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Educational Robotics as Leadership Development for Youth

Kathleen P. Morgan
University of Nebraska-Lincoln, kp_morgan922@yahoo.com

EDUCATIONAL ROBOTICS AS LEADERSHIP DEVELOPMENT FOR YOUTH

By

Kathleen Phelps Morgan

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Kathleen Phelps Morgan, M. A. S.

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Adviser: Bradley S. Barker

This study explored how competitive educational robotics programs for youth contribute to the development of future innovative leaders in the science, technology, engineering, and mathematics (STEM) fields. The importance of leadership in creating a climate for innovation is recognized by scholars (Eisenbeiss, van Knippenberg, & Boerner, 2008; Oke, Munshi, & Walumbwa, 2009; Sarros, Cooper, & Santora, 2008) and educational robotics programs, like *FIRST*® LEGO® League (FLL), that include leadership development in their organizational missions. While youth interest in STEM and youth leadership development have been previously researched, the intersection of leadership development and STEM learning appears to be a new field for research.

In this study, questionnaires assessing attitudes toward leadership importance, leadership development, and perceived leader development changes as a result of participating in FLL were collected from 501 youth participants at four Nebraska FLL tournaments. Across 74 teams, 67.9% of youth were male and 85.4% were white. Teams consisted of youth, age eight to 15 (M = 11.4) with one to five years of FLL experience (M = 1.5) and had a team size mean of 7.71 members. On a five point Likert scale, participants reported high levels of Leadership Importance (M = 4.45, SD = 0.59) and Leader Development (M = 4.26, SD = 0.51). On the scale measuring perceived

leadership development changes due to their FLL experience, youth reported improvement ($M = 4.25$; $SD = 0.62$).

Multilevel linear models assessed team and individual level effects. For Leadership Importance, significant effects were gender within teams, team age, and experience within teams. For Current Leader Development, team age and experience within teams were significant. No demographic variables had significant effects on the scale assessing perceived leader development changes. The models explained 15 – 24% of variance for the leadership outcomes, indicating additional research is needed to further understand factors influencing youth leadership development through FLL. Overall, results suggest that educational robotics competitions are contributing to the "STEM pipeline" and influencing youth to become innovative leaders in STEM.

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Introduction

Advances in science, technology, engineering, and mathematics (STEM) have impacted nearly every aspect of life. Examples include electrification, automobiles, airplanes, water supply and distribution, electronics, radio and television, agricultural mechanization, computers, telephony, air conditioning and refrigeration, highways, spacecraft, internet, imaging, household appliances, health technologies, petroleum and petrochemical technologies, lasers and fiber optics, nuclear technologies, and high-performance materials, which are listed as the 20 greatest engineering achievements in the 20th century by Constable and Somerville (2003).

In addition to improving daily life, the STEM fields have been the primary driver of the economy since the industrial revolution (Committee on Prospering in the Global Economy of the 21st Century, 2007). People are employed not only in manufacturing and selling technological innovations, but also in research and development. Nearly every new job created now is the result of advances in the STEM fields, and over half of the Gross Domestic Product has been attributed to technological innovations (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010). While only 4% of Americans are employed as scientists or engineers, they create jobs for the other 96% of the population (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010). The STEM industries have a disproportionate influence in their role as the economic leaders of the world and in their responsibility for countries' national defense efforts (National Academy of Engineering & National Research Council, 2012).

Globalization, through science and technology, has produced two conditions for

the first time; individuals and small groups can significantly influence the lives of large groups of people and distance no longer impacts many industries' ability to engage in collaborative work (National Academy of Engineering & National Research Council, 2012). As technology has reduced barriers caused by distance, citizens of one country must compete for jobs with those across the world. For example:

> Software written in India is now shipped to the United States in milliseconds to be integrated into systems that same day. Flowers grown in Holland are flown overnight for sale in New York the next morning. Magnetic Resonance Images (MRI's) of patients in United States hospitals are read moments later by radiologists in Australia. Pilots stationed in the United States guide unmanned aircraft to attack targets in Afghanistan. United States accounting firms prepare United States citizens' income taxes using accountants located in Costa Rica and Switzerland. Water collected in France is sold in grocery stores in California. The receptionist in an office in Washington, DC lives in Pakistan. A physician in New York removes the gall bladder of a patient in France with the help of a remotely controlled robot. (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010, p. 18)

Such globalization has driven many countries to work toward building more knowledge-driven economies (National Science Board, 2012).

In 2005, a committee of twenty people from the National Academies gathered to study the competitive status of the United States. Their work, known as the "Gathering Storm" report (Committee on Prospering in the Global Economy of the 21st Century, 2007), determined that the United States was at a crisis point, at risk of losing its status as

the economic and innovative leader of the world.

The report provided four general recommendations for American educators, policy makers, and business leaders including:

- Move the United States K-12 education system in science and mathematics to a leading position by global standards.
- Double the real federal investment in basic research in mathematics, the physical sciences, and engineering over the next seven years.
- Encourage more United States citizens to pursue careers in mathematics, science, and engineering.
- Rebuild the competitive ecosystem by introducing reforms in the nation's tax, patent, immigration, and litigation policies. (Committee on Prospering in the Global Economy of the 21st Century, 2007, p. 5-12)

The authors recognized the immense level of difficulty in their recommendations and included 20 action steps for implementation.

In 2010, the group gathered again to review progress toward global competitiveness and assess the country's current status. In the updated report, the committee determined that although some actions had been taken, the United States global competitive position had worsened. The report describes the challenges the United States faces in the global marketplace (see Table 1).

The 2010 committee stood by its 2005 recommendations to improve the global competitiveness status of the United States. In their review, the authors of the 2010 report argue that is not necessary or possible to match China or India in actual numbers of scientists or engineers. According to the committee, there is some disagreement in the

Table 1
Facts about the Global Competitiveness Status of the United States

- In 2009, 51 percent of *United States* patents were awarded to non-United States companies.
- The World Economic Forum ranks the United States 48th in quality of mathematics and science education.
- Only four of the top ten companies receiving United States patents last year were United States companies.
- In 2000 the number of foreign students studying the physical sciences and engineering in United States graduate schools for the first time surpassed the number of United States students.
- GE has now located the majority of its R&D personnel outside the United States.
- The United States ranks 27th among developed nations in the proportion of college students receiving undergraduate degrees in science or engineering.
- The United States ranks 20th in high school completion rate among industrialized nations and 16th in college completion rate.
- Almost one-third of U.S. manufacturing companies responding to a recent survey say they are suffering from some level of skills shortages.
- According to the ACT College Readiness report, 78 percent of high school graduates did not meet the readiness benchmark levels for one or more entry-level college courses in mathematics, science, reading and English.

Note. From Members of the 2005 "Rising Above the Gathering Storm" Committee. (2010). *Rissing Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (p. 6-11). Washington, D.C.: The National Academies Press.

STEM fields about whether our current educational system is producing too many or not enough qualified individuals in the STEM fields. The committee calls, instead, for a renewed focus on *innovation* as a source of prosperity. "'Innovation' commonly consists of being first to acquire new knowledge through leading-edge research; being first to apply that knowledge to create sought-after products and services, often through world-class engineering; and being first to introduce those products and services into the marketplace through extraordinary entrepreneurship" (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010, p. 49). The 2010 *Gathering Storm* report identifies the ingredients of innovation as "(1) new knowledge; (2) capable people, and (3) an environment that promotes innovation and entrepreneurship" (Members of the

2005 “Rising Above the Gathering Storm” Committee, 2010, p. 44).

New Knowledge

Increased “knowledge capital” is the most “fundamental building block of innovation…often in the form of scientific or technological advancements” (Members of the 2005 “Rising Above the Gathering Storm” Committee, 2010, p. 44). Basic research, as described by the Organization for Economic Cooperation and Development (2002), includes experimental or theoretical work with the primary goal of acquiring new knowledge without considering any particular application or use. Basic research and development, despite being important to innovation, is risky and expensive for industry to undertake (Members of the 2005 “Rising Above the Gathering Storm” Committee, 2010). In their efforts to increase the knowledge base of their science and technology industries, countries have worked to stimulate industrial research and development and expand their higher education systems (National Science Board, 2012). The 2010 *Gathering Storm* report recommends addressing this ingredient of innovation by increasing governmental support for research and development in universities.

Capable People in Science and Engineering

Researchers such as Mead, Thomas, and Weinberg (2012), Schuhmann (2010), Melchior, Cohen, Cutter, and Leavitt (2005), and others have studied the *Gathering Storm* committee’s second ingredient of innovation, developing capable people in the STEM fields. According to Mead, et al. (2012), the collective experiences that inspire young people to enter STEM careers as adults have become commonly described as the “STEM pipeline.” The concept of the STEM pipeline is built on self-efficacy and achievement expectancy models (Mead et al., 2012). When people believe in their ability

to be successful at a specific task, they are significantly more likely to achieve their goals. Self-efficacy builds success, leading to an expectation of achievement and additional motivation to continue working toward goals. In a self-fulfilling model, youth who have high science self-efficacy set more challenging goals, work harder to achieve their goals, and earn higher grades (Mead et al., 2012).

Following the STEM pipeline theoretical models described in Mead, et al. (2012), many programs working toward the goal of recruiting capable people into the STEM fields begin by engaging students' interest in STEM activities. Program coordinators expect opportunities to participate in STEM will introduce youth to the "pipeline" and set them down a path that will inspire them to take science classes in high school, choose a STEM major in college, and eventually enter a STEM career.

While there are many approaches to engaging youth in STEM, educational robotics has become a popular vehicle for organizations working to address the need for capable people as a means to create competitive innovation posed in the 2010 *Gathering Storm* report. In Eguchi's (2012) overview of robotics programs and competitions, educational robotics is presented as a tool for students to learn 21st century skills. Research suggests that participation in educational robotics programs successfully increases interest in STEM, improves workplace and life skills, and inspires youth to enter STEM careers (Melchior et al., 2005; Nugent, Barker, & Grandgenett, 2012). For example, in the Melchior, et al. (2005) study of the *FIRST*® Robotics Competition, participants were twice as likely to major in science or engineering and twice as likely to expect to enter a STEM career as the average college student.

While there is strong evidence supporting the benefits of participating in robotics

competitions and programs, research has also revealed room for improvement. In Nugent, et al. (2012), assessments of engineering design decreased after participation in a robotics competition and among girls, teamwork scores decreased after participation in a robotics camp.

Environment for Innovation and Entrepreneurship

In their research, Sarros, et al. (2008) addressed the third ingredient of innovation, an environment that supports innovation and entrepreneurship. They considered "climate for innovation as an indicator of the capacity of organizations to become innovative. That is, the degree of support and encouragement an organization provides its employees to take initiative and explore innovative approaches" (Sarros et al., 2008, p. 146). Scholars predict that a climate for innovation will create actual innovation in organizations (Sarros et al., 2008).

Leadership, organizational culture, and innovation.

Research has documented leadership's influence on organizational culture through encouraging employee engagement, motivation, creativity, and achievement (Damanpour & Schneider, 2006; Eisenbeiss et al., 2008; Gumusluoglu & Ilsev, 2009; Jung, Chow, & Wu, 2003; Sarros et al., 2008). Drath, et al. (2008) broadly defined leadership as a shared group process that creates direction, alignment, and commitment within the group. Leaders can be thought of as people or organizations that contribute to goal setting, coordinate group efforts, or develop commitment to the group. According to Drath, et al. (2008), several people or even every member in a group might be considered leaders. In a similar description, Northouse defined leadership as "a process whereby an individual influences a group of individuals to achieve a common goal" (Northouse,

2010, p. 3)**.**

According to Damanpour and Schneider (2006), top managers affect organizational outcomes by creating organizational culture, influencing organizational climate, and building capacity for change. Jung, et al. (2003) focused on the impact of transformational leadership, arguing that it creates innovation by engaging people's personal values systems, increasing motivation to improve performance, and encouraging creative thinking. Sarros, et al. (2008) found that articulating a vision and providing individual support were specific transformational leadership behaviors related to an organization's climate for innovation. Transformational leadership provided support for innovation, but in Eisenbeiss, et al. (2008), team innovation only occurred when the climate for excellence was high. Crawford, Gould, and Scott (2003) found that a combination of influence and technology factors of innovation accounted for over 30% of the variance of transformational leadership. Likewise, Oke, Munshi, and Walumbwa (2009) listed both transformational and transactional leadership practices that supported specific types of innovation.

Developing Leaders in STEM

Research suggests leadership can create innovation (Damanpour & Schneider, 2006; Gumusluoglu & Ilsev, 2009; Jung et al., 2003; Oke et al., 2009; Sarros et al., 2008), therefore, the U.S. economic interests can work to address the need for innovation by developing leadership among those in STEM careers. Leadership development begins with individual's personal development and is an incremental process (Campbell, Dardis, & Campbell, 2003; Van Velsor, McCauley, & Ruderman, 2010). Leadership development programs should be intentionally designed for a specific person or group

and include elements of assessment, challenge, and support (Van Velsor et al., 2010). The Center for Creative Leadership (CCL), as the world's largest organization dedicated to leadership research and education, models leadership development as improving abilities to be self-aware, learn, manage conflicting demands, clarify leadership values, build relationships and work groups, communicate effectively, develop others, manage, think and act strategically and creatively, and initiate and implement change (Van Velsor et al., 2010). Other models cover similar characteristics including development of intra-personal attributes, interpersonal qualities, cognitive abilities, communication skills, and task-specific skills (Campbell et al., 2003).

Youth leadership development.

Although the body of research into youth leadership development is growing, several recent studies have described a need for additional leadership development research focused on youth, rather than adults (Avolio & Vogelgesang, 2011; Lord, Hall, & Halpin, 2011; Murphy & Johnson, 2011). The authors advocate for viewing leadership development as a nearly life-long activity beginning in childhood (Avolio & Vogelgesang, 2011; Lord et al., 2011; Murphy & Johnson, 2011). With a similar theoretical basis as the STEM "pipeline," the models of youth leadership development describe a self-reinforcing process. When youth learn about leadership and practice being leaders, they gain self-efficacy that prompts them to continue as leaders in future opportunities, resulting in increased leadership self-efficacy. Like language acquisition, there may be a "sensitive period" in which it is easier to learn how to be a leader earlier in life rather than later (Bornstein, 1989; Murphy & Johnson, 2011).

In addition to gaining leadership skills, identifying one's self as a leader is considered an important aspect of leadership development (Komives, Longerbeam, Osteen, Owen, & Wagner, 2009; Komives, Longerbeam, Owen, Mainella, & Osteen, 2006). In the Komives, et al. (2009) model, leaders must move through stages of awareness of leadership, exploration and engagement in leadership, identify themselves as a leader, differentiating between types of leaders, set their own leadership priorities, and finally integrating and synthesizing leadership as a part of their own identities and across situations.

Addressing the lack of youth leadership development research, Murphy and Johnson (2011) proposed a framework for a life span approach to leader development that includes the early development factors of early influences, parenting styles, and early learning experiences contributing to a leader's identity and self-regulation. Later stages of the model become self-reinforcing as a leader becomes more effective, reinforcing identity and self-regulation, and seeking out additional development experiences. The framework should be viewed within the context of the leadership activities, such as the leader's development stage, societal expectations, and time in history.

Murphy's (2011) work recognizes that leadership characteristics and behaviors exist among children as young as pre-school, and that since youth leadership should be age-appropriate, it may appear very different from adult leadership. For example, children in preschool might start becoming leaders by getting others to like them, influencing others, and communicating. Elementary school youth begin working in teams and serving as leaders in the classroom. Youth in middle school start coordinating teams and projects and have an increased need for self-management. High school and

college leadership begins to look more like the adult leadership models, including organizing complex projects, motivating others, establishing their own organizations, and serving in more complicated leadership roles.

Research has shown youth report increased leadership skills as a result of participating in various youth programs. For some programs, leadership development is a part of a wider youth development mission, such as YMCA of the USA, 4-H Youth Development Program, Girl Scouts of the USA, and the National FFA Organization (K. Anderson & Karr-Lilienthal, 2011; Edwards, 1994; Rutherford, Townsend, Briers, Cummings, & Conrad, 2002; Sabatelli, Anderson, Kosutic, & Sanderson, 2009; Seevers, 1994; Wingenbach & Kahler, 1997). Other youth programs focus directly on leadership development like the National Youth Leadership Council, Youth Leadership Institute, youth community organizing programs, and high school and college-based organizations (Brungardt, 1997; Christens & Dolan, 2010; Libby & Sedonaen, 2006; and others).

Educational robotics and leadership development.

Robotics programs like *FIRST*®, VEX Competitions, and Botball include leadership development in their goals, similar to other youth programs, in addition to inspiring youth to learn science and eventually enter STEM careers. For example, *FIRST* (For Inspiration and Recognition of Science and Technology), an organization that develops robotics competitions for youth ages 6 – 18, states its mission as:

> Our mission is to inspire young people to be science and technology leaders, by engaging them in exciting mentor-based programs that build science, engineering and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership (*FIRST*,

2011, p. 60).

FIRST organizes four levels of robotics programs, including Jr. *FIRST*® LEGO® League (ages 6-9), *FIRST* LEGO League (ages 9-14), *FIRST* Tech Challenge (high school), and *FIRST* Robotics Competition (high school). The CREATE Foundation, which sponsors competitions using the VEX robotics platform, includes leadership as one of its values (CREATE Foundation, 2012). The KISS Institute states that participation in Botball competitions helps prepare a workforce with leadership and teamwork experience (KISS Institute for Practical Robotics, 2012). These programs are aligned with Nelson's (2012) listing of leadership among skills developed through educational robotics programs for youth that can be directly transferred to the STEM workplace.

FIRST, as one of the longest-running educational robotics programs, has been evaluated in several studies. Researchers studying *FIRST* participants focused on attitudes toward the STEM fields, plans to enter STEM careers, and STEM learning (Melchior et al., 2005; Melchior, Cutter, & Cohen, 2009; Oppliger, 2001; Skorinko et al., 2010; Tougaw, Will, Weiss, & Polito, 2003; Varnado, 2005). Despite leadership being a central mission of robotics programs for youth, no studies were found investigating youth leadership development within robotics programs.

Problem Statement

Researchers have studied the impact of robotics competitions on science learning and attitudes toward the STEM fields (Grandgenett, Ostler, Topp, & Goeman, 2012; Melchior et al., 2005, 2009; Nugent et al., 2012; Skorinko et al., 2010). Youth leadership development has also generated interest from scholars (J. Anderson & Kim, 2009; Hastings, Barrett, Barbuto, & Bell, 2011; Min & Bin, 2010; Ricketts & Rudd, 2002;

Seevers, 1994; Wingenbach & Kahler, 1997; Van Linden & Fertman, 1998). The intersection of leadership development and STEM learning appears to be a new field for research.

Increased understanding of youth leadership development within the STEM fields will have a broad impact for scholars, youth development professionals, and the STEM industries. Following the STEM and leadership "pipelines," improving the effectiveness of programs that develop both STEM interest and leadership, may encourage more youth to see themselves as leaders and be inspired to continue learning STEM. As additional strong leaders enter the STEM fields, they will enhance the environment for innovation and entrepreneurship. Innovation is the key to remaining competitive and successful in the constantly changing global economy (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010). Through the "pipelines" that develop STEM interest and leadership, successful youth programs can indirectly influence the competitive status of the United States.

This study explores the contribution of educational robotics programs to the development of future innovative leaders in the STEM fields. The study bridges the research gap between educational robotics and youth leadership development by assessing leader development among middle school aged participants in four Nebraska *FIRST* LEGO League (FLL) educational robotics competitions.

Chapter 2

Literature Review

Robots in Education

To be considered a robot, a machine should have some type of "intelligent connection between perception and action" (Siciliano & Khatib, 2008, p. 1). For most robots, this means that they have sensors, can be programmed to react to sensor input, and have wheels or arms that are activated in response. The intelligent connection may include "programming, planning, and control" (Siciliano & Khatib, 2008, p. 2).

In recent years, robots have become a popular tool for teaching youth about STEM. "Educational robotics" is the term now commonly used to refer to robotics being used as a tool for learning (Eguchi, 2012). Since the early 1980's, robotics platforms designed for education represent a wide range of costs, types of parts, and complexities (Eguchi, 2012; Grandgenett et al., 2012; Miller, Nourbakhsh, & Siegwart, 2008). Many robotics kits include a programmable brick or controller and can be programmed in one or more languages (Eguchi, 2012).

Why use robots for education?

Educational robotics programs can be grouped by the purpose for using robots; trends are using robotics as the learning objective, robotics as a learning aid, and robotics as a learning tool (Eguchi, 2012). Across programs, educators find robotics appealing because of the robots' ability to catch the attention of youth; robots are highly engaging and motivating and encourage learning about STEM concepts (Eguchi, 2012; Hendricks, Ogletree, & Alemdar, 2012; Melchior et al., 2005; Miller et al., 2008; Nugent et al., 2012). In addition, robots provide a way for youth to quickly apply abstract concepts like

mathematical equations to tangible tasks (Bers, 2008). Further, robotics activities promote collaboration, teamwork, positive youth development, and foster learning of 21st Century Skills and computational thinking (Bers, 2006; Eguchi, 2012; Melchior et al., 2005, 2009; Miller et al., 2008). For example, in an introductory engineering course project, robots inspired increased shared leadership and engagement when compared to a similar assignment without robots (Scholz & McFall, 2011). Robots have even been used for storytelling (Bers, 2006) and by kindergarteners to express aspects of their identities (Bers & Ettinger, 2012).

Beyond the benefits of youth learning skills relevant to their current development, educational robotics promotes learning of STEM skills directly transferrable to the workplace. Nelson (2012) lists transferrable skills as including use of the scientific method and engineering design, applied math and logical reasoning, computer literacy, technical communication, and creativity. Generally applicable skills include vision, leadership, work ethic, initiative, goal setting, time and resource management, and working with teams.

Barriers to implementing robotics activities exist for many educational organizations. Challenges include lack of teacher time, teacher training, age-suitable academic materials, ready to use lesson materials, and a limited range of affordable robotic platforms (Mataric, Koenig, & Feil-Seifer, 2007). Educational robotics competitions suffer from a lack of connection, communication, and sharing ideas and the tendency of each organizer to attempt to reinvent a successful program (Bredenfeld, Hofmann, & Steinbauer, 2010).

Theoretical basis for educational robotics.

In addition to getting youth engaged in STEM through robotics activities, educational robotics has a strong connection to learning theory. Bers (2006) and Eguchi (2012) set the foundation for the impact of educational robotics on learners in Piaget's (1929, 1954) theory of constructivism and Papert's constructionism (Harel & Papert, 1991; Papert, 1980). Constructivism holds that gaining knowledge is not simply a matter of transmitting information into a person's mind. Instead, according to constructivism, learning is an active process of constructing and reconstructing knowledge through interactions with the environment (Piaget, 1929, 1954). Learning occurs when youth manipulate physical objects and observe their interactions. Constructionism builds on constructivism, but asserts that learning is even stronger when youth are involved in constructing physical objects that allow them to apply, build on, and reconstruct knowledge. Learning under constructionism is best when youth are provided the tools to support their learning and engage in self-directed, interactive exploration (Harel & Papert, 1991; Papert, 1980). The physical objects become tools for learners to think with and make their abstract ideas in the real world. In addition to constructivism and constructionism, robotics activities facilitate creative ideas by asking youth to come up with their own questions, projects, and solutions to challenges (Eguchi, 2012).

Educational robotics programs.

Learning through educational robotics can take place in varied program and activity structures. Educational robotics projects may be associated with specific curricula or projects associated with one of the educational robotics competitions (Eguchi, 2012). Some educational robotics programs focus on particular settings or uses for robots, such as medical robotics (Rockland, Kimmel, Carpinelli, Hirsch, & Burr-

Alexander, 2012), underwater robotics (McGrath, Lowes, McKay, Sayres, & Lin, 2012), or connecting robotics to geospatial technology (Adamchuk et al., 2012).

Robotics competitions are highly visible educational robotics contests, usually for teams of middle school or high school youth (Nugent et al., 2012). Competition programs include those organized by *FIRST*, BotBall, RoboCup-Junior, BEST, Micro Maze, Sumo, RC Jr. Dance, Trinity College's Firefighting Robot Contest, and the CEENBoT Showcase (Grandgenett et al., 2012; Miller et al., 2008). While differences exist among the competitions, teams generally build and program robots to accomplish specific tasks, communicate their engineering design processes, and/or complete a related research project (Nugent et al., 2012).

Current educational robotics programs, including *FIRST*, disproportionately serve white male students who do not have a disability (Ludi, 2012; Melchior et al., 2005, 2009). However, in an effort to ensure students from underrepresented groups have the same opportunity to learn about careers and build STEM skills, educational robotics activities can be an ideal method to engage minority youth, youth in rural areas, and girls in STEM. Rusk, Resnick, Berg, and Pezalla-Granlund (2007) and Ludi (2012) provided recommendations for program designers to increase inclusiveness. Strategies for engaging diverse learners included focusing on themes, not only challenges, combining art and engineering, encouraging storytelling, and organizing exhibitions rather than competitions. In addition to specific methods for engaging diverse youth, Ludi (2012) suggested educational best practices for all youth also benefit girls, minorities, and rural youth. Techniques include assigning and rotating roles, facilitating teamwork, adjusting the pace of activities to match student's abilities, and recognizing each member's specific

contributions to the group. Students who have disabilities may require adaptions to the educational materials, modifications to the robots themselves, or partnering with a student who does not have a disability (Ludi, 2012).

Evaluating educational robotics programs.

Educational researchers are working to document the impact of robotics programs on participants' knowledge and attitudes in the STEM fields. Stubbs, Casper, & Yanco (2012) provided a guide for coordinators to evaluate their programs, and suggested program planners follow recommended evaluation and measurement methods in designing evaluations, as well as consider a program's duration, size and maturity. Programs should have two types of evaluation: success of the program's design and effectiveness of the program. Stubbs, et al. (2012) reviewed evaluation methods used by robotics programs to measure effectiveness, and found that pre- and post-tests and comparison groups were common. Programs used questionnaires, interviews, and observations to make their measurements. Challenges in evaluation included gathering a large enough sample size, using instruments that are valid and reliable, analyzing data, and being able to compare multiple target audiences. Stubbs, et al. (2012) recommend that program evaluators choose assessment methods appropriate for the program's stage of development. As programs grow, they should focus more on the evaluation of program outcomes, and documenting replication as more sites are added. Short duration programs might be stuck with short, post-program evaluations, while longer ones should have pre- and post-program questionnaires. As programs move beyond anecdotal support for their efforts, Stubbs, et al. (2012) recommend that coordinators strive for overall community support of program evaluation and work toward connecting short-term data to

longitudinal results.

In the Nugent, et al. (2012) summary of studies on robotics competitions, the researchers reported participation successfully increases youth interest in STEM and improves workplace and life skills. In their evaluation of the *FIRST* Robotics Competition (FRC), Melchior et al. (2005) found that participants were a diverse group and were successful high school students. The program provided challenging experiences for youth and facilitated positive relationships, with 76% reporting they served in a leadership role on their FRC team. Impacts of participation included an increased understanding of the value of teamwork, the role of STEM in everyday life, interest in STEM and in STEM careers, self-confidence, motivation to do well in school, and serving others. In the study, 46% of youth reported participation in *FIRST* as much more influential than other high school programs. FRC participants were twice as likely to major in a science or engineering field, expect to enter a STEM career, and perform some type of volunteer service as the average college student.

With the younger *FIRST* LEGO League (FLL) participants, Melchior's (2009) team added coach and parent surveys to their evaluation design. The 2009 study was a repeat of a similar 2003 evaluation of the FLL program. Participants reported increased interest in science and technology, better understanding of the role of STEM in everyday life and solving everyday problems, increased interest in school, improved life and workplace skills, and a more positive outlook on self and future. In addition, more than 90% of participants had made important decisions, had important responsibilities, felt they belonged and were part of the team, got attention from adults, felt safe, and had fun. More than 90% also reported gains in ability to work with others, find information,

manage time, use trial and error to solve problems, and make presentations. Coach and parent results supported the participant's self-reports.

In addition, differences among boys and girls were reported in the 2009 FLL evaluation (Melchior et al., 2009). Boys were more likely to be involved with the robot and girls were more likely to be involved with project and team support activities. Girls were more likely to report gains in social skills and communication skills, where boys were more likely to report gains in STEM skills. While the consistency between the 2003 and 2009 studies demonstrates the ability of FLL to grow the program while retaining positive impacts on participants, the program would benefit from more detailed evaluation of the gender differences.

When evaluating the impact of participation in educational robotics, few studies have used the same instrument across different types of programs. Most studies also only document impacts on attitudes rather than content learning and only use self-report surveys of parents, participants, team leaders, and/or coaches (Nugent et al., 2012). Nugent, et al. (2012) reported increases in content learning, attitudes toward specific tasks, self-efficacy, workplace skills, and career interests for youth participating in robotics and geospatial technology summer camps and a robotics competition. Through a pre-post questionnaire design, the study showed significant increase in learning for both camp and competition participants. Significant increases in attitudes were found for youth attending camps, but the increase for youth in the competition was not significant. Youth in competitions had a greater interest in engineering, mathematics, and computer careers than the youth in camps. Nugent, et al. (2012) found some results surprising. For example, in competitions, girls reported lower teamwork attitudes than boys, revealing an

area needing further research.

Other programs have also documented content knowledge learning through quantitative assessments such as the Air Force Research Laboratory La Luz Academy (Cole, 2012). Pre- and post-assessments of attitudes toward STEM content and careers were also used by the iCODE project, a web-based multi-platform curriculum for afterschool robotics (Martin, Scribner-MacLean, Christy, & Rudniki, 2012).

Leadership Theory

Leadership scholars have experienced a progression over time from believing leadership to be a purely innate, natural ability to focusing on the leader's traits and behaviors and leaders' effects on a group (Chemers, 1995). Scholars soon recognized the importance of context and followers and began investigating the mechanics of how leadership occurs, leaders' effects on individual followers, and approaching leadership as a group function.

Early leadership theories were "great man" theories. Scholars believed that great men were born rather than made and the traits that created great leaders were inherited (Kirkpatrick & Locke, 1991). Soon, attention moved to determining the characteristics of successful leaders. When Judge, Bono, Ilies, and Gerhardt (2002) conducted a meta-analysis of trait theories, they found little consistency; without a common taxonomic structure for leadership traits, many different results had been found for the most important traits for leaders. Using the Five Factor Model of Personality to group leadership trait research results, Judge, et al. (2002) found that leadership is positively related to extraversion, openness, and conscientiousness, and negatively related to neuroticism.

Stogdill (1948) was an early critic of leadership trait theory. Instead, he proposed that while leader and follower traits remain relatively constant, leader behaviors must be relevant to the specific interactions occurring in ever-changing situations. In response to Stogdill and others, Fielder (1971) proposed a contingency model of leadership effectiveness. In the contingency model, if the same leadership style is applied to different situations, it will be more effective in some groups than in others. In a meta-analysis, Peters, Hartke, and Pohlmann (1985) found mixed support for Fiedler's Contingency Theory, suggesting that it is incomplete to explain the situational factors effecting leadership.

In the late 1970's, leadership scholars were looking for additional factors that would explain the influence of leadership on group performance. House (1977), building on Weber's (1947) article, attempted to explain some of the mystery behind leaders' influences with charisma. Charismatic leaders have high self-confidence and a strong conviction about the moral righteousness of their beliefs (House, 1977). They articulate ideological goals and high expectations to motivate their followers. Charismatic leadership was initially described as a leadership style, but House, Spangler, and Woycke (1991) later defined it as a relationship between leaders and followers. About the same time as House's research on charismatic leadership, Greenleaf (1977) described servant leadership, based on the idea that great leaders must be servants first. A servant leader's primary motivation is to serve people and enhance organizations (Spears, 1995) whereas other types of leaders may have less altruistic motivations.

Burns (1978) expanded the original idea of charismatic leadership by describing transactional and transforming leadership. Transactional leadership is the exchange of

valued things without a higher purpose. In transformational leadership, both leaders and followers work toward the same moral goal together. Transformational leadership consists of four characteristics according to Bass and Riggio (2006): idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration.

Full Range Leadership theory was the answer to the building frustration with leadership research in the late 1970's (Hunt, 1999). Full Range Leadership places transformational and transactional leadership, along with a laissez-faire style, or the avoidance of leadership, on a sliding scale of effectiveness. Laissez-faire is least effective, followed by management-by-exception, then contingent reward, with transformational leadership as the most effective leadership style (Bass & Riggio, 2006).

Since the proposition of Full Range Leadership in 1978, most leadership research has centered on mechanics and application to determine how leadership works. Leader-member exchange theory (LMX) (Dienesch & Liden, 1986) investigated relationships between individual leader-follower dyads rather than homogenous groups and found that high LMX relationships contribute to increased organizational citizenship behaviors in followers (Ilies, Nahrgang, & Morgeson, 2007). Scholars also attempted to understand why people follow leaders by describing sources of power like French and Raven's power bases (expert, referent, legitimate, reward, and coercive powers) and influence tactics (rational persuasion, inspirational appeals, consultation, ingratiation, personal appeals, exchange, coalition, pressure, and legitimizing tactics) (Hughes, Ginnett, & Curphy, 1993). Some researchers turned their attention to followers directly, proposing that there are styles of effective followership (Kelley, 1988) and recommending that

leaders match their behavior with followers' preferred influence tactics (Barbuto, Fritz, & Marx, 2000).

Recent leadership research has recognized a characteristic not explicitly stated previously: leaders should be true to themselves. Authentic leaders have the role of leader central to their self-concepts, high self-resolution, self-concordant goals, and self-expressive behavior (Shamir & Eliam, 2005). Studies have found that authentic leadership has positive results distinct from other leadership styles (Walumbwa, Avolio, Gardner, Wernsing, & Peterson, 2008; Walumbwa, Wang, Wang, Schaubroeck, & Avolio, 2010).

Another perspective in recent leadership theory is viewing leadership as a group process. Drath, et al. (2008) define leadership as a process creating direction, alignment, and commitment within a group. Specifically, direction is considered to be setting of goals and objectives. Alignment is any organizational structure or process that gets the group working together toward the appropriate outcomes. The individuals' dedication to the group is their commitment. Under the Drath, et al. (2008) framework, a leader can be anyone at any level who contributes to the group's direction, alignment and commitment. The Center for Creative Leadership (CCL), an international leadership development organization, uses the direction, alignment, commitment definition in their work (Van Velsor et al., 2010).

Throughout the history of studying leadership, researchers have tended to focus on either big "L" leaders that have formal positions (CEO's, politicians, etc.) or little "l" "everyday" leaders who contribute functions of leadership from many different roles within a group (Gardner & Csikszentmihalyi, 2011; Sternberg, 2011). As the focus of

leadership research transitions to identifying predictors of leadership and leadership development, both types of leaders continue to be of interest to scholars.

Leadership development.

After deciding what should be considered "leadership," some scholars have turned their attention to understanding leadership development. The CCL separates "leader" development from "leadership" development, defining leader development as focusing on the individual where leadership development enhances group capacity to create direction, alignment and commitment. Specifically, "leader development" is considered to be the "expansion of a person's capacity to be effective in leadership roles and processes" (Van Velsor et al., 2010, p. 2). Some authors distinguish between "leadership development" as any developmental activity, "leadership education" as the learning activities and educational environments intended to develop leadership, and "leadership training" as learning the leadership skills needed for a specific job or role (Brungardt, 1997).

Globally, leadership development is vital to the success of companies and organizations. According to Avolio and Vogelgesang (2011), as birthrates are falling in industrialized countries, more people are retiring, and the smaller Generation X (born from the early 1960's to the early 1980's) and Millennial Generation (born in the early 1980's to the early 2000's) will soon not have enough people to fill the same number of jobs that previously employed the Baby Boomers (born about 1946 to 1964). Some companies, like Boeing, are preparing for the retirement of the majority of their senior and middle level leadership. In addition, business models have transitioned away from a traditional hierarchy, creating the need for leaders at all levels of organizations (Avolio &

Vogelgesang, 2011). Because of such demand for leaders, Avolio and Vogelsgang argue that the need is too great for organizations to train their own leaders. Instead, they say, "we must facilitate the next generation of leaders to take responsibility for their own development at earlier stages in their life stream and for institutions such as family, elementary, middle, and high schools, and universities to also aid in the honing of leadership potential" (Avolio & Vogelgesang, 2011).

Researchers have attempted many different angles to explain who becomes a leader. After reviewing early "great man" leadership studies and recent investigations into genetic influence on leadership, Arvey and Chaturvedi (2011) determined that genetics are a factor on emergent leadership and leadership styles. Genetic factors explained 30% of the variance of Arvey and Chaturvedi's measure of emergent leadership. Genetic factors explained 50% of the variance of the measure of transformational leadership. Even with genetics as a basis, Arvey and Chaturvedi suggest that any genetic influences might be dormant until there is a specific environmental factor that causes a person to demonstrate those leadership behaviors.

Gender is a well-researched genetic factor in leadership. Since the mid 1980's, the metaphor of the "glass ceiling" has been used to describe the barriers that women face when advancing to leadership positions in the workplace (Hoyt & Johnson, 2011). Although women have increased their representation in positions of leadership since that time, women still head only 4.2% of Fortune 500 companies (Catalyst, 2013) and hold just over 18% of U.S. Congressional seats (Center for American Women and Politics, 2013). The "glass ceiling" is no longer a fixed, rigid barrier, however, as women are making their way to top leadership positions. Instead, women must overcome unequal

access to lower-level management positions and numerous smaller obstacles to leadership (Eagly & Carli, 2007). Women's winding path to leadership was described by Eagly and Carli (2007) as a labyrinth, where women must work harder than men to achieve leadership positions.

Many of the challenges faced by women in leadership may relate to gender stereotypes and the ways boys and girls are socialized to hold different roles in society. Hoyt and Johnson (2011) described the direct barriers for women in leadership as self-perception (self-efficacy and self-esteem) and societal factors like stereotypes, prejudice, and discrimination. Perceived incongruity between leadership and female gender roles leads to women being seen as less favorable candidates for leadership roles as well as being seen more negatively than men when demonstrating similar leadership behaviors (Eagly & Karau, 2002). Women also face indirect barriers through sex segregation in the workplace: jobs traditionally held by women are primarily lower-status positions like nurses, secretaries, and pre-school teachers (Hoyt & Johnson, 2011). Further, since women have been found to do more housework than men on average, women find themselves having greater difficulty than men finding a balance between work and home life.

Hoyt and Johnson (2011) recommended leadership development aimed at improving the gender balance of leadership positions should begin by increasing girls' leadership self-confidence at early ages. Women and girls can also benefit from having positive mentors. Women should use their skills in effective transformational leadership to meet the societal standards of being both "leader" and "female" while society works to

change the impression that leadership is a masculine characteristic (Eagly, Johannesen-Schmidt, & van Engen, 2003; Hoyt & Johnson, 2011).

In addition to the genetic factors, other influences on leadership may remain relatively constant over time. However, personality traits do not necessarily lead to transformational leadership (Bono & Judge, 2004). When Avolio and Vogelgesang (2011) reviewed both the predetermined and environmental factors in leadership development, they concluded that leaders are both born and made since neither genetics nor personality can fully explain a person's likelihood to become a leader.

Avolio and Vogelsgang (2011) provides an overview of the evidence that leadership can be developed through learning and experiences. First, leadership development depends on a person's readiness for the experiences that will help them learn leadership skills. Leadership can also be developed through a person's interest and ability to learn from new situations, motivation to lead, learning goal orientation, increasing leadership self-efficacy, and cognitive ability. Avolio and Vogelsgang also describe agentic leader efficacy, which approaches leader efficacy as being composed of a leader's personal agency, belief they can succeed at leadership, and confidence in the means available for their leadership tasks. Other leader investigations into the origins of adult leadership have found that life experience (Avolio, 1994), emotional intelligence (Barbuto & Burbach, 2006), and leaders' motivational sources (Barbuto et al., 2000) are antecedents of leadership.

Avolio and Vogelsgang (2011) present leadership development as a lifelong process that relies on creating a positive leader self-concept by continuously learning and improving on leadership attainment and effectiveness. Across the lifespan, leaders may

have moments that trigger leadership development, events that stimulate growth, and catastrophic, distressing crises that force a person to learn and grow. The learning caused by experiencing and reflecting on these moments helps a person develop their leader identity and improve their leadership abilities.

Lord, Hall, and Halpin (2011) are among the scholars attempting to develop a comprehensive model of leadership development that encompasses leaders' early experiences. Their model focuses on a person's development of an identity as a leader. Personal identities include individual characteristics, group categories, and evaluations of a person's self-worth, roles, images, emotions, and body. The concept of identities provides a structure that links past leadership development experiences to present situations and can help explain leader behaviors, thoughts, emotions, and leadership skill development. Lord, Hall and Halpin's (2011) model of leadership development incorporates a twisting "chicken-and-egg" pattern of causal ordering: a person needs to have "leader" as part of their identity to seek out leadership experiences, yet one's identity as a leader develops as a result of those experiences. The model also predicts that two people may experience a divergence in their leadership identities even when beginning with similar abilities and motivations due to outside influences such as others' reactions to their leadership attempts. Others' biases against women and minorities in leadership roles can have lifelong effects as negative leadership experiences become incorporated in their leadership identities.

Implications of Lord, Hall, and Halpin's (2011) model include the need to begin early with leadership identity development and the need to focus on leader identity within leadership development programs for all ages. Further, their model suggests a need for

greater attention to variable rates of development in leadership skills. The divergence part of the model suggests that instead of only focusing leadership development programs on those who have self-identified as leaders, everyone may benefit from leadership skill improvement. Leaders may take different paths and different amounts of time to arrive at their identities as strong, positive leaders.

College student leadership development has received significant attention from researchers since there are many programs aimed at leadership development among college students (Komives, 2011). Komives (2011) groups the existing models focusing on college students as social change models of leadership development or relational leadership models. Like Lord, Hall, and Halpin (2011), Komives takes a leadership identity development perspective and proposes a six-stage grounded theory of college student leadership identity development. The stages are (1) awareness, (2) exploration and engagement, (3) leader identified, (4) leadership differentiated, (5) generativity, and (6) integration and synthesis. The students progressed from being able to identify people they viewed as leaders to joining and participating in groups with peer leadership structures to being able to identify themselves as leaders or followers in groups. By the fourth stage, college students became aware that leaders could exist without specific titles or positions. Finally, students were part of mentoring or creating leaders, and leadership eventually became an integrated part of their identities.

While researchers often provide implications of their findings and recommendations for implementation, the leader development models do not always state what factors influence a person to learn from and incorporate an experience into their leadership identity. The CCL recommends a two-part leader development model that

incorporates both development experiences and a development process (Van Velsor et al., 2010). Developmental experiences should have elements of assessment to determine needs, challenge to encourage a leader to learn, and support to reflect on and learn from the experience. Within a specific leadership context, the development process should consider a leader's ability to learn, incorporate a variety of developmental experiences, and intentional design of the experiences.

Recognizing the need for a common framework for leader development, Campbell, et al. (2003) viewed leadership development as acquiring specific personal characteristics and skills that help a person influence others. Specifically, they identified intra-personal attributes, interpersonal qualities, cognitive abilities, communication skills and task-specific skills as areas to improve through leadership development activities.

Youth as leaders.

When children choose a game on an elementary school playground, leadership plays a role in the many decisions to be made. They must determine who decides what will be played, who will play what role, and how toys are shared among a group. Each child follows others or chooses a strategy to convince the others that his or her ideas are best. These interactions illustrate that children demonstrate leadership behaviors such as communication, charisma, influence, persuasion, status, and emotional intelligence (Murphy, 2011). Clearly, leadership is not confined to adults in the workplace. There is an increasing volume of research investigating leadership behaviors among youth and approaching childhood factors as more than predecessor influences to create successful adult leaders. A need for more research still exists, however, as several authors have commented about the lack of studies on youth leadership and youth leadership

development (Avolio & Vogelgesang, 2011; A. E. Gottfried et al., 2011; A. W. Gottfried & Gottfried, 2011).

Research into youth leadership has tended to focus on one particular factor for leadership. A. W. Gottfried and Gottfried's (2011) research chose academic intrinsic motivation for their study, as they believed it requires conceptually similar behaviors to leadership, such as orientations toward mastery, curiosity, persistence, engagement, and initiative. They found that the motivationally gifted youth held more leadership roles than intellectually gifted youth. In a separately published part of their study, A. E. Gottfried, et al. (2011) used longitudinal data to connect academic intrinsic motivation to motivation to lead in adulthood. Results showed a connection from childhood to adolescent motivation; adolescent motivation predicted adult motivation to lead along the theoretical constructs that were conceptually similar.

When Murphy (2011) proposed the youth leadership model introduced earlier in this paper (see page 10), the goal was to provide a theoretical framework for youth leadership and youth leadership development that incorporated research on adult leadership and child development. In the model, gender, personality traits, communication skills, and emotional and social intelligence are precursors to youth leadership. Developmental factors include parenting style (authoritarian / authoritative / laissez faire / neglectful and attachment focus) and learning experiences (role models, formal experiences, and informal experiences). Self-management behaviors like mental models of leadership, self-efficacy, optimism, coping style, and motivation to lead also contribute to leader behavior. The development factors and self-management factors promote leader behaviors that might be described as task and relationship behaviors and

transformational, situational, or charismatic leadership. In Murphy's model, outcomes of youth leader behaviors could be informal influence, peer acceptance, project completion, increased number of leadership positions, and effectiveness as a team leader.

Murphy's (2011) model is situated in the context of youth leadership. The types of behaviors and leadership tasks that are appropriate for youth leaders should align with developmental stages. For the purposes of Murphy's framework, the stages are defined as early childhood (about age 2-6), late childhood (ages 6-11), early adolescence (ages 12-14), late adolescence (ages 15-19), and early adulthood (19-22). Murphy provided a list of possible tasks and leadership skills appropriate for each developmental stage. Murphy also presented possible developmental experiences for each developmental stage. Murphy and Johnson (2011) issue a call for exploring the lifespan approach to leadership development described in the model through additional research into youth leadership and longitudinal influences of leader development experiences.

Youth leadership development.

In addition to identifying youth leadership behaviors and predictors of future leadership, many researchers are interested in youth leadership development. There is evidence leadership development programs may have more impact on people under age 22 than those over the age of 45 (Avolio & Vogelgesang, 2011). As described by Avolio and Vogelgesang (2011), some leadership development programs attempt to improve youth leadership so youth can use their skills in their future roles as adult leaders. Other programs intend for youth to put their improved leadership skills to work right away, as leaders among other youth or leaders in groups of mixed ages. However, program coordinators intending to develop leadership have often known what methods they use to

develop leadership, but do not have a clear idea of how leadership development actually works (Brungardt, 1997).

After conducting a meta-analysis of youth leadership development research, Ricketts and Rudd (2002) proposed a comprehensive model for youth leadership education. The framework consists of five dimensions and three stages of development, and is intended to serve both as a conceptual model and as a curriculum development guide. The five dimensions are (1) leadership knowledge and information, (2) leadership attitude, will, desire, (3) decision making, reasoning, and critical thinking, (4) oral and written communication skills, and intra and interpersonal relations. The stages of awareness, interaction, and integration describe how youth should proceed through each of the five dimensions.

Many youth programs aim to develop leadership as a part of a larger set of goals, such as general positive youth development, life skills development, or community development and social change. For example, K. Anderson and Karr-Lilienthal (2011), interested in general life skills development, asked youth whether they were better leaders and had learned greater responsibility as a result of their involvement with a 4-H horse project. Christens and Dolan (2010) approached youth leadership development through youth involvement in community organizing, and proposed that the community organizing structure might be more effective at developing youth leadership than programs only focusing on leadership.

In addition to physical fitness, leadership development can be included as an intended outcome of youth sports programs. Chelladurai (2011) argued that the pursuit of excellence in sports supports leadership development. Chelladurai listed visioning,

intellectualizing, cultivating self-efficacy, focusing on winning, being self-interested, being competitive, being task and ego oriented, cultivating and enjoying the flow experience as behaviors associated with competitive sports and leadership development. Chelladurai called for additional research to document whether learning skills related to leadership in sports is transferrable to other contexts.

Youth leadership programs apply various educational techniques within their activities. In each dimension of Ricketts and Rudd's (2002) model, the authors recommended applying levels of educational objectives and principles of experiential education to leadership training activities developed using the model. Brungardt (1997) found common techniques in adolescent leadership development training were simulations, role-playing, lectures, and group discussion.

Measuring youth leadership development.

Various researchers developed methods to measure youth leadership development and documented the impact of participating in youth leadership programs. Leadership development outcomes of agriculture-themed programs were commonly studied. Connors, Swan, Poly, and Luis (2006) found 65 studies between 1988 and 2003 about leadership development in agricultural education. Instruments used to measure youth leadership development included researcher-developed or modified instruments (J. Anderson & Kim, 2009), Roets Rating Scale for Leadership (Chan, 2000), and the Youth Leadership Life Skills Development Scale (YLLSDS) (Seevers, Dormody, & Clason, 1995; Seevers, 1994; Wingenbach & Kahler, 1997). Min and Bin (2010) also listed the Student Leadership Inventory, Leadership Skills Inventory, Multifactor Leadership Questionnaire, and qualitative techniques as methods to assess youth leadership

development.

J. Anderson and Kim (2009) used a modified version of a questionnaire from the National FFA Organization to evaluate leadership development within urban Chicago participants. Findings included perceived importance of leadership across community, family, friends, future career, organizations, and school and participant ratings of interactivity, organization, fun, real-world applications and group work as important qualities of youth leadership experiences. Using van Linden and Fertman's (1998) three stages of youth leadership development, youth in J. Anderson and Kim's (2009) study showed progression from awareness to interaction, but were not yet to mastery.

In a study of college students, Shertzer, et al. (2005) used four items as measures of attitudes about the importance of leadership: (1) Leadership is important to me, (2) I consider myself to be a leader, (3) Leadership will be an important part of my life after college, and (4) Leaders need to be able to work in teams/groups. Each of the four items was a dependent variable. Demographic information and attitudes toward types of leadership and involvement in leadership were also collected. In the analysis, leadership importance questions were shown to be internally consistent and reliable. A factor analysis determined Leadership Importance was independent from the other factors in the study with no covariance. While other relationships among variables were found, gender was not a predictor, nor was being in the College of Engineering.

Zula, Yarrish, and Christensen (2010) also focused on college student leadership development. They used the Campbell, et al. (2003) areas of leadership development as the foundation for creating an instrument for measuring leadership development. Zula, Yarrish, and Christensen's (2010) questionnaire contains 18 items across four factors.

The items combine inter-personal and intra-personal skills into one, with task-specific skills, cognitive skills, and communication skills as the other three scales. Participants rated the items on a scale of 5 (Moderately Strong), 4 (No Opinion), 3 (Not Applicable), 2 (Moderately Weak), and 1 (Very Weak). The overall instrument had a Cronbach's alpha of .84.

The YLLSDS is a 30-item, one-dimensional scale that asks youth to self-report their gain as a result of participation in a youth program. When Seevers, et al. (1995) were developing the YLLSDS scale, they started with 68 items in multiple dimensions. When items were eliminated down to 30, analysis showed that youth reports of leadership development using the scale were actually in just one dimension. The researchers also reported procedures undertaken to ensure the scale is valid. Comparing to other variables, participation in 4-H leadership activities, achievement, ethnicity, and gender explained significant amounts of variance in the YLLSDS scores (Seevers, 1994). In the study, the complexity of youth leadership and life skills development as a construct was demonstrated, since only 20% of variance in scores was explained by measured variables. The YLLSDS was shown to be highly reliable (Seevers et al., 1995; Seevers, 1994; Wingenbach & Kahler, 1997).

In the YLLSDS, retrospective assessment has been found to give a more accurate assessment of leadership skills than traditional pre-post evaluation structures (Rohs, 1999). In Rohs' (1999) study, participants reported no impact on the YLLSDS when assessed with the pre-post model, but significant results with the then-post model. It appears that when assessing leadership skills, participants' pre-program ratings may be overestimated. By the end of an experience, participants have a changed perspective on

their leadership skills before the program, leading to differences between pre-participation and retrospective ratings. This phenomenon, known as "response shift bias," has been documented as a source of contamination of self-report measures, resulting in inaccurate pre-test ratings. An alternative method is to ask participants first to give themselves ratings after a program, and then ask them to provide ratings of their skills before the program. Rohs (1999) recommends using the then-post model to get a less conservative and more accurate picture of the impacts of leadership development programs.

Integrating the STEM Fields, Youth, and Leadership Development

Is scientific leadership different?

Since studies have shown that context is an important factor in leadership, researchers are interested in focusing on leadership within the STEM fields. Crumpton-Young, et al. (2010) define engineering leadership as "the ability to lead a group of engineers and technical personnel responsible for creating, designing, developing, implementing, and evaluating products, systems, or services" (p. 10). The National Academy of Engineering (2004, as cited in Crumpton-Young et al., 2010) sees the need for leadership within engineering as well as the need to have engineers in leadership positions "from which they can serve as positive influences in the making of public policy and in the administration of government and industry" (p. 18). Farr and Brazil (2009) commented engineering leadership was more complicated than other career fields because of the technological aspects and unusually quick pace of change. In Crumpton-Young, et al. (2010), professionals in the engineering fields rated the most important leadership and useful capabilities are demonstrating honesty and integrity, inspiring

people with a compelling vision of the future, understanding current and future customer needs, teambuilding, teamwork, personal development, continual learning, and communication.

Robledo, Peterson, and Mumford (2012) argue applying traditional leadership theories such as motivational and transformational leadership to the STEM fields may be ineffective. Scientists and engineers may be differently motivated than people in other fields. Further, when a transformational leader communicates a vision, it may inhibit autonomy and creativity, preventing innovative results of research and development efforts. Instead, Robledo, Peterson, and Mumford (2012) propose a new model of scientific leadership. Like all leadership theories, context is relevant to the model. Leading scientists and engineers requires special consideration of their typical personality traits. Scientists are likely to be open, conscientious, autonomous, ambitious, achievement oriented, and self-confident or perceived as arrogant (Feist, 1999); they may be likely to prefer working independently rather than in teams. The scientific leadership model is based on the stages for successful creative projects, from scanning or exploring, elaboration, development, assessment, and implementation. The model is divided into leading the group, the work and the organization, and provides suggestions for leader's actions at each stage. This scientific leadership model requires verification by research, but may provide a more effective framework for leadership in the STEM fields.

Leadership development in the STEM fields.

An awareness of the need to develop leadership skills among engineers has existed since at least the publishing of a report from the American Society of Engineering Education in 1994 (Dowell, Baum, & McTague, 1994; Farr & Brazil, 2009). The most

Table 2
Top Skills for Future Leaders in Engineering

• Knowing where to fit within the organization	• Dealing with different people and personalities
• Mentoring	• Team dynamics
• People skills	• Ethics
• Negotiation skills	• Project management
• Understanding team limits	• Cross-functional projects
• Time management	• Globalization
• Communication skills	• Planning
• Resource leverage	• Facilitation and communication skills
• Being open minded	• Strengths discovery
• The ability to develop a vision	• Conflict resolution
• Being a good listener	• Cross-cultural communication
	• Learning from mistakes.

Note. A summary of results from Farr and Brazil (2009)

important things for future leaders in engineering to learn, according to Farr and Brazil's (2009) study, are listed in Table 2.

Crumpton-Young, et al. (2010) suggested developing "a holistic engineering leadership program that entails the aforementioned skills such as the ability to control a group's critical thinking, how to be a visionary, inspirational, influential, adaptable, open-minded, people-centered, action-oriented, equitable, interpersonal, likable, determined, confident, good communicator, credible, honorable, fair, and a networker" (p. 18).

A few programs are in place or have been proposed to address the need for increased leadership skills among engineers (Farr & Brazil, 2009; Kirschenman & Fasano, 2012; Schuhmann, 2010). Penn State's Engineering Leadership Development Minor provides a formal structure for students to develop leadership (Schuhmann, 2010). The priority themes addressed through the program are global awareness and appreciation for diversity, self-knowledge, character, and ethics, communication skills, both oral and written, creativity, innovation, and a focus on results, and project planning

theory, practice, and teamwork (Schuhmann, 2010). Farr and Brazil (2009) borrow from leadership theory research to recommend applying the Center for Creative Leadership's techniques to leadership development programs for engineers. Farr and Brazil (2009), Kirschenman and Fasano (2012), and Schuhmann (2010) each discuss curricular approaches to engineering leadership development, but did not present any results experienced by engineering students as a result of participating in leadership development programs.

Robotics as a tool for youth leadership development.

The research shows there is a clear need for leadership within the STEM fields. The research also shows that educational robotics can be a tool to engage interest in STEM, increase interest in STEM careers, and enhance STEM skills among youth. However, only one author, Nelson (2012), mentions developing youth leadership in the context of an educational robotics program. Nelson lists leadership among the skills developed in educational robotics programs that are transferrable to the STEM workplace. Nelson's article gives examples in various curricula, including working in teams, practicing leadership when leaders assign specific youth to lead groups, demonstrating to others how a youth solved a problem, youth teaching others about one's area of expertise, and generally being encouraged to think about the "big picture" of a project.

The current study.

As Nelson (2012) was the only author found to specifically address youth leadership development within an educational robotics program, this is an important topic for further research. With the goal of furthering the understanding of how educational

robotics programs contribute to the development of the future innovative leaders in the STEM fields, this study assessed leader development among youth participating in an educational robotics competition.

Purpose statement.

The purpose of this survey study is to examine youth leadership development and leader identity development models (Campbell et al., 2003; Komives et al., 2006; Murphy & Johnson, 2011) as applied to Nebraska middle school aged participants in four *FIRST* LEGO League (FLL) educational robotics competitions. Specifically, this study described FLL participants' perceptions of the importance of leadership, their own leader development, and their perceived changes in leader development as a result of FLL participation. Further, the study investigated relationships between FLL participants' characteristics (age, length of participation, gender, and team size) and their ratings of leadership importance, leader development, and change in leader development as a result of participating in FLL.

For the study, leadership is considered to be a process where any individual may influence the group to come together and work toward achieving a common goal (Zula et al., 2010). Leadership importance is defined as youth's ratings of the significance of leadership in their lives as modeled in the Shertzer, et al. (2005) study. Leader development has four factors identified as contributing to the development of leadership including interpersonal/intrapersonal skills, task-specific skills, cognitive skills, and communication skills (Zula et al., 2010). The measure of change consists of youth perceptions of their change in the leader development factors because of their participation in the *FIRST* LEGO League competition.

Research questions.

The first group of research questions relates to youth perceptions of the importance of leadership in their lives.

- Question 1a: To what extent is leadership important to Nebraska FLL participants?
- Question 1b: To what extent do demographic characteristics of FLL participants (age, years of participation, gender, team size) predict their ratings of leadership importance?

The next set of questions will describe youth perceptions of their own development as leaders.

- Question 2a: At what level do Nebraska FLL participants rate their own leader development?
- Question 2b: To what extent do demographic characteristics of FLL participants (age, years of participation, gender, team size) predict their ratings of leader development?

Last, the study will investigate the impact of participation in FLL:

- Question 3a: To what extent do youth report a change in their leadership development due to their participation in FLL?
- Question 3b: To what extent do demographic characteristics of FLL participants (age, years of participation, gender, team size) predict their perceptions of change in leader development due to FLL?
- Question 3c: Are participants' current leader development ratings correlated to their reported change in leader development?

Chapter 3

Methods

This study surveyed participants in four Nebraska *FIRST* LEGO League qualifying tournaments in order to contribute to the understanding of youth leadership development in the context of educational robotics competitions. Information gathered through survey research may be generalized from the study's participants to a larger group with similar characteristics (Babbie, 1990 as cited in Creswell, 2009). For this study, a survey research design was chosen so that results might apply to all FLL participants internationally. In addition to generalizability, a survey design was chosen in order to collect quantitative data about a large number of participants in a short period of time. Survey design was also cost effective and efficient to administer, as the leadership items were added to a questionnaire as part of a larger study. The larger study included questions about attitudes toward the STEM fields and the engineering design process.

The survey was cross-sectional, with data collected at the end of four tournaments in December 2012 and January 2013. The study attempted to measure change over time by asking participants to self-report their learning across leadership development scales as a result of their experiences in FLL. All data was collected through a paper questionnaire. Participants were asked to complete the questionnaires between completing their last event at the competition and the awards ceremony. The questionnaires were printed on paper so that the number of youth completing them simultaneously was not limited.

The study protocol followed University of Nebraska – Lincoln policies governing the use of human subjects for research. The study was approved by the Institutional

Review Board, Approval #: 200510055 EP (See Appendix A).

Participants

FIRST LEGO League is designed for youth, 9 to 14 years old, who compete in teams of two to ten members. A total of 74 teams competed in the tournaments included in the study. Between 14 and 23 teams competed at each event. All teams at the following four events were asked to participate in the survey research:

- December 8, 2012, University of Nebraska – Lincoln East Campus Union, Lincoln, NE
- December 15, 2012, Lewis and Clark Middle School, Bellevue, NE
- January 12, 2013, Kearney Catholic High School, Kearney, NE
- January 19, 2013, HTRS High School, Humboldt, NE

Teams were asked to provide numbers of youth participants in their event registration. Participants were notified of the option to participate in the research via e-mail messages to the team coaches. Coaches received links to parent consent and youth assent forms, which were signed before arriving at the tournament. Forms were returned upon check in at each event. If forms were not completed before check in, parents were asked to complete extra copies of the form at that time.

Questionnaires were provided to teams in envelopes in team packets. Pens and pencils were available for teams that did not have them available. Teams were asked to return the packet to the registration/information table at each event before the beginning of the awards ceremony. An event staff member reminded each team to complete their questionnaires in the early afternoon and delivered pencils to teams as needed. As an incentive, each youth who completed a survey received a Nebraska *FIRST* LEGO League

button. Each button was numbered and served as an entry for a drawing to receive a free LEGO Mindstorms NXT robotics kit. One kit was given away at the awards ceremony for each tournament.

Instrument Design

The instrument used for this study was a compilation of the four items from Shertzer, et al. (2005) and a modification of the items from the Zula, et al. (2010) Student Perceptions of Leadership Instrument (SPLI). The Shertzer, et al. (2005) items were chosen for their small quantity and direct measurement of the importance of leadership. The items were written at a reading level appropriate for all ages. The leadership importance questions demonstrated internal consistency and independence from other leadership factors in the Shertzer, et al. (2005) study.

The Zula, et al. (2010) instrument was chosen for its recent publication date and connection to research-based factors that contribute to leadership development. The SPLI items required modifications to 12 of the 18 items to be appropriate for youth ages 9 to 14. For example, “I enjoy relating to others on an interpersonal basis” was changed to “I like getting to know people and making new friends.” An example of an unchanged item is “I am good at planning.”

Following the precedent set by the YLLSDS (Seevers et al., 1995; Seevers, 1994), the SPLI items were modified to measure the impact of participation in *FIRST* LEGO League. For example, “I am comfortable giving directions to others” was changed to “Through FLL, I learned to be more comfortable giving directions to others.” Appendix B provides each item as written in the original source, any changes that were made, and the matching item assessing learning.

In order to make the instrument as straight forward as possible to complete, all items were placed on the same Likert scale: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. The entire instrument, including the items from the larger study, is included in Appendix C. The instrument was compiled and analyzed as three scales: importance of leadership, leader development, and self-reported change in leader development.

Variables

The following demographics served as independent variables for the study: age, length of participation in years, gender, and team size. The participants reported each demographic item on the instrument. Each scale on the survey was treated as a dependent variable: importance of leadership, leader development, and perceived change in leader development. In addition, the study treated leader development as an independent variable and assessed correlation with perceived change in leader development as a dependent variable.

Data Analysis

Initial data collection was not anonymous, as participants' names on each form were matched to their parent consent and youth assent forms. After ensuring that the appropriate consent was received for each participant, questionnaires were scanned, facilitating quick compilation of the data. Once scanned, participants' names were not associated with their questionnaire answers.

Since every team who participated in the four FLL tournaments completed instruments, response rates were not analyzed. Next, means, standard deviations, and ranges of scores were calculated and reported to describe each variable as well as each

individual item. Each leadership scale was checked for normality and Cronbach's alphas were calculated for each scale.

Research question 1a (To what extent is leadership important to Nebraska FLL participants?), question 2a (At what level do Nebraska FLL participants rate their own leader development?), and question 3a (To what extent do youth report a change in their leadership development due to their participation in FLL?) were descriptive questions and were addressed through calculation of means and standard deviations for the three leadership scales.

Since participants were clustered within teams, a multilevel linear model was created to determine statistical effects of demographics (age, years of participation, gender, and team size) on each of the leadership scales as specified in Question 1b (To what extent do demographic characteristics of FLL participants predict their ratings of leadership importance?), Question 2b (To what extent do demographic characteristics of FLL participants predict their ratings of leader development?), and Question 3b (To what extent do demographic characteristics of FLL participants predict their perceptions of change in leader development due to FLL?). The multilevel model assessed the effects specified in each leadership question both between teams and within teams. The multilevel hierarchical linear model provided information about the effect size for each demographic variable on the leadership scales between teams and within teams and allowed the analysis to account for all of the variables simultaneously. Multilevel linear models are recommended whenever participants are organized into groups (Tabachnick & Fidell, 2013). Multilevel linear models can accommodate violation of the assumption of independence in errors that occurs when shared group experiences, such as being on

the same team, may affect responses.

A two-level hierarchical model assessed the effects of gender, ethnicity, age, experience, and team size for each of the outcome variables. The individual youth effects were designated as level 1 in the model and the between team effects were considered level 2 in the model. In the hypothesized model, individuals and teams are declared random effects to assess variability among individual youth as well as variability between teams. The multilevel modeling was implemented through SAS mixed procedures, version 9.2.

A correlation coefficient was calculated to determine the relationship specified in Question 3c (Are participants' current leader development ratings correlated to their reported change in leader development?). Finally, implications and conclusions from the relationships found are reported.

Chapter 4

Results

After collecting surveys at four FLL tournaments, the surveys were scanned into PDF documents. The data was compiled using optical mark recognition software, which read the scanned PDF documents and created a spreadsheet indicating responses for each item on the instrument. The data was checked for errors in scanning and missing results and text answers were entered into the results spreadsheet. The results were transferred into IBM SPSS Statistics, version 21, for initial analysis.

Demographics

A total of 501 survey instruments were collected from youth on 74 teams, across the four FLL tournaments. Participation at each location is reported in Figure 1. The youth included 340 males (67.9 %), 152 females (30.3%), and 9 who did not report a gender (1.8%). The majority of participants identified as White (85.4%); ethnicities of all

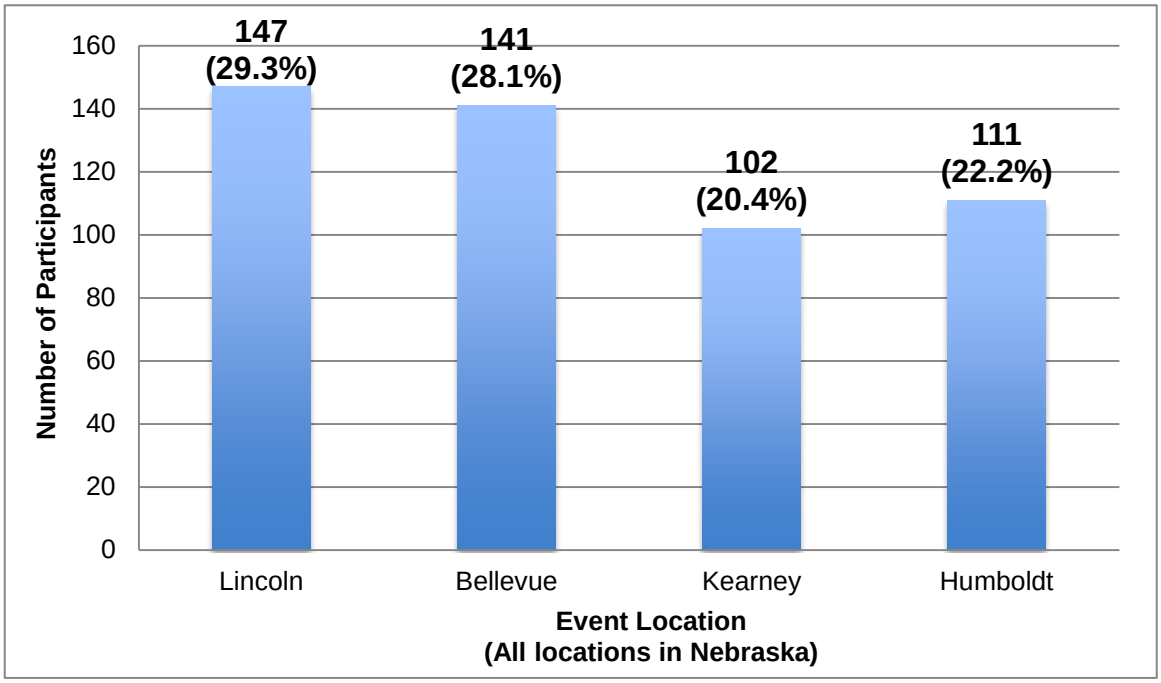

Figure 1: Youth Participants by Tournament

Table 3
Ethnicities of Participants

Ethnicity	Frequency	Percentage
Asian/Pacific Islander	19	3.8
Native American	6	1.2
Hispanic/Latino	16	3.2
Black/African-American (non-Latino)	3	0.6
White (non-Latino)	428	85.4
Multi-Racial	20	4.0
Other	6	1.2
Total Reported	498	99.4
Missing	3	0.6
Overall Total	501	100.0

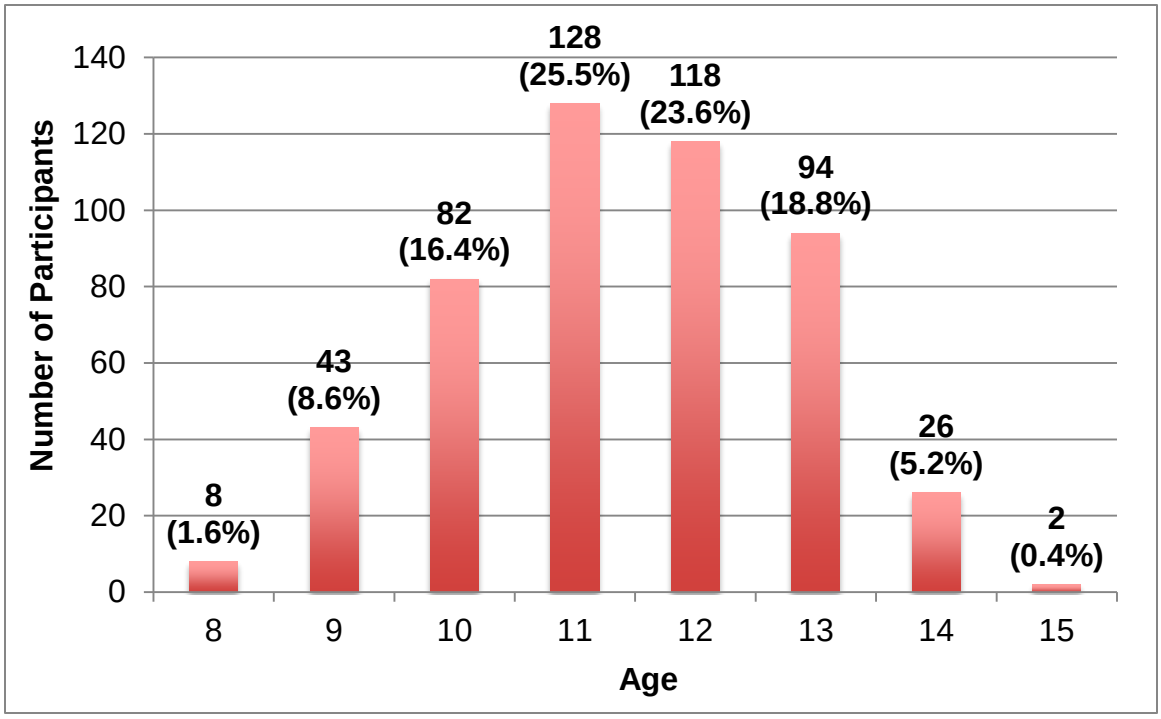

Figure 2: Ages of Participants. All 501 participants reported their age.

participants are reported in Table 3. The FLL participants represented a slightly higher proportion of White (not Hispanic or Latino) youth than the population of the state of Nebraska (81.4%) (U. S. Census Bureau, 2012). The ages of participants ranged from eight to 15, with a mean of 11.4 years old (SD = 1.419), as shown in Figure 2. The age

distribution closely matches a normal distribution. Youth had participated in FLL for one to five years, with a mean of 1.5 years in the program. For the majority of participants, it was their first year participating in FLL (63.1%) and 88.1% had one or two years of FLL experience (See Figure 3). *FIRST* LEGO League teams were relatively large, with a mean of 7.71 members. Despite FLL rules requiring at least two team members, participants reported having a range of one to ten team members.

Attitudes toward Leadership

Each dependent variable was measured on a five point Likert scale. Questions 10, 11, 12, and 13 composed the Importance of Leadership scale. Results were limited to those who replied to at least three of the four questions, providing 496 valid responses.

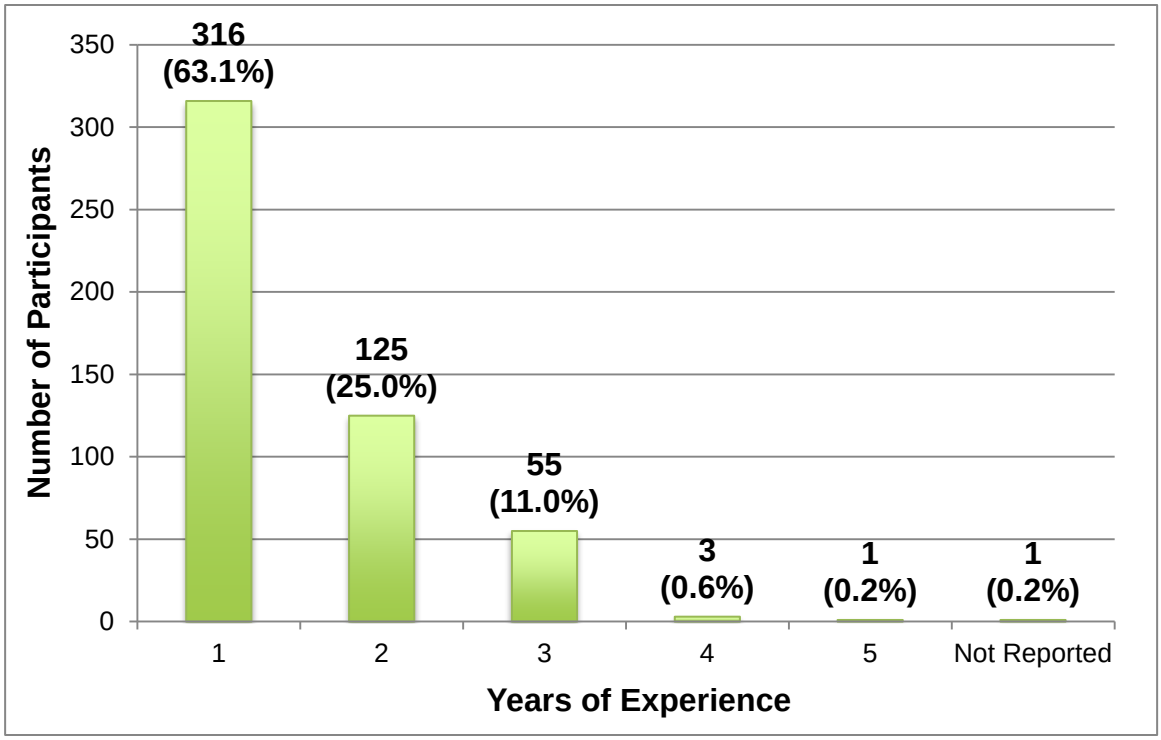

Figure 3: Participant Experience in FLL in Years. Participants were asked to include the current year in their response.

Table 4
Leadership Importance Scale Question Means

Q#	Question	N	M	*SD*
Q10	Leadership is important to me.	496	4.55	0.77
Q11	I consider myself to be a leader.	493	4.08	1.01
Q12	Leadership will be an important part of my life in the future.	495	4.42	0.82
Q13	Leaders need to be able to work in teams and groups.	495	4.76	0.56

Participants rated leadership as very important with a mean rating of 4.45 (*SD* = 0.59). Question means are reported in Table 4.

Questions 14 to 31 asked participants to report their current leadership development. Only participants who answered at least half of the questions were included in the final results, leaving 488 valid responses. Like the importance of leadership, participants rated their leadership development high, with a mean of 4.26 (*SD* = 0.51). Fourteen of the 18 questions received a mean of over four. Questions 17, 19, 25, and 31 had a mean below four. The lower rated questions related to wanting to take charge, desire to be a leader, collecting and interpreting data, and enjoying change.
In questions 32 to 49, youth were asked to rate their improvement in various elements of leadership development due to their participation in FLL. Like the Current Leadership Development scale, participants were required to answer at least half of the questions, leaving 497 valid responses. Perceived change due to FLL also received high ratings by participants, with a mean of 4.25 (*SD* = 0.623). Only two items, questions 37 and 49, had means below four. These two questions related to the ability to admit and correct mistakes and enjoying change. Table 5 reports the means for each question. In the table, the questions from the Current Leadership Development scale are paired with the corresponding question about self-reported improvement due to FLL participation.

Table 5
Question Means for Current Leadership Development and Change in Leadership Development Scales

Question Pair	Question Theme	Current Leadership Development			Change Due to FLL		
		N	M	SD	N	M	SD
Q14 / Q32	Working on teams	497	4.54	0.74	488	4.47	0.78
Q15 / Q33	Getting to know people / making friends	498	4.59	0.67	487	4.5	0.76
Q16 / Q34	Delegating tasks to others	494	4.16	0.87	485	4.23	0.88
Q17 / Q35	Wanting to take charge	495	3.99	1.07	485	4.09	1.04
Q18 / Q36	Giving feedback	497	4.36	0.79	486	4.38	0.79
Q19 / Q37	Desire to be a leader	498	3.70	1.15	486	3.74	1.18
Q20 / Q38	Giving directions	494	4.13	0.99	496	4.13	0.91
Q21 / Q39	Planning	496	4.10	0.90	494	4.35	0.80
Q22 / Q40	Knowing rules and their importance	489	4.59	0.61	493	4.50	0.75
Q23 / Q41	Setting and carrying out goals	487	4.45	0.69	496	4.35	0.80
Q24 / Q42	Solving problems	484	4.35	0.80	497	4.45	0.73
Q25 / Q43	Collecting and interpreting data	486	3.95	0.98	495	4.08	0.98
Q26 / Q44	Doing things in new ways	489	4.27	0.85	496	4.33	0.85
Q27 / Q45	Curiosity	488	4.60	0.69	498	4.27	0.97
Q28 / Q46	Asking for advice	487	4.39	0.80	495	4.30	0.90
Q29 / Q47	Admitting and correcting mistakes	487	4.36	0.77	496	4.23	0.92
Q30 / Q48	Working with diverse people	488	4.51	0.77	497	4.41	0.85
Q31 / Q49	Enjoying change	488	3.55	1.15	498	3.68	1.25

Reliability Analysis

To determine the reliability of each scale in the study, Cronbach's alphas were calculated: Leadership Importance ($\alpha = .692$), Current Leadership Development ($\alpha = .892$), and Change in Leadership Development ($\alpha = .938$). Current Leadership Development and Change in Leadership Development both met the recommended

minimum of 0.7 (Field, 2005). However, Leadership Importance was below the 0.7 level. If Question 13 (Leaders need to be able to work in teams and groups.) was removed, the Cronbach's alpha for Leadership Importance increased to .742. In keeping with the recommended level, Question 13 was removed for the remainder of the analysis on the Leadership Importance scale. The new three-question scale had a mean of 4.34 (*SD* = 0.712).

Tests for Normality

Before running any further analysis, each scale was checked for normality. Normally distributed data is an assumption required for parametric tests and multilevel models to be accurate (Field, 2005; Tabachnick & Fidell, 2013). Each scale was negatively skewed, as is visible in Figures 4, 5, and 6. The histograms show the normal distribution for reference. Since the results are grouped at the high end of each scale, the normal distribution goes beyond the maximum value of the scale

As a confirmation, skewness and kurtosis values were calculated for each variable. The skewness index values were -1.26, -0.07, and -0.97 for Leadership Importance, Current Leadership Development, and Change In Leader Development respectively. Each skewness value was less than absolute value of three, indicatingAs a confirmation, skewness and kurtosis values were calculated for each variable. The skewness index values were -1.26, -0.07, and -0.97 for Leadership Importance, Current Leadership Development, and Change In Leader Development respectively. Each skewness value was less than absolute value of three, indicating the skew was not significant enough to cause problems for statistical analysis (Kline, 2005). The kurtosis values were 1.63, -1.38, and 1.41 for Leadership Importance, Current Leadership

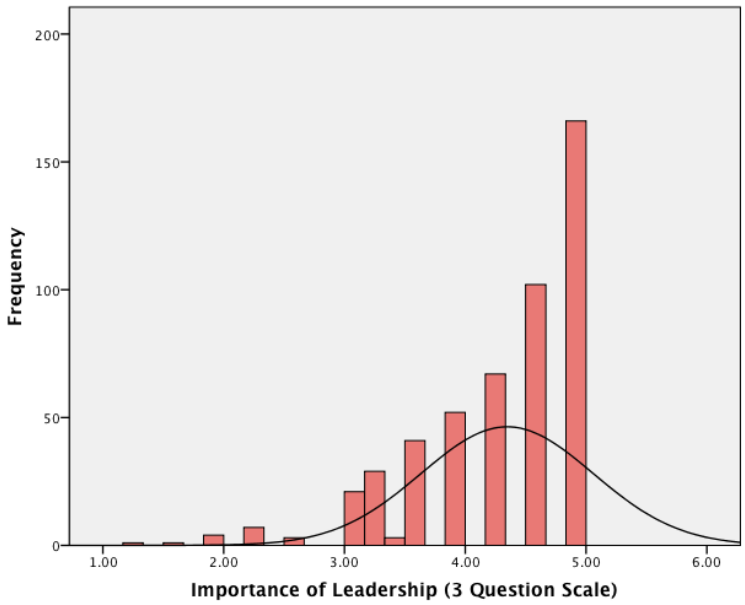

Figure 4: Importance of Leadership Scale Frequencies of Mean Ratings. A normal curve is shown for reference.

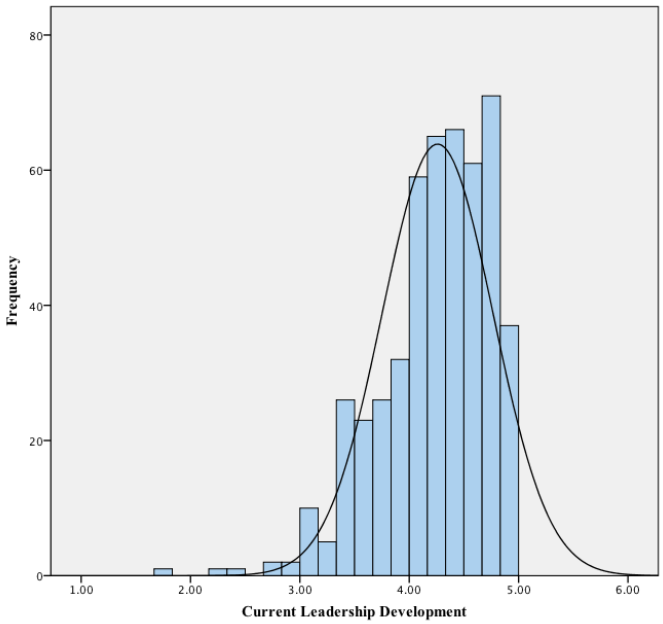

Figure 5: Current Leadership Development Scale Frequencies of Mean Ratings. A normal curve is shown for reference.

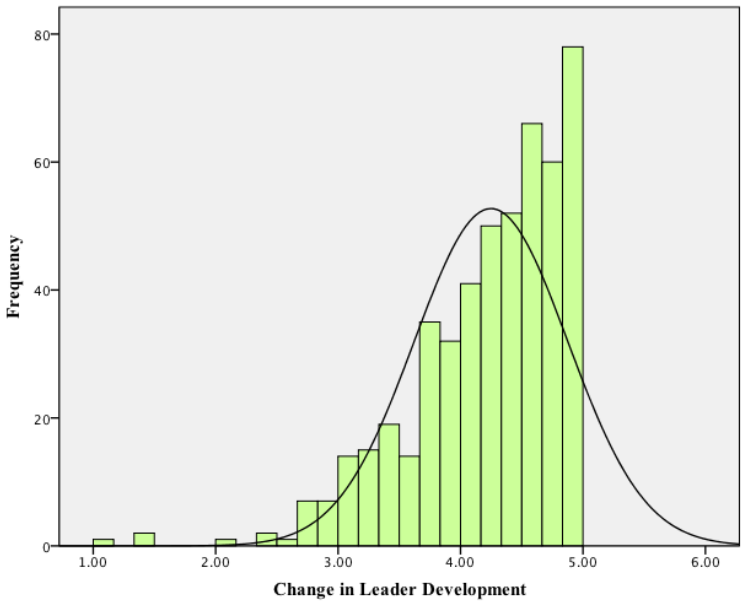

Figure 6: Perceived change in Leader Development Scale Frequencies of Mean Ratings. A normal curve is shown for reference.

Development, and Change In Leader Development respectively. The kurtosis values are all below 10 in absolute value, showing that the shape of the curve was not too flat or pointed for analysis (Kline, 2005).

Although it was not required for statistical validity, outliers were identified and removed from the data in order to reduce the skew. Following the steps outlined by Field (2005), outliers more than two standard deviations from the 5% mean were identified for each scale. The threshold for identification of outliers was 2.64 for the three-question Leadership Importance scale, 3.02 for Current Leadership Development, and 2.73 for Change in Leadership Development. For the initial analysis, the outliers were removed and each variable was re-labeled as "trimmed." Leadership Importance had 15

participants removed as outliers, Current Leadership Importance had seven removed, and Change In Leader Development had eight removed.

Correlations and Reported Impact of Participation

As a first step, correlations were calculated between each scale and demographic variable, using the trimmed scales, and are listed in Table 6. Only the correlations between Gender and Current Leadership Development and between Gender and Change in Leadership Development were statistically significant at the .05 level (one-tailed). Since males were coded as 0 and females coded as 1, the gender correlation suggests that females gave higher ratings on the two leadership development scales.

Correlation was also calculated between the Current Leader Development and Change in Leader Development scales. The two scales were 63.04% correlated, however, this was only significant at the .01 level (one-tailed). Since correlation only measures linear relationship, it only accounts for the effects of one variable at a time and holds all other variables constant.

Multilevel Linear Modeling

Initially, all demographic variables were included in the multilevel linear models

Table 6
Correlations with Demographics
(Pearson correlations squared as a percentage)

	Leadership Importance (3 Question Scale, Trimmed)	Current Leader Development (Trimmed)	Perceived Change in Leader Development due to FLL (Trimmed)
Gender	1.39 %**	0.90 %*	0.79 %*
Ethnicity	0.12 %	0.03 %	0.04 %
Age	2.19 %**	1.59 %**	0.28 %
Team Size	0.03 %	0.01 %	0.00 %
FLL Experience	4.67 %**	3.20 %**	1.12 %**

Note: *$p < .05$, one-tailed, **$p < .01$, one-tailed

for each of the three outcome variables. For the ethnicity variable, all youth who reported an ethnicity other than White were grouped together and the variable was labeled as Ethnicity. In preparation for creating the multilevel linear models, the team mean values were subtracted from each participant's value to center the results and create Level 2 (between team) variables. For example, the team's mean age was subtracted from the individual participant ages to represent difference from team average age.

Although the skew and kurtosis values were not large enough for concern, additional steps were taken to ensure that the negative skews would not compromise the assumption of normality required for a multilevel linear model. For multilevel models, having a large sample size (over 200) reduces problems caused by skew and kurtosis (Tabachnick & Fidell, 2013). Since Tabachnick and Fidell (2013) recommend resisting manipulation of data that is a legitimate part of a data set, Cook's distance values were calculated for the Level 1 (within team) variables and the Level 2 (between team) variables. Cook's distance gives the difference between the predicted value for a participant and the actual score and provides a measure of the values' influence on the model. The largest Cook's D within each of the variables was below 1, indicating that the inclusion of each case would not have a significant influence on the model as a whole (Field, 2005). Since no cases influenced the entire model, all three variables were analyzed using the untrimmed data sets.

As an additional precaution, since the Leadership Importance variable was most skewed, it was transformed to accommodate a J-shaped severe negative skew (New X = 1/(K-X); K= 5 demographic variables +1). The Current Leader Development and Change in Leader Development variables were not transformed.

For each model, the intraclass correlation (ICC) was calculated to determine whether the effect of being in a team was large enough for analysis through the multilevel model. The ICC provides a ratio of the variance between groups to the variance within groups. If the ICC is significant, the variability between groups is significant enough to warrant a hierarchical analysis. After each model was created, any non-significant variables were removed and the analysis was completed again to give a more meaningful representation of the effect sizes for the significant variables.

In the multilevel model, the intercept represents a participant for whom the other variables have no effect. Since the other variables have no effect, the participant represented by the intercept is one who responded with the mean values for every variable in the model. For each variable, the estimate is the effect of that variable on the intercept. The effects are cumulative; for example, if gender increases the estimated value and if age within the team also increases the value, both effect values can be added to the estimate to predict responses.

Multilevel model for leadership importance.

The multilevel model for Leadership Importance ratings had an ICC of 0.04, demonstrating significant variability between teams. The full model was an improvement on the intercepts-only model that did not include any predictors. The full model accounted for 15.89% of the overall variance in Leadership Importance (x^2 (1, N = 484) = 2.49; p > 0.114). This model did not explain the remaining 84.11% variance. Gender within teams, team age, and experience within teams were significant effects on the predicted values. Gender between Teams, Ethnicity between and within Teams, Age

within Teams, Experience between Teams, and Team Size were each non-significant effects. The complete model is shown in Table 7.

A second version of the model was created. In the updated model, variables that were non-significant ($p > .05$) at both Level 1 and Level 2 were eliminated, leaving only the significant effects. The updated model is reported in Table 8 (x^2 (1, N = 484) = 2.21; $p > 0.14$). On the transformed scale, on average, girls rated Leadership Importance 0.11 higher than boys. For each year of increased average team age, ratings increased by 0.03. For each year of experience within a team, ratings increased by 0.07. The cumulative significant effects, represented in Figure 7, indicate that a female with more experience compared to others on her team, whose team who was older than average, tended to give

Table 7
Multilevel Model for Leadership Importance – All Demographic Variables

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Gender within Teams	0.10	0.03	415.00	3.26	0.00 *
Gender between Teams (Percent)	-0.07	0.05	192.00	-1.50	0.14
Ethnicity within Teams	0.01	0.04	416.00	0.42	0.67
Ethnicity between Teams	-0.05	0.08	135.00	-0.62	0.54
Age within Teams	0.00	0.01	416.00	0.17	0.86
Age between Teams	0.03	0.01	82.00	2.55	0.01 *
Experience within Teams	0.07	0.02	415.00	3.27	0.00 *
Experience between Teams	0.05	0.03	79.40	1.80	0.08
Team Size	0.00	0.01	117.00	0.80	0.43

Note: *$p < .05$

Table 8

Multilevel Model for Leadership Importance – Only Significant Variables

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	0.70	0.02	69.20	41.54	<.0001
Gender within Teams	0.11	0.03	419.00	3.36	0.00 *
Gender between Teams (Percent)	0.00	0.00	196.00	-1.52	0.13
Age within Teams	0.00	0.01	419.00	0.21	0.84
Age between Teams	0.03	0.01	80.70	2.56	0.01 *
Experience within Teams	0.07	0.02	418.00	3.20	0.00 *
Experience between Teams	0.05	0.02	76.40	1.91	0.06

Note: *$p < .05$

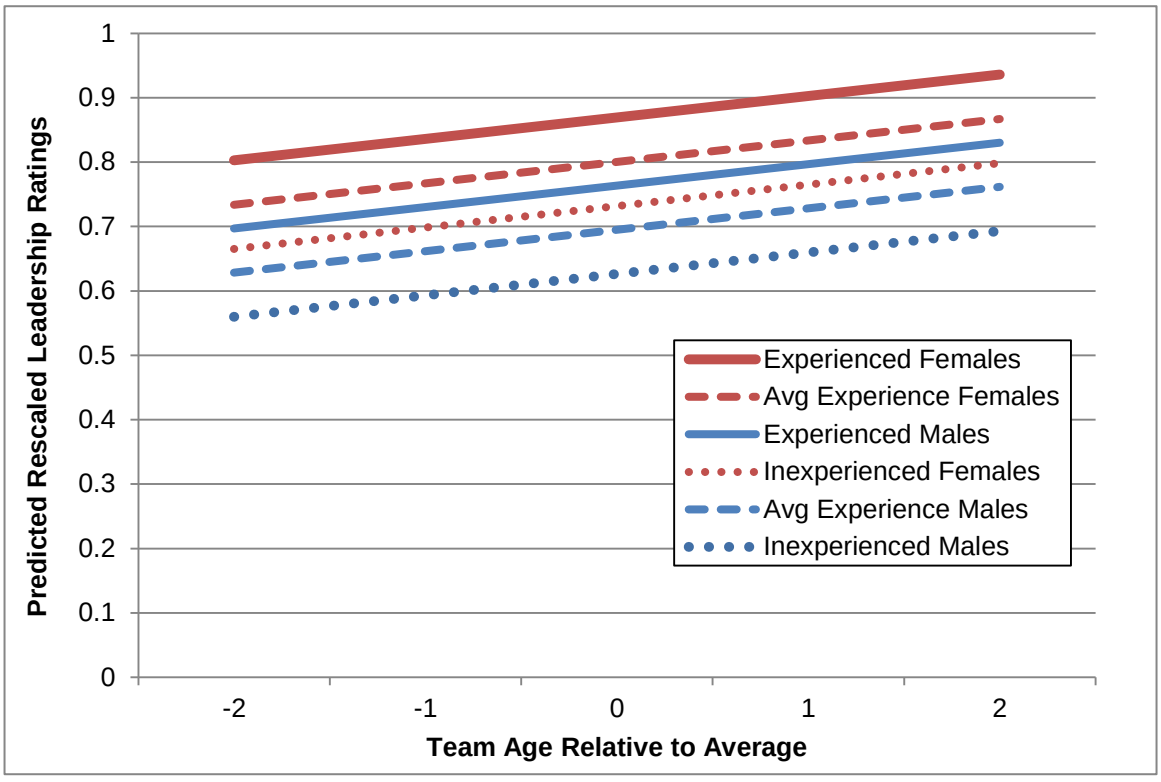

Figure 7: Predicted Rescaled Leadership Importance Ratings for Gender and Experience Groups

the highest ratings of Leadership Importance. A male with less experience than others on his team, who was on a team younger than average, tended to give the lowest ratings of Leadership Importance.

Multilevel model for current leader development.

The multilevel model for the Current Leader Development scale had an ICC of 0.1, demonstrating significant variability between groups. The full model was an improvement on the intercepts-only model that did not include any predictors. The full model accounted for 23.29% of the overall variance in Current Leader Development (x^2 (1, N = 475) = 11.95; p > 0.0005). This model did not explain the remaining 76.71% variance. In the first run, only Age between Teams and Years of Participation between Teams had significant contribution to the overall variance. Gender between and within Teams, Ethnicity between and within Teams, Age within Teams, Experience between Teams, and Team Size were each non-significant effects. Results are shown in Table 9.

Table 9
Multilevel Regression for Current Leadership Development – All Demographic Variables

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	4.28	0.17	106.00	25.05	<.0001
Gender within Teams	0.08	0.06	408.00	1.32	0.19
Gender between Teams	0.00	0.11	163.00	0.01	0.99
Ethnicity within Teams	-0.04	0.07	408.00	-0.54	0.59
Ethnicity between Teams	-0.09	0.18	123.00	-0.48	0.63
Age within Teams	0.00	0.02	410.00	-0.19	0.85
Age between Teams	0.09	0.03	83.80	2.94	0.00 *
Experience within Teams	0.15	0.04	407.00	3.48	0.00 *
Experience between Teams	0.05	0.06	82.80	0.77	0.44
Team Size	0.01	0.01	131.00	0.56	0.57

Note: $*p < .05$

Table 10
Multilevel Regression for Current Leadership Development – Significant Variables

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	4.26	0.03	71.60	149.94	<.0001
Age within Teams	0.00	0.02	418.00	-0.22	0.82
Age between Teams	0.08	0.03	81.90	2.76	0.01 *
Experience within Teams	0.14	0.04	417.00	3.24	0.00 *
Experience between Teams	0.05	0.06	78.20	0.83	0.41

Note: $*p < .05$

Following a similar procedure as for the Leadership Importance scale, a second version of the Current Leadership Development model was created. In the updated model, non- significant variables ($p > .05$) at both Level 1 and Level 2 were eliminated, leaving only the significant effects. The updated model only included the Age and Years variables and is shown in Table 10 (x^2 (1, N = 487) = 11.48; $p > 0.0007$). On average, for each year of increased mean team age, the Current Leadership Development score increased by 0.08. For each year of experience within a team, Current Leadership Development increased by 0.14.

The cumulative significant effects are represented in Figure 8. A youth with more experience than others on his or her team, who was on a team older than average, tended to give the highest Leader Development ratings. A team member with less experience than others on his or her team, who was on a team younger than average, tended to give the lowest ratings of Current Leader Development.

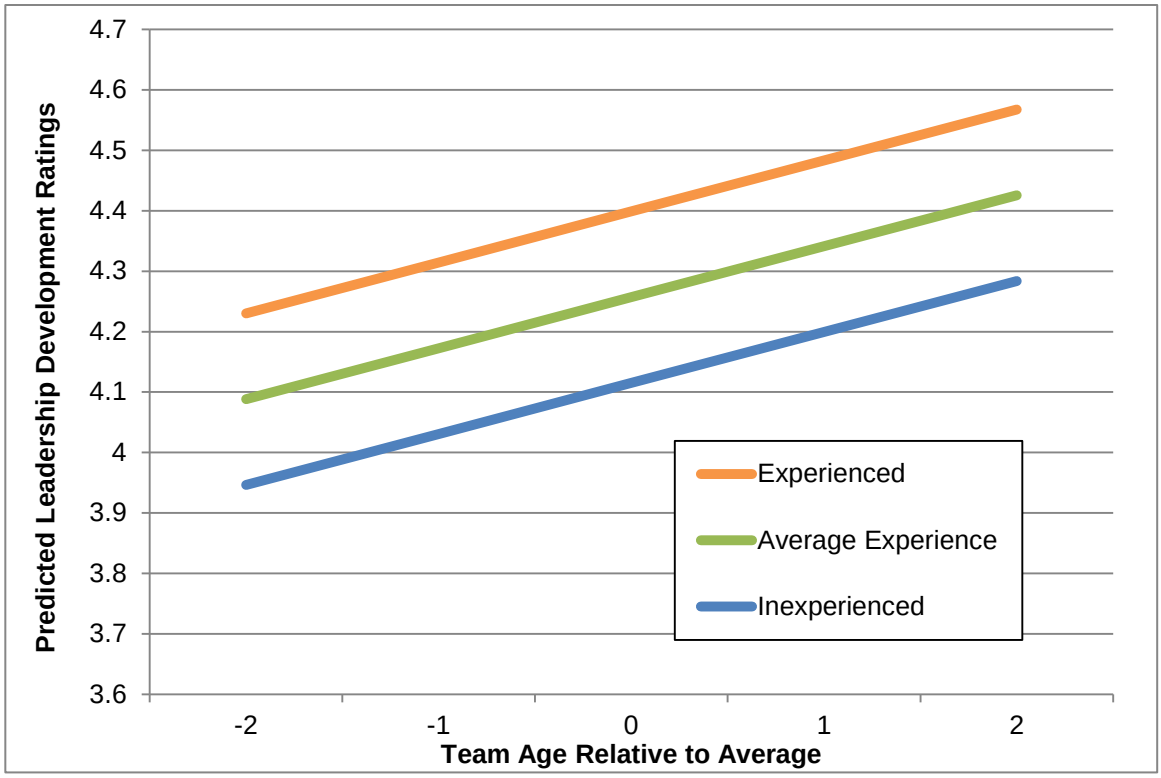

Figure 8: Predicted Current Leader Development for Significant Effect Variables

Multilevel model for perceived change in leader development.

The multilevel model for the Change in Leader Development scale had an ICC of 0.11, demonstrating significant variability between groups. The full model was an improvement on the intercepts-only model that did not include any predictors. The full model accounted for 24.25% of the overall variance in Current Leader Development (X^2 (1, N = 484) = 13.25; p > 0.0003). This model did not explain the remaining 75.75% variance. In the first run, none of the demographic variables were significant contributors to the overall variance of the Change in Leadership Development scale. Results are shown in Table 11. Since Experience within Teams was close to the .05 significance

level, the model was run again with only the Experience Variables. They remained non-significant effects.

Table 11

Multilevel Regression for Perceived Change in Leadership Development – All Demographic Variables

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	4.39	0.21	101.00	20.51	<.0001
Gender within Teams	0.13	0.08	415.00	1.59	0.11
Gender between Teams	-0.01	0.14	160.00	-0.04	0.97
Ethnicity within Teams	-0.13	0.09	414.00	-1.44	0.15
Ethnicity between Teams	-0.15	0.22	119.00	-0.67	0.50
Age within Teams	-0.03	0.03	414.00	-1.06	0.29
Age between Teams	0.07	0.04	80.30	1.68	0.10
Experience within Teams	0.10	0.05	413.00	1.91	0.06
Experience between Teams	0.07	0.08	80.10	0.90	0.37
Team Size	0.01	0.02	127.00	0.44	0.66

Chapter 5

Discussion

This research set out to advance the understanding of how educational robotics programs for youth can contribute to the development of future innovative leaders in the STEM fields. Specifically, the study examined youth leadership development and leader identity development models (Campbell et al., 2003; Komives et al., 2006; Murphy & Johnson, 2011) as applied to Nebraska middle school aged participants in four *FIRST* LEGO League (FLL) educational robotics competitions. The study focused on describing FLL participants' perceptions of the importance of leadership, their own leader development, and their perceived changes in leader development as a result of FLL participation, and demographics as predictors of the leadership variables. Results show youth reported high levels across all leadership scales: Leadership Importance, Current Leader Development, and Perceived Change in Leadership Development.

Leadership Importance

Research questions 1a (To what extent is leadership important to Nebraska FLL participants?) and 1b (To what extent do demographic characteristics of FLL participants predict their ratings of leadership importance?) focused on youth perceptions of the importance of leadership in their lives.

Question 1a.

Overall, the participants reported agreement that leadership is important to them, they see themselves as leaders, and leadership will be important in their future lives (M = 4.34 on the three-question Leadership Importance scale). Several scholarly models of leader development include awareness of leadership and recognition of the importance of

leadership as a first stage in leadership development (Komives et al., 2009, 2006; Komives, 2011; Ricketts & Rudd, 2002; van Linden & Fertman, 1998). Identifying as a leader is also a stage in leadership development in many models (Komives et al., 2009, 2006; Komives, 2011; Lord et al., 2011). According to these leadership development models, the FLL participants' high ratings of leadership importance suggest they are on the path to develop their leadership skills and become leaders in the future.

Question 1b.

Gender within teams, average team age, and experience within teams each had significant influence on the Leadership Importance scale. On average, girls gave ratings slightly (0.1) higher than boys on the rescaled Leadership Importance variable. This suggests *FIRST* LEGO League is being successful at achieving Hoyt and Johnson's (2011) recommendation to develop girls' leadership self-confidence at early ages.

Experience within teams had a significant effect on leadership importance ratings; Youth rated leadership importance slightly higher for each year of previous FLL experience (0.07 increase). Within teams, youth who have prior knowledge of robot building and programming likely teach new team members their skills and lead the team in developing their strategy. Beyond awareness and identity as a leader, leadership development models (Avolio & Vogelgesang, 2011; Lord et al., 2011; Murphy & Johnson, 2011) describe self-reinforcing cycles of leadership development, where leadership skills increase as leadership is practiced and learned. The small but significant effect of experience, with other variables held constant, provides evidence the FLL program is developing awareness of leadership and encouraging youth to self-identify as

leaders. Youth returning to the program in additional years benefit from being able to practice being leaders through FLL and learn from their leader development experiences.

Average team age also had a significant effect on the rescaled Leadership Importance ratings; for each year of team age, youth ratings of Leadership Importance increased by 0.03. Murphy's (2011) framework describes leadership as being dependent on context, including age and developmental stage. In Murphy's model, youth leadership behaviors look different for each age group. The youth on older FLL teams may be at a developmental stage to be more aware of leadership and may have had more leadership experiences than youth on younger teams.

The non-significant effects suggest youth see leadership as equally important regardless of their team's gender division, ethnicity, or average team experience level. The non-significant effect of Age within Teams shows being older or younger than teammates does not influence youth attitudes towards the importance of leadership. The non-significant effect of time size demonstrates youth on both small and large teams have similar views on the importance of leadership.

The demographic variables included in the multilevel model explained 15.9% of the variance in the Leadership Importance Scale. This suggests most of the variance in this scale is due to other factors not measured in this study. Overall, the Leadership Importance results support that youth on FLL teams believe leadership is important and identify themselves as leaders. The results suggest FLL is successful at leadership development for girls and has an increased effect for teams of older youth and youth who participate in the program for multiple years.

Current Leader Development

Research question 2a (At what level do Nebraska FLL participants rate their own leader development?) and question 2b (To what extent do demographic characteristics of FLL participants predict their ratings of leader development?) assessed current leadership development across four factors.

Question 2a.

The Current Leader Development scale was adapted from Zula, et al. (2010), which was based on the framework compiled by Campbell, et al. (2003) and included development of intra-personal and interpersonal qualities, cognitive abilities, communication skills, and task-specific skills. The high mean (4.26) of the Current Leader Development scale suggests FLL youth are experiencing leader development across the factors included in the model.

Question 2b.

Similar to the Leadership Importance scale, team age and experience within teams were both significant predictors of Current Leader Development ratings. Average scores increased by 0.08 for each year of mean team age and by 0.14 for each year of experience within a team. Like for Leadership Importance, the significance of team age and experience within teams supports the self-reinforcing models of leadership development (Avolio & Vogelgesang, 2011; Lord et al., 2011; Murphy & Johnson, 2011).

Since the multilevel model for Current Leadership Development scale only accounted for 23.3% of the variance, the demographic variables included in the model do not explain most of the variance. Unknown factors not measured in this study account for most of the variance in this scale. A similar amount of variance was measured by researchers who used the YLLSDS instrument (Seevers, 1994), demonstrating the

continued complexity factors influencing youth leadership development. Overall, the results suggest youth participating in *FIRST* LEGO League are experiencing leadership development. Teams of older youth and youth who participated for multiple years reported the highest levels of leadership development.

The non-significant effects suggest youth perceive having a similar leadership development experience in FLL regardless of their gender, ethnicity, or average team experience level. The non-significant effect of Age within Teams shows youth on teams with a wide age range do not view themselves as having improved leadership skills than teams compared to youth on teams who are close in age. The non-significant effect of time size suggests youth experiencing similar leadership development on both small teams and large teams.

Perceived Change in Leader Development

Research questions 3a (To what extent do youth report a change in their leadership development due to their participation in FLL?) and question 3b (To what extent do demographic characteristics of FLL participants predict their perceptions of change in leader development due to FLL?) addressed Change in Leader Development. The Change in Leader Development questionnaire items asked youth to report whether they had improved at each element of leadership development.

Question 3a and 3b.

Youth reported participating in FLL improved their leader development (M=4.25). The lack of significance in the demographic variables indicates youth across gender, ethnicity, age, experience, and team size all tended to report similar scores for their Perceived Change in Leader Development. The consistent mean scores suggest

youth across the measured groups had similar leader development experiences through participation in FLL.

The demographic variables included in the multilevel model explained 24.3% of the variance in the Change in Leader Development, although each variable's influence was at a non-significant level. Most of the variance in Change in Leader Development was not explained by the variables measured. Possible additional variables influencing perceived change in leader development include the coach's influence or training in youth leader development, relationships with peers, and family focus on youth leadership. Youth prior knowledge and experience in robotics, youth self-awareness levels, and youth's prior experience with leader development could influence the youth's perceptions of the impact of FLL on leader development. In addition, as the questions relating to impact of participation were last in the questionnaire, the lack of significance of demographic variables might be explained by fatigue in testing. Measurement error could also be a factor.

Question 3c.

Question 3c (Are participants' current leader development ratings correlated to their self-reported change in leader development?) compared leadership development and change in leadership development. Results showed a correlation significant at the .01 level (one-tailed). This suggests youth who have high levels of leader development may report the most amount of perceived change as a result of participation in FLL. This question should be addressed in future research to determine whether a significant correlation exists in other groups of FLL participants.

Practical Implications

The *Gathering Storm* committee set a goal for educators, administrators, and policy makers to develop innovation as the primary source for the United States continued economic competitiveness (Members of the 2005 "Rising Above the Gathering Storm" Committee, 2010). Several educational robotic programs, including *FIRST* LEGO League, have been designed in order to support this goal and create future innovative leaders within the STEM fields. This study provides evidence for the contribution of FLL participation toward leadership development among youth. The findings may be used to support the value of participation in educational robotics and improve youth leadership development within educational robotics programs.

Government and Policy Makers.

Legislators and policy makers across governmental agencies are interested in working to create economic prosperity in the United States. Some, such as the National Science Foundation, are specifically dedicated to supporting innovation and discovery in the STEM fields (National Science Foundation, 2011). This study provides initial evidence that participation in *FIRST* LEGO League develops leadership skills among youth. Other studies have documented that youth participants in *FIRST* programs show a strong interest in entering the STEM fields (Melchior et al., 2005, 2009; Oppliger, 2001; Skorinko et al., 2010; Tougaw et al., 2003; Varnado, 2005). Together, the research supports the value of educational robotics programs and their contributions toward developing future innovative leaders in STEM. Policy makers should consider this research connecting leadership development with the STEM pipeline an additional reason to continue supporting and funding educational robotics programs.

Educational Program Administrators and Teachers.

Educational program administrators, like governmental officials, are tasked with providing ways for youth to become contributors to the economic health of the community. Often, education must focus on providing funding to those programs that most directly influence youth test scores and academic successes. Educational administrators can use the findings of this study to support the ability for educational robotics programs to develop leadership skills among youth and ultimately enter the pipeline to become STEM leaders.

In addition to the general support provided by the youth's high rankings across the leadership scales, the predictors of team age and experience should become factors in program design and structure. Since youth at the older end of the FLL age range experienced the largest leadership development impacts, program administrators should consider targeting educational robotics programs for ages 12-14. In addition, educational robotics programs should be intentionally designed to recruit new students to participate each year, in order to facilitate the greatest leadership development experiences for youth who are experienced in the program.

Formal educators have the difficult mission of teaching youth content knowledge and developing life skills among their students simultaneously. Teachers might use the questionnaire compiled for this study as an assessment of students' perceptions of leadership and their current levels of leadership development. The instrument could be modified into a pre- and post-measure of youth perceptions of leadership skills; results might be compared to the then-post strategy used in this study.

Informal Educators.

Informal educators may have more freedom to implement educational robotics programs, but often face the same demands for evidence of impact as formal educators. Team coaches, parents, afterschool educators, and community program coordinators can use the results in similar ways as their formal education counterparts when recruiting business and community supporters and requesting funding to support their programs. Additionally, the significant demographic predictors of team age and experience within teams should guide informal educators as they recruit participants in educational robotics competitions. The significance of team age suggests *FIRST* LEGO League coaches, like educational program administrators, should target recruitment efforts at the older end of FLL's range of participation in order to have a larger impact on leadership development. Since age within teams was not a significant effect, there was no additional leadership development benefit from having a wide age range of youth on a team. The significance of experience within teams, however, should encourage coaches to seek out new team members each year to facilitate the greatest leadership development benefits for experienced team members.

Informal education programs, including YMCA of the USA, 4-H Youth Development, Girl Scouts of the USA, and the National FFA Organization, often include leadership and life skills development in their missions. The results of this study provide evidence that participation in educational robotics activities develops leadership skills in youth. This study suggests educational robotics programs, in addition to inspiring youth to enter the STEM fields, also contribute to the broader goals of youth organizations working to develop youth into successful adults.

Overall Contributions

The findings provide initial evidence that youth who participate in *FIRST* LEGO League see themselves as leaders and believe leadership is important. FLL participants reported high levels of leader development. In accordance with models of youth leadership development, the results support that FLL participants are on the path to become leaders in the future. In addition, participants reported high levels of improvement across leader development factors as a result of their participation in FLL.

Researchers have documented that youth who participate in educational robotics competitions including FRC and FLL reported high levels of interest in entering careers in the STEM fields (Melchior et al., 2005, 2009; Nugent et al., 2012). With their high levels of engagement and interest in STEM, educational robotics program participants are in the "STEM pipeline" and are likely to build their self-efficacy in the STEM fields, work harder as they expect achievement, and experience additional success as they continue in STEM (Mead et al., 2012).

Youth leadership development models and the "STEM pipeline" share a common self-reinforcing structure in which youth gain interest, have opportunities for experience and practice, see and expect success, learn from their experiences, and become more successful and engaged as they have additional practice. In accordance with the theoretical models, the combination of high levels of leader development and high levels of interest in STEM suggest youth who participate in *FIRST* LEGO League are on the path to become leaders in the STEM fields in the future.

By directly measuring leadership development among *FIRST* LEGO League participants, the findings support the *FIRST* LEGO League program's alignment with the organization's mission of developing leaders in the STEM fields. As programs like

FIRST LEGO League develop youth leadership and interest in STEM, they influence the future competencies of innovative leaders in STEM and indirectly contribute to the competitive status of the United States.

Future Research Directions

Results of this study suggest *FIRST* LEGO League is successful at developing youth leaders and inspiring youth in the STEM fields. Since this was the first time the instrument was used in this format, future research is needed to confirm its reliability and validity for assessing leadership development among nine to 14 year old youth. Additional validation of the instrument should be conducted by using it with youth in other parts of the country and youth in other programs. Future studies should use the instrument with youth older and younger than the nine to 14 age range, as well as break the participants in two age groups for comparison of reliability and validity statistics. The non-significance of team size could be confirmed by using this instrument with other youth programs that allow teams with greater than 10 members. In addition, although Rohs (1999) found more accurate results through the use of a then-post instrument format compared to a pre-post assessment, the ability of youth in this age group to self-report improvement due to program participation would benefit from further research.

Since the measured demographic variables explained less than 25% of the variance in each scale, additional research is required to understand the predictors of variance in each scale. Because no demographic variables had significant effects on the Change in Leader Development scale, additional research is needed to identify factors influencing youth reports of program participation benefits. For example, participants' socioeconomic status or academic achievement levels might influence views on

leadership importance or current leader development. Any training a team's coach has in youth leadership development may affect youth ratings on the leadership scales.

Since all outcomes were measured through a self-report instrument, future research might investigate leadership development through coaches' or parents' observations of youth throughout program participation. In addition, the data was gathered as a one-time measure. Longitudinal research is needed to determine the long-term effects of *FIRST* LEGO League participation on leadership development.

While each of the scales and predictors used in this study would benefit from additional research, this study provides initial evidence linking educational robotics with youth leadership development. Supported by the parallel structures of the youth leadership development and STEM "pipeline" theoretical models, the findings suggest youth participating in educational robotics activities are likely to develop into innovative leaders in the STEM fields. Educational robotics programs, as documented by this study, appear to be part of creating a future United States STEM workforce that leads the global economy through continuous innovation. This study reinforces the vital contributions of educational robotics programs as stated by *FIRST* Founder Dean Kamen:

> It's not about the robots. Robots are just a vehicle. What you are building is way bigger. It's about self-confidence. It's about relationships. It's about making sure the future is better than the past. Don't blow this opportunity by thinking it's about robots. (as quoted in Benedict, 2011, January launch, para. 2 & 4).

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Appendix A: IRB Approval Letter

Welcome Kathleen Morgan | logout

Main Menu Search Preferences Help

Robotics Intervention Study

Human Research Protections Program
nugrant-irb@unl.edu

Project ID: 7029 | IRB Approval #: 200510055 EP | Review Type: Expedited
Project Status : Approved by the IRB | Valid Until Date: 12/15/2013 | Collaboration:

Project Summary | Project Forms: Original | Cnt - 01/16/2013 | Chg - 12/05/2012 | Chg - 06/19/2012 | >> | Add a new Form

Change Request Form
Coordinator: Rachel Wenzl
Phone: 402 472 8196

Form ID: 19249
Form Status: Approved by the IRB
Form Review Type: Expedited

Submitted On: 11/12/2012
Last Action: 12/05/2012

Workflow Steps
- Add/Edit Form
- Routing Signatures
- IRB Review
- Form PDF
- IRB Protocol-Consent Errors
- IRB Personnel List SOP

Investigators	CITI
Bradley Barker *(lead)* 4-H State Office	Up-To-Date
Gwen Nugent Nebraska Center for Research on Children, Youth, Families and Schools	Up-To-Date

Type of Change : MinorChanges

Description of Proposed Changes:

1. We are requesting the addition of an instrument for use with youth in the annual robotics competition. This instrument is intended to assess the impact of the robotics competition on youth leadership skills.

2. We are also requesting the inclusion of a robotics competition leader/coach ques...
More

Justification of Proposed Changes:

Leadership development is one of the skills targeted by 4-H, as well as robotics competitions. It is important to obtain some measure of whether the competition is meeting this goal. Thus, we are requesting inclusion of an instrument assessing participating youth leadership skills.

We also need...
More

Required Informed Consent: Yes

Messages View Messages | Send a Message

Number of Messages attached to this form: 7

File Attachments View Files

Number of files attached to this form : 5
Approved Files:
coach_consentforms competition-Approved.pdf

Timestamps (descending order)

Approved by the IRB	12/05/2012 02:11 pm
Revisions Submitted	12/04/2012 04:36 pm
Revisions Requested	12/03/2012 03:30 pm
IRB Reviews Submitted	11/27/2012 04:11 pm

Submitted to Reviewer	11/19/2012 11:36 am
Submitted to RCS Office	11/12/2012 09:00 am
Routing	11/09/2012 09:34 am
Preparation	11/08/2012 02:06 pm

General Comments Add a Comment

By Rachel Wenzl on 12/05/2012 2:11 pm

Dear Drs. Nugent and Barker,

The change request for project #7029 titled Robotics Intervention Study submitted on November 12, 2012, has been approved. It has been approved to include an instrument that is intended to assess the impact of the robotics competition on youth leadership skills and to also include a leader/coach questionnaire to provide basic information about the background of the robotics team the coach is leading.

The stamped and approved coach informed consent form has been uploaded to NUgrant within the file attachments section. Please use this form to make copies to distribute to participants. If changes need to be made, please submit the revised informed consent form to the IRB for approval prior to using it.

Please allow sufficient time for the official IRB approval letter to be available within the messages section in NUgrant.

Cordially,

Rachel Wenzl
Research Compliance Services Specialist
Human Research Protection Program

By Gwen Nugent on 12/04/2012 4:36 pm

1. This change request is only adding items to an existing ongoing data collection.

2 - 3. We have removed the entry asking for the coaches name from the coaches survey.

By Rachel Wenzl on 12/03/2012 3:30 pm

Dear Drs. Barker and Nugent,

The IRB Expedited reviewer has completed the review of the change request for project #7029 titled Robotics Intervention Study. Based upon this review, additional clarifications and revisions will have to be made to the protocol before it can be given final approval.

1. Please clarify if this change request is only adding items to an existing ongoing data collection or if it is a separate data collection administration on its own accord. If it is a separate data collection administration please modify the informed consent form to discuss the separate administration process.

2. The IRB reviewer is assuming that the coach name is on the survey to allow the linking of the coach and student data, but is it possible to have the identifying information removed and destroyed from the dataset after being linked? If so, please discuss this process within the change request form.

3. If it is necessary to retain the identifying information, please use a coding system with ID numbers and a master list linking names and codes to de-identify the responses within the dataset and the information collected. Please discuss this within the change request if necessary.

4. Please upload the coach recruitment script.

Once you have addressed the outlined concerns, please submit your protocol for review. Please note, revisions are required to be submitted via NUgrant by December 17, 2012. If the revisions have not been submitted, the change request will be set to a Preparation status. You will then have 30 days to complete the revisions or the change request will be administratively closed.

Cordially,

Rachel Wenzl
Research Compliance Services Specialist
Human Research Protection Program

Routing Comments Routing History

none

Appendix B: Questionnaire Item Modifications

Item	Original *(Source)*	Modified Wording	Modified to Assess Change
1	Leadership is important to me. (*Shertzer et al., 2005)*	*Retain original wording.*	
2	I consider myself to be a leader. (*Shertzer et al., 2005)*	*Retain original wording.*	
3	Leadership will be an important part of my life after college (*Shertzer et al., 2005)*	Leadership will be an important part of my life in the future.	
4	Leaders need to be able to work in teams and groups. (*Shertzer et al., 2005)*	*Retain original wording.*	
7	I enjoy working on teams. (Zula et al., 2010)	*Retain original wording.*	Through FLL, I learned that I enjoy working on teams.
8	I enjoy relating to others on an interpersonal basis. (Zula et al., 2010)	I like getting to know people and making new friends.	Through FLL, I learned that I like getting to know people and making new friends.
9	I could delegate work to others. (Zula et al., 2010)	When there is a lot to do, I can assign tasks to others to help spread out the work.	Through FLL, I got better at assigning tasks to others to help spread out the work.
10	I want to take charge. (Zula et al., 2010)	I want to take charge and be a leader.	Through FLL, I learned that I want to take charge and be a leader.
11	I could appraise and provide feedback to employees. (Zula et al., 2010)	I know if my teammates are doing a good job and I can give them ideas on how to get better.	Through FLL, I got better at knowing if my teammates are doing a good job and I am better at giving them ideas on how to improve.
12	One of my greatest desires is to become a leader. (Zula et al., 2010)	*Retain original wording.*	Through FLL, I learned that one of my greatest desires is to become a leader.
13	Giving directions is comfortable to me. (Zula et al., 2010)	I am comfortable giving directions to others.	Through FLL, I learned to be more comfortable giving directions to others.
14	I am good at planning. (Zula et al., 2010)	*Retain original wording.*	Through FLL, I got better at planning.
15	I can interpret rules and regulations. (Zula et al., 2010)	In my school classroom, when I'm playing a game, or in *FIRST* LEGO League, I know what the rules are and why they are important.	Through FLL, I learned that I need to know what the rules are and why they are important.

16	I know how to develop goals and carry them out. (Zula et al., 2010)	I know how to set goals and carry them out.	Through FLL, I improved at setting goals and carrying them out.
17	I am good at problem solving. (Zula et al., 2010)	I am good at solving problems such as figuring out why something is not working.	Through FLL, I improved my problem solving skills, such as figuring out why something is not working.
18	I enjoy collecting and analyzing data. (Zula et al., 2010)	I enjoy collecting data and deciding what it means.	Through FLL, I learned to enjoy collecting data and deciding what it means.
19	I am comfortable at implementing new techniques. (Zula et al., 2010)	I am comfortable doing things in new ways.	Through FLL, I learned to be more comfortable doing things in new ways.
20	I am curious. (Zula et al., 2010)	*Retain original wording*	Being in FLL has made me more curious.
21	I am comfortable asking others for advice. (Zula et al., 2010)	*Retain original wording*	Through FLL, I learned to be more comfortable asking others for advice.
22	If I made a mistake, I would admit it and correct it. (Zula et al., 2010)	*Retain original wording*	Because I am in FLL, I am better at admitting when I make mistakes and correcting them.
23	I believe in workplace diversity. (Zula et al., 2010)	I think it's important to work with people who are different from me, for example, people who are from different races or cultures.	Through FLL, I learned that it's important to work with people who are different from me, for example, people who are from different races or cultures.
24	I thrive on change. (Zula et al., 2010)	I love it when things change.	Through FLL, I learned that I love it when things change.

Appendix C: Questionnaire

Robotics Expo 2012 [Post LEGO]

Do not mark on this form. Please completely darken the bubble on the ANSWER SHEET for the best answer to the question.

Like this: ● Not like this: ✓ ✗ /

Part I. Workplace and Leadership Skills

We want to know how well the robotics competition helps you to develop certain skills. Please respond to the items below in terms of how you contributed to your team in solving the robotics challenge and in preparing the team project and documentation. It may be helpful to think of *leadership* as a process where a person influences a group of people to achieve a common goal. Some things leaders do are planning and organizing, problem solving, informing, monitoring, motivating, recognizing, supporting, managing conflict, team building, and delegating.

Statement	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1. I use a step by step process to solve problems.	5	4	3	2	1
2. I make a plan before I start to solve a problem.	5	4	3	2	1
3. I try new methods to solve a problem when one does not work.	5	4	3	2	1
4. I carefully analyze a problem before I begin to develop a solution.	5	4	3	2	1
5. In order to solve a complex problem I break it down into small steps.	5	4	3	2	1
6. Leadership is important to me.	5	4	3	2	1
7. I consider myself to be a leader.	5	4	3	2	1
8. Leadership will be an important part of my life in the future.	5	4	3	2	1
9. Leaders need to be able to work in teams and groups.	5	4	3	2	1
10. I enjoy working on teams.	5	4	3	2	1
11. I like getting to know people and making new friends.	5	4	3	2	1
12. When there is a lot to do, I can assign tasks to others to help spread out the work.	5	4	3	2	1
13. I want to take charge and be a leader.	5	4	3	2	1
14. I know if my teammates are doing a good job and I can give them ideas on how to get better.	5	4	3	2	1
15. One of my greatest desires is to become a leader.	5	4	3	2	1
16. I am comfortable giving directions to others.	5	4	3	2	1
17. I am good at planning.	5	4	3	2	1

18. In my school classroom, when I'm playing a game, or in *FIRST* LEGO League, I know what the rules are and why they are important.	5	4	3	2	1
19. I know how to set goals and carry them out.	5	4	3	2	1
20. I am good at solving problems such as figuring out why something is not working.	5	4	3	2	1
21. I enjoy collecting data and deciding what it means.	5	4	3	2	1
22. I am comfortable doing things in new ways.	5	4	3	2	1
23. I am curious.	5	4	3	2	1
24. I am comfortable asking others for advice.	5	4	3	2	1
25. If I made a mistake, I would admit it and correct it.	5	4	3	2	1
26. I think it's important to work with people who are different from me, for example, people who are from different races or cultures.	5	4	3	2	1
27. I love it when things change.	5	4	3	2	1

Part II. Attitudes towards Science, Technology, Engineering and Math

Statement	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
28. I am confident that I can program a robot to move forward two wheel rotations (i.e. 720 degrees) and then stop.	5	4	3	2	1
29. I am certain that I can build a LEGO or similar robot by following design instructions.	5	4	3	2	1
30. I am certain that I can fix the software program for a robot that does not behave as expected.	5	4	3	2	1
31. I am confident that I can program a LEGO or similar robot to follow a black line using a light sensor.	5	4	3	2	1

Part III. How have you grown through participating in *FIRST* LEGO League?

Statement	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
32. Through FLL, I learned that I enjoy working on teams.	5	4	3	2	1
33. Through FLL, I learned that I like getting to know people and making new friends.	5	4	3	2	1
34. Through FLL, I got better at assigning tasks to others to help spread out the work.	5	4	3	2	1
35. Through FLL, I learned that I want to take charge and be a leader.	5	4	3	2	1
36. Through FLL, I got better at knowing if my teammates are doing a good job and I am better at giving them ideas on how to improve.	5	4	3	2	1

37. Through FLL, I learned that one of my greatest desires is to become a leader.	5	4	3	2	1
38. Through FLL, I learned to be more comfortable giving directions to others.	5	4	3	2	1
39. Through FLL, I got better at planning.	5	4	3	2	1
40. Through FLL, I learned that I need to know what the rules are and why they are important.	5	4	3	2	1
41. Through FLL, I improved at setting goals and carrying them out.	5	4	3	2	1
42. Through FLL, I improved my problem solving skills, such as figuring out why something is not working.	5	4	3	2	1
43. Through FLL, I learned to enjoy collecting data and deciding what it means.	5	4	3	2	1
44. Through FLL, I learned to be more comfortable doing things in new ways.	5	4	3	2	1
45. Being in FLL has made me more curious.	5	4	3	2	1
46. Through FLL, I learned to be more comfortable asking others for advice.	5	4	3	2	1
47. Because I am in FLL, I am better at admitting when I make mistakes and correcting them.	5	4	3	2	1
48. Through FLL, I learned that it's important to work with people who are different from me, for example, people who are from different races or cultures.	5	4	3	2	1
49. Through FLL, I learned that I love it when things change.	5	4	3	2	1

Demographics:

1. Gender:

   A. Male
   B. Female

2. Ethnicity:

   A. Asian/Pacific Islander
   B. Native American
   C. Hispanic/Latino
   D. Black/African-American (non-Latino)
   E. White (non-Latino)
   F. Multi-Racial
   G. Other

3. What is your age today?

   8 9 10 11 12 13 14 Other_____

4. How many youth are on your *FIRST* LEGO League team?

   1 2 3 4 5 6 7 8 9 10

5. How many years, *including* this year, have you participated in *FIRST* LEGO League?

   1 2 3 4 5 6 7 8 9 10