Informal Pathways to Engineering: Interim Findings from a Longitudinal Study

Dr. Christine Andrews Paulsen, Concord Evaluation Group

Christine Andrews Paulsen is founder of Concord Evaluation Group (CEG) in Massachusetts. Dr. Paulsen holds a Ph.D. in education research, evaluation, and measurement from the University of Pennsylvania. She has been conducting evaluation research since 1990 and, prior to CEG, worked for the Institute for Social Analysis and the American Institutes for Research. Dr. Paulsen routinely directs evaluations of STEM-related projects in informal settings, focusing on learners as well as practitioners. Her main research interest lies in evaluating programs that hold the promise of enhancing the lives of traditionally underserved populations (children, parents, and communities).

Dr. Monica E Cardella, Purdue University, West Lafayette

Monica E. Cardella is the Director of the INSPIRE Institute for Pre-College Engineering Education and is an Associate Professor of Engineering Education at Purdue University.

Tamecia R Jones, Purdue University, West Lafayette

Tamecia Jones is currently a doctoral student in the Engineering Education department at Purdue University with a research focus on K-12 engineering education, assessment, and informal and formal learning environments. She is a graduate of Johns Hopkins and Stanford University. Originally trained as a biomedical engineer, she spent years in the middle school classroom, teaching math and science, and consulting with nonprofits, museums, and summer programs.

Marisa Wolsky, WGBH Educational Foundation

Marisa Wolsky is an Executive Producer at WGBH Educational Foundation with over 20 years of experience turning STEM content into entertaining and educational media for kids. Ms. Wolsky is the PI and Executive Producer for the NSF-funded environmental science series PLUM LANDING, a PBS KIDS digital project that uses animated webisodes, online games, hands-on science activities, and live-action videos—plus a curious alien named Plum—to connect 6- to 9-year olds to nature, teach them about ecosystems, and get them pumped up about their role as caretakers of the planet. She is also Executive Producer and PI of the NSF-funded series Design Squad—for which she oversees all aspects of the production, translating its engineering content into entertaining across many platforms—and PEEP and the Big Wide World, responsible for managing its production and working closely with the series' advisors to oversee the implementation of PEEP's educationally rich preschool science curriculum. Prior to this, she worked on the development and production of many children's series, including Long Ago & Far Away, Where in the World Is Carmen Sandiego?, Where in Time Is Carmen Sandiego?, Arthur, and ZOOM.

Informal Pathways to Engineering: Interim Findings from a Longitudinal Study

Study Rationale

As we face the beginning of the 21st century, economists and government agencies are putting forth an urgent call for a new engineering workforce. But, despite the increased need for engineers in this country, the pipeline remains narrow. The U.S. Department of Labor expects the demand for some types of engineers, such as biomedical engineers, to increase as much as 27% over the next decade, yet the percentage of students graduating with engineering degrees has been steadily declining for the past twenty years.[1,2] The lack of engineers is especially pronounced among women and minorities—in 2010, only 12% of bachelor's degrees in engineering were awarded to black and Hispanic students, and 17% to women.[3] *In order to maintain its competitive advantage, it is imperative that the United States inspire and prepare more students to become engineers.*

Informal settings can play a significant role in accomplishing this mandate. Research shows that children only spend approximately 18.5% of their waking time inside classroom environments, leaving the majority of their time available for learning during out-of-school time.[4] In addition to large blocks of time, informal programs have other unique benefits over formal schooling. They offer low-stakes assessments and a greater variety of topics to explore (school curricula tend to focus narrowly on math and literacy due to testing policies). They have also been shown to more deeply engage participants, better encourage direct interaction with real-world phenomena, and build on prior knowledge and interests.[5] Moreover, as a recent study sponsored by the Noyce Foundation reports, within informal programs, "youth not only become excited and engaged in these fields but develop STEM skills and proficiencies, come to value these fields and their contributions to society, and—significantly—begin to see themselves as potential contributors to the STEM enterprise." [6] Indeed, "75% of Nobel Prize winners in the sciences report that their passion for science was first sparked in an out-of-school environment." [7]

While individual evaluation studies have offered insight into the successes and failures of these discrete informal engineering programs—and occasionally pinpointed correlations between participation and studying STEM subjects in college—*more research is needed to look across programs to determine how children move from one experience to another and what motivates them to keep progressing along an engineering-related pathway.* The Committee on Learning Science in Informal Environments espoused this view in its report to the National Research Council, stating that, "Rather than focusing on discrete moments of learning (e.g., as in a short-term, pre-post assessment), an ecological perspective strives to understand learning across settings: exploring, for example, how learning experiences in one setting prepare learners to participate in other settings. Working from an ecology of learning perspective, educators and researchers focus on learning experiences as they occur in specific settings and cultural communities and on the continuity of a learner's experiences across science learning environments." [8]

Informal Pathways to Engineering (IPE), a project of the WGBH Educational Foundation in collaboration with consultants Concord Evaluation Group (CEG) and Purdue University, is answering the National Research Council's call with a study that researches the diverse pathways students take while pursuing an interest in engineering.

Research Questions

Our goal with the IPE study is to answer the following research question: *How do informal engineering programs (such as Design Squad, a WGBH multimedia informal engineering program for middle school-aged children) support engineering-related learning over time (i.e., engineering pathways)?*

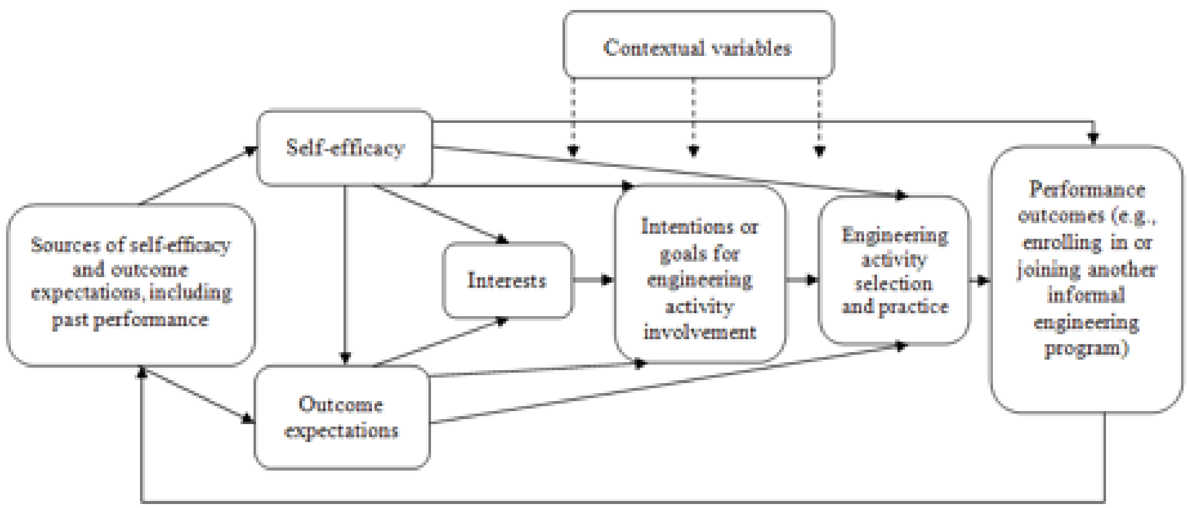
To get at this larger question, we will also explore five related, secondary questions:

1. What is the profile of children who benefit the most (i.e., develop positive outcome expectations about engineering, greater engineering-related self-efficacy, and an increased interest in engineering) after exposure to informal STEM programs?
2. How much exposure to informal STEM programs is sufficient to support these positive outcomes?
3. What type of exposure to informal STEM programs is sufficient to support these positive outcomes?
4. What are the elements of informal STEM programs that support positive outcomes?
5. What engineering pathways do children pursue, if any, after using or participating in informal STEM programs?

Definitions: We are defining *"informal engineering programs"* as activities, resources, and events that occur outside of a school setting. Some of these informal programs may have an in-school component, too. However, for the purposes of this study, we are defining informal programs as ones that children can engage in alone or with others, on their own time outside of school. Such programs may be self-regulated, assisted by a parent, or led by an informal educator (e.g., a camp counselor). We are defining *"engineering pathways"* very broadly for the purposes of this study. Since engineering-related learning can happen in many different settings, we are seeking to track the learning that happens across a wide variety of venues in and outside of school, which may include museums, websites, TV programs, books, clubs, and afterschool programs. We are defining *"profile"* as children's background and demographic characteristics, including factors like gender, age, school achievement, socioeconomic status, race/ethnicity, as well as contextual factors like family support. *"Interest"* is defined as the extent to which children express an intention in participating in specific activities or behaviors (such as joining engineering clubs). *"Exposure"* means any interaction with informal engineering program resources—this includes reading the content on a website, trying out hands-on activities, viewing *Design Squad* episodes, posting comments on the website, and downloading resources. *"Self-efficacy"* is defined as children's beliefs about whether they are capable of successfully doing an activity (e.g., believing they can be a successful engineer). *"Outcome expectations"* includes children's expectations for the consequences of participating in specific activities, engaging in certain behaviors, or making certain choices (e.g., children's beliefs about whether engineering can help them contribute to society).

Study Design and Theoretical Framework

The IPE study, based on Social Cognitive Career Theory (SCCT), seeks to investigate the effect of informal, out-of-school activities, as well as other factors (self-efficacy, outcome expectations, and personal interests, and intrapersonal factors) on children's interest in engineering and decisions to engage in engineering-related activities.[9] SCCT has its roots in Bandura's Social Cognitive Theory, which posits that personal characteristics, behaviors, and environment all play important roles in an individual's academic and career choices. The SCCT framework argues that these choices are influenced by three main factors: self-efficacy (the degree to which one believes that one can succeed at a given activity), outcome expectations (one's beliefs about the outcomes of certain behaviors), and personal interests (i.e., intentions).



Adapted from Lent, R.W., Brown, S.D., & Hackett, G. (1994).

Researchers have used SCCT to demonstrate that self-efficacy plays a crucial role in recruiting women into college-level STEM program.[10,11] Other studies have explored hands-on STEM activities within the framework of SCCT and have found that it provides an efficient model for studying such activities.[12] According to Zimmerman (2001), self-efficacy and outcome expectations help learners to consider future consequences, which in turn enable them to set goals for themselves.[13] As learners reach specific goals, their self-efficacy changes. They begin to see themselves as being capable of achieving goals, which then motivates them to continue learning.

Researchers have also found that self-efficacy and positive outcome expectations lead to enrollment in science and engineering programs. Using data from over 3,300 student surveys from the National Education Longitudinal Study of 1988, Tai et al. (2006) looked at eighth grade children's expectations for what career they thought they would be in at age 30 and then correlated responses to which degrees children had earned 12 years later.[14] Students who expected to have a science-related career were 3.4 times more likely to earn physical science and engineering degrees than children without similar expectations. The study also found that about half of eighth graders who expected to have a science career followed through on their eighth-grade career choices, while only a third of children who expected non-science careers switched into science.

In addition to self-efficacy and positive outcome expectations, the SCCT framework also argues that interest is a main factor influencing choice. There is research to support this contention. Seymour and Hewitt (1997) found that children who persisted in science, math, and engineering tracks were more likely to have chosen engineering based on interest rather than other reasons like excellence in high school math and science courses or the influence of family members.[15] In a study designed to determine who drops out of collegiate engineering programs, Besterfield-Sacre et al. (1997) found that children with high GPAs who dropped out of engineering had less interest in engineering than those who persisted.[16] These findings led them to conclude that intrinsic interest strongly favors persistence in STEM fields.

Because SCCT is a widely used and accepted model within the field of engineering education research, we believe that it provides a useful framework for our study. Our working hypothesis is that informal engineering education activities may provide opportunities for children to try out the engineering design process and build their self-efficacy for such activities. We also hypothesize that, in turn, children's familiarity with such activities may encourage them to become more interested in engineering and to develop positive outcome expectations related to informal or formal pathways that include engineering.

In addition to the factors outlined in the SCCT framework, there are contextual variables that have been shown to play a role in academic and career choices (e.g., gender, background variables, math and science achievement). For example, one predictor of who pursues a career in engineering is achievement in math and science (a background variable). In their analysis of data provided by 12,000 freshmen from the University of Pittsburgh and Texas A&M University, Nicholls et al. (2007) found a positive correlation between majoring in STEM subjects and SAT mathematics scores and high school grade point averages.[17] The study also found that qualitative measures like self-reported mathematical ability (self-efficacy) and computer skills were also good indicators of those students who planned to major in STEM.

Another key contextual variable is parental influence. About three quarters of the member engineers of the American Society of Mechanical Engineers surveyed in the "Why Engineering?" survey say most often a parent (46%) or a teacher (29%) influenced their childhood interest in engineering.[18] Strutz (2008) also found that parents were major influencers for both college students studying engineering and engineers who had completed an engineering degree (practicing engineers, retired engineers and engineering faculty).[19] For each group, the most often cited influencer (i.e. the individual who influenced the engineer's decision to study engineering) was either a mother or a father without an engineering background. This is notable for two reasons: 1) in this study, the influence of a parent was linked with persisting in

engineering, and 2) the parents were able to influence their children towards studying engineering even without having an engineering background themselves. This highlights the importance of engaging parents and families in informal engineering education.
There is some evidence that suggests participation in engineering programs in secondary school can lead to an interest in studying engineering or eventual enrollment in college. In a recent review of the 18 STEM programs targeting girls, the Harvard Family Research Project's Out-of-School Time Database found that most of the programs increased participant's confidence in their math skills, improved attitudes toward and engagement in math, and increased plans to attend or enroll in college.[20] In their evaluation of FIRST (a robotics club), Melchior et al. (2005) reported that the program's alumni were significantly more likely to attend college and three times as likely to major in engineering than compared to a group of students with similar background and achievement in science and math.[21] A similar study was conducted in order to evaluate Project Lead the Way (PLTW), a non-profit organization that promotes pre-engineering courses in middle and high schools. This study found that PLTW graduates were five times more likely to select engineering courses compared to first-time freshmen at four-year institutions, and their average freshman GPA was higher than their peers.[22]

Because there is some evidence that participation in engineering-related programs is a predictor of studying engineering in college, the IPE study will use involvement in engineering activities, clubs or other programs as a proxy for enrollment in an engineering degree program. Thus, if children in our study move along a pathway from one type of informal engineering program to another, it may be evidence of an early link between participating in informal engineering programs as children and later enrollment in engineering courses, degrees, and careers as young adults.

Study Design

To answer our research questions, we have embarked on a qualitative, single-group, interrupted time series study in which we are following a sample of 60 middle school children over a period of three academic years (sixth grade through eighth grade). Our rationale for proposing a qualitative study is that such a design will enable us to gather rich, descriptive data about the factors that contribute to children's decision processes over time as they relate to engineering activities.

Sampling and Recruitment: We recruited a sample of 60 middle school children in Indiana (IN) and Massachusetts (MA) that is diverse in terms of socioeconomic status, ethnicity, and geography (e.g., urban, rural, suburban). Recruitment was accomplished by reaching out to parents through advertisements placed in local, free, parenting publications; websites; and informal clubs and afterschool programs, such as Girl Scouts. We invited parents whose children might be interested in participating in the study to contact the study team for screening to determine their child's eligibility for the study.

From the pool of eligible children, we randomly selected 60 for participation in the study (30 in MA and 30 in IN). We collected written documentation of informed consent from the parents of these minor participants. As an incentive to stay in the study for three years, we offered $100 to each family for each year of participation in the study.

Children were enrolled in the study if their parents indicated that their children were interested in engineering-related activities (instead of “engineering” we used the phrase “designing, creating, or building”). For example, 100% of the sample had played with engineering-related toys (such as Legos, K’NEX, robots); 85% of the sample had watched a TV show, webisode or DVD related to designing, creating, or building; and 75% had previously built something, *not in school*. At the start of the study, most children (80%) reported that they knew what engineering was or had heard of it and the same proportion agreed or strongly agreed that “engineering is cool.” Upon enrollment in the study, 21 children (35%) reported that they would like to be an engineer someday.

To date, 10 children from MA and 10 children from IN have left the study (an attrition rate of 33%). We have analyzed demographic, background, and key study variables for “study drop-outs” versus “study stayers” and have found no significant differences between the two groups. Thus, we are confident that families have dropped out of the study due to random factors, rather than any factors related to key study variables, such as children’s interest (or lack of interest) in engineering.

Procedures: Upon enrollment in the study, we conducted one-on-one interviews with each of the participants and at least one of his or her parents. Following the baseline interviews, children were provided with access to *Design Squad* resources. Beyond providing families with links to the *Design Squad* website, we did not attempt to prescribe the amount of exposure that the children should have or suggest the “best” ways to use the resource nor did we direct participants to explore any other specific types of resources. In addition to the baseline interviews, children and their parents were also interviewed by trained researchers from the study team in seventh grade, and will be interviewed again at the end of eighth grade.

Approximately each quarter, children were asked to complete a short web-based survey to learn which informal STEM activities they engaged in, if any, especially those related to engineering.

In addition to interviews with the children and their parents, the study team also interviewed a small sample of the children’s informal educators (when applicable), teachers and/or principals to gain a fuller understanding of potential influencing factors in the children’s lives (e.g., what engineering-related content is being covered in the children’s classrooms and what engineering-related activities are offered at schools).

Study Instruments: For the interviews, we developed interview scripts for three different audiences: (1) children, (2) parents, and (3) educators (including informal educators, teachers, and principals). The objective of the interviews was to gather qualitative data that may enable us to assess the factors that influence children’s engineering-related interests, intentions, and behaviors. To assess these constructs, the team used a combination of existing, validated instruments from repositories, such as the “Assessing Women and Men in Engineering” resource (developed by Penn State and the University of Missouri with NSF funding) and the interview protocols developed for the Academic Pathways Study by the Center for the Advancement of Engineering Education.[23] In cases where existing instruments were not available or applicable, CEG and Purdue developed custom instruments. To validate these custom instruments, the team pilot tested them with a sample of children who represented the target population.

Analysis: Rather than approaching the data analysis with a preconceived set of themes and data classifications into which one could fit the data ("emic" approach), analysts are using an "etic" approach, in which they look for the themes and narratives that naturally emerge from the data.[24] This approach offers a more authentic interpretation of the data. Any quantitative data collected during the surveys (i.e., responses to Likert scales) will be analyzed with descriptive statistical analysis (e.g., measures of central tendency). Because the goal of the study is to collect mainly qualitative data, CEG and Purdue are not planning to construct and test complex inferential models.

Interim Findings

The IPE study is currently in the final year of data collection, so all findings reported here are still preliminary. The study will be complete in June of 2015.

As a reminder, our main goal with the IPE study is to answer the following research question: *How do informal engineering programs (such as Design Squad, a WGBH multimedia engineering program) support engineering-related learning over time (i.e., engineering pathways)?*

Implicit in our research question is an assumption that the children in our sample would, in fact, engage in informal engineering activities throughout the study and that we would be able to explore the factors related to their participation and their adherence to, or deviation from, "engineering pathways" over time. Thus, we recruited children who, according to their parents, had already expressed an interest in engineering or regularly participated in engineering-related activities, such as building with Legos, taking things apart and putting them back together, or reading books related to building and design.

So, during the first year of enrollment in the study (for most children, this was sixth grade, but for some it was seventh grade), we explored factors that were related to children's interest in STEM, especially engineering.

Our findings, so far, indicate that early in middle school, STEM enjoyment and self-perceptions of STEM self-efficacy ("I am good at math") may be mutually reinforcing—children who like math, enjoy it, and vice versa. Based on interviews with children, we found that children in sixth and seventh grade who reported they were good at math and science also tended to report that they liked learning about, and participating in, math and science activities. Additionally, we learned that enjoyment of STEM subjects in school tends to be closely related to factors such as whether children enjoy their STEM teachers and whether children's own learning styles are consistent with their teachers' approaches.

Early interest and aptitude in STEM were also related to having positive attitudes towards the field of engineering. We found that sixth graders who liked math and science were more likely to believe that "engineers are innovative" than were children who did not like math and science. By seventh graders, these same children were also more likely to agree that "engineering is cool" than other children.

Early interest and aptitude in STEM, however, was not alone sufficient to keep children engaged in engineering-related activities as they journeyed through middle school. In sixth grade, children who reported that they were good at math or design, and liked math or design, also reported participating in more engineering activities than children who were less interested in math or design. But, by seventh grade, participation levels among all children decreased (from an average of 7 activities per child in sixth grade to an average of 6 activities per child in seventh grade). Additionally, we saw no relationships between interests, skills, and participation levels. Based on interviews with children, it appears that, as the children get older, there are more demands on their time because of an increase in the amount of homework and their growing participation in other activities, like sports. Based on interviews with parents and educators, the situation is also likely compounded in some areas by a lack of available STEM activities, plus a lack of parental awareness about them.

Our findings indicate that children's interest in specific types of engineering shifted over time. Children in sixth and seventh grade expressed interest in becoming engineers someday or in performing jobs related to engineering (even if they didn't know what engineering was). But, the types of engineering-related work they were interested in changed slightly over time, from interest in cars and machines that help people walk in sixth grade, to an interest in medicines and computer applications in seventh grade. Student interest in developing technology that can help the environment persisted from sixth to seventh grade.

Our findings indicate that, as children move through the middle school experience, they become more aware of and sensitive to the perceptions of their peers, while still aware of their parents' positive perceptions about engineering. Sixth graders, who liked to design, build, and create, demonstrated more positive attitudes towards engineering than they did in seventh grade, despite the fact that they were highly likely to report that their parents would be happy if they became engineers someday. We observed a similar finding for children who reported that they liked to help people: Their attitudes became less positive over time, even though they reported that their parents would be happy if they became engineers. Perceptions of their peers became more important than those of their parents. During our interviews, we found that sixth graders were likely to report that their parents helped them choose afterschool activities, but by seventh grade, children were more likely to report that they chose activities based on what their friends were doing rather than what their parents wanted them to do. Moreover, they felt that their friends would make fun of them for doing engineering activities.

Sixth graders were more likely to express an interest in being engineers someday and report that their expectations for engineering activities were positive when they had parents who knew what engineering was, believed it was important, and provided activities to support engineering learning. However, again, by seventh grade, while children were still aware that their parents believed it was good to participate in engineering activities, children were more likely to believe that other kids would make fun of them if they did so—regardless of their parents' knowledge, attitudes, or behaviors. Thus, by seventh grade, the perceptions of one's peers seems to have become more important to the children in our sample than their parents' perceptions.

Related to this finding, we are also exploring the potential impact of older siblings on children's interest in engineering activities. Through interviews, we have learned that older siblings, or even older cousins who take high school courses in technology, design, or engineering or participate in extracurricular activities, may act as "peer influencers" on middle school students who may not have access to such academic options at their school.

For children who do stay involved in informal engineering programs, we are beginning to explore (and will continue to explore) the elements that facilitate positive engineering-related outcomes (related to our secondary research questions). We are learning that Girl Scouts and Boy Scouts are tremendous vehicles to access STEM and engineering opportunities. 4-H also provides multiple options for hands-on engineering-related activities that increase in difficulty, and students appear to have longevity in 4-H (meaning they stay for more than one year). Video games that involve design (and have social components) are also activities that have longevity (e.g., Minecraft), and are cross gender.

One finding that may be emerging (but we need to explore further) is that while parents may express a positive attitude toward engineering, they may not have a deep understanding of what engineering involves or how to encourage their children to participate in engineering-related activities. It's possible that this lack of deep understanding could inhibit parents from getting their children involved in informal engineering activities. For example, all but one parent in the study agreed that engineering improves society, yet only slightly more than half of the parents (55%) reported that they actually knew what engineers do. One-third of parents reported that they didn't know how to help their children learn about engineering; they didn't know how engineering could be used to help society; and they didn't know how engineering is different from science. (Only nine of the 60 children (15%) in the sample had one or more parents who was an engineer, while slightly more than half of the sample (51%) reported that they did not have any regular interaction with engineers.)

Broader Significance of the IPE Study

The broader significance and importance of this project will be to support the engineering field's ability to inspire more children to pursue engineering pathways, from initial interest in engineering clubs and other extracurricular activities to choices in college majors and an ultimate career as a professional engineer. In addition, the project will help us consider how we might provide resources and education to parents to help them support their children's engineering-related interests.

Acknowledgement

This material is based upon work supported by the National Science Foundation, Division of

Engineering Education and Centers, Grant Number 1129342. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] Bureau of Labor Statistics, US Department of Labor. (2014). *Occupational outlook handbook, 2014 edition*. Washington DC: U.S. Government Printing Office. Accessed online: http://www.bls.gov/ooh/architecture-and-engineering/home.htm

[2] National Science Foundation. (2006). *Science and engineering degrees: 1966–2004*. Arlington, VA: Division of Science Resources Statistics.

[3] National Action Council on Minorities in Engineering, Inc.. (August 2012). African-Americans in engineering. *Research and Policy*, 2*(4)*, 1-2.

[4] Stevens, R. Bransford, J. & Stevens, A. (2005). *The LIFE Center's lifelong and lifewide diagram*. Accessed from: http://life-slc.org

[5] Bell, P., Lewenstein, A.W., Shouse, A.W., & Feder, M.A. (Eds.) (2009). *Learning science in informal environments: People, places, and pursuits*. National Academies Press: Washington DC.

[6] Krishnamurthi, A., Ballard, M., & Noam, G.G. (2014). *Examining the impact of afterschool STEM programs*. Palo Alto, CA: The Noyce Foundation.

[7] Friedman, L.N. & Quinn, J. (2006). Science by stealth. *Education Week*, 25*(24)*: 45, 48, 49.

[8] Bell, P., Lewenstein, A.W., Shouse, A.W., & Feder, M.A. (Eds.) (2009). *Learning science in informal environments: People, places, and pursuits*. National Academies Press: Washington DC.

[9] Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice and performance. *Journal of Vocational Behavior*, 45, 79-122.

[10] Pajares, F., & Valiante, G. (2001). Gender differences in writing motivation and achievement of middle school students: A function of gender orientation? *Contemporary Educational Psychology*, 26, 366-381.

[11] Sanders, J. (2005). *Gender and technology in education: A research review*. Retrieved January 2011, from http://www.josanders.com/pdf/gendertech0705.pdf

[12] Adya, M., & Kaiser, K. M. (2005). Early determinants of women in the IT workforce: A model of girls' career choices. *Information Technology & People*, 18, 230-259.

[13] Zimmerman, B.J. (2001). Theories of self-regulated learning and academic achievement: An overview and analysis. In Zimmerman, B.J. & Schunck, DH. (Eds.) (2001). *Self-regulated learning and academic achievement: Theoretical perspectives*. New Jersey: Lawrence Erlbaum and Associates, 1-38.

[14] Tai, R. H., Liu, C. Q., Maltese, A.V., & Fan, X. (2006). Planning early for careers in science. *Science*, 312, 26 May, 2006.

[15] Seymour, E., & Hewitt, N.M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

[16] Besterfield-Sacre, M., Atman, C.J., & Shuman, L.J. (1997). Characteristics of freshman engineering students: Models for determining student attrition in engineering. *Journal of Engineering Education*, Vol. 86*(2)*: 139-149.

[17] Nicholls, G.M., Wolfe, H., Besterfield-Sacre, M., Shuman, L.J., & Larpkiattaworn, S. (2007). A method for identifying variables for predicting STEM enrollment. *Journal of Engineering Education*, 96, 33-44.

[18] University of Central Florida, College of Engineering and Computer science. (2004). *The "Why engineering?" survey*. http://partner.cecs.ucf.edu/WhyEng/FES_Report/ Accessed February 2, 2011.

[19] Strutz, M.L. (2008). A retrospective study of skills, traits, influences, and school experiences of talented engineers. In the *Proceedings of the 2008 ASEE IL/IN Section Conference*, Terre Haute, IN.

[20] Chun, K. & Harris, E. (2011). *Research update: Highlights from the Out-Of-School-Time Database*. Number 5, January 2011.

[21] Melchior, A., Cohen, F., Cutter, T., & Leavitt, T. (2005). *More than robots: An evaluation of the FIRST Robotics Competition participant and institutional impacts*. Center for Youth and Communities Heller School for Social Policy and Management. Waltham, MA: Brandeis University.

[22] Walcerz, D. (2007). *Report on the third year of implementation of the True Outcomes Assessment System for Project Lead The Way*. PLTW document, October 1, 2007.

[23] Atman, C. J., Sheppard, S. D., Turns, J., Adams, R.S., Fleming, L.N., Stevens, R., Streveler, R.A., Smith, K.A., Miller, R. L., Leifer, L. J., Yasuhara, K., & Lund, D. (2010). *Enabling engineering student success: The final report for the Center for the Advancement of Engineering Education*. San Rafael, CA: Morgan & Claypool Publishers.

[24] Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin and Y. S. Lincoln (Eds.), *Handbook of qualitative research*. Thousand Oaks, CA: Sage, 105-117.