathway is having far-reaching impact by engaging K-12 communities and institutions of higher education, engineering professional societies, engineering research centers, NSF K-12 programs, and ABET.

- **Engineering Equity Extension Service** (GSE, 0533520, National Academy of Sciences)

The Center for the Advancement of Scholarship on Engineering Education of the National Academy of Engineering will, over a five year period, implement an Engineering Equity Extension Service (EEES) as a comprehensive research-based consultative and peer mentoring infrastructure in support of enhanced gender equity in engineering education in the US. Based on key leverage points identified from the literature, EEES will focus its efforts on bringing expertise in gender studies and the research base on science and engineering education to a) academic preparation for engineering study for students at the middle school (grade 6) through collegiate sophomore levels, b) the out-of-class social environment, c) the in-class social environment, c) curricular content, d) curricular scope and sequence design, e) curriculum delivery and instructional style. A key part of our strategy is reaching those teachers and faculty who do not have an a priori interest in gender equity activities by suffusing attention to gender equity into other core areas of concern. The study team is developing a handbook on proposing and managing engineering education projects and conducting workshops on this topic at national and regional engineering meetings. The handbook will fuse attention to gender equity, engineering education, and project management into a seamless whole.

- **Examining Engineering Perceptions, Aspirations and Identity among Young Girls** (GSE, 0734091, Purdue University)

The primary goal of this research project is to examine girls' (grades 1-5) conceptions of self and engineering and how these conceptions are shaped by their engagement and learning in various engineering activities. More specifically, the study seeks to learn how girls approach, experience, and interact with engineering activities and how their learning informs who girls think they are (what community of practice they participate in) and who they want to be (what communities of practice they aspire to). The context of this research study is Purdue University's Institute for P-12 Engineering Research and Learning (INSPIRE), a new initiative focused on creating an engineering literate society through P-12 engineering education research and scholarship. The specific research questions that guide the study include: 1) What are elementary school children's perceptions of engineering and career aspirations? How do girls' perceptions and aspirations compare to boys' perceptions and aspirations? 2) What do elementary school girls report as who they think they are and who they want to be? How do girls' self-images compare to boys' self-images? 3) What new engineering content knowledge do children construct and are there gender-related differences in the new knowledge children construct? and 4) What is the relationship between girls' perceptions, career aspirations, identity development, and learning in engineering? Using a mixed-methods approach (Engineering Identity Development Scale [EIDS], Pre/Post Engineering Knowledge Tests, semi-structured interviews, and document review), the three year study measures individual differences in relational, school, and occupational identity; engineering perceptions and aspirations; and engineering content knowledge construction through problem solving and modeling. The research team works with elementary school teachers and students from school sites in Detroit, MI and Lafayette, IN.

- **Girls Understand, Imagine, and Dream Engineering** (GSE, 0735000, Girl Scouts of the USA)

Girl Scouts of the USA (GSUSA) is developing three separate culturally-relevant parent/girl engineering career toolkits entitled ""GUIDE - Girls Understand, Imagine and Dream Engineering,"" for dissemination to African American, Native American and Hispanic parents and their daughters ages 13-17. The goal of this informal education resource is to inform and engage parents from the three racial/ethnic groups about engineering in a culturally-relevant manner, so that they may take an active role in encouraging their daughters to consider engineering careers. The GUIDE Toolkit will consist of: (1) the GUIDE Handbook, a customized, culturally-appropriate engineering career resource for use with both parents and girls; and (2) GUIDE Workshops to introduce the GUIDE Handbook to parents and girls from the target racial groups at Girl Scout councils and the larger community.