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Building Teen Futures with Underwater Robotics

Michael L. Wallace
Washington State University, mlwallace@wsu.edu

William M. Freitas
Logic Play, williamf@logicplay.us

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Abstract

Preparing young Americans with science and technology skills has been on the forefront of educational reform for several years, and Extension has responded. Robotics projects have become a natural fit for 4-H clubs, with members' experiences ranging from using Lego® Mindstorms® and other "purchase and assemble" robotics kits to building and programming robots from raw materials. This article addresses one such club's impacts on educational engagement, career trajectory, and life skills development. An annotated resource list for engaging youth in building underwater robots is provided in the Tools of the Trade article "Resources for Underwater Robotics Education" in this issue of the *Journal of Extension*.

Michael L. Wallace
Extension Educator
Washington State University Extension
Bellingham, Washington
mlwallace@wsu.edu

William M. Freitas
Lego Serious Play Facilitator
Logic Play
Sarasota, Florida
williamf@logicplay.us

It is a rainy Friday afternoon in Washington, and while many high school youth have gone to graze at the food court of a local mall, a team of exuberant and focused 4-H teens have gathered in what used to be a garage to wield soldering guns and power tools. They organize into small groups to address and debate design problems and make other plans for their underwater robots, which must be ready in a few weeks for a regional competition. The excitement is palpable. This scene begs the question: Why are such opportunities so important and so rare?

Numerous publications have cited declining postsecondary enrollments in computer science and the need for enhanced science, technology, engineering, and math (STEM) skills preparation and opportunities, in particular for U.S. students, females, and minorities (Barker & Ansorge, 2007; National Academy of Science, 2007; National Center for Educational Statistics [NCES], 2005; Salamon, Housten, & Kupersmith, 2008). Through a survey of over 1,000 teens (conducted online October 11–18, 2011, by Penn Schoen Berland), the Intel Corporation uncovered that one of the greatest barriers to youth's entering the engineering field is a lack of exposure to engineering concepts. Of the teens surveyed, only 29% indicated having any familiarity with career opportunities in engineering, and 63% reported never considering a career as an engineer (Intel Corporation, 2011). A review of almost any state's reported standardized test scores reflects that there is an ongoing critical need to enhance science education, particularly for high school youth (NCES, 2005). A particularly noticeable decline occurs in competence in science from middle school to high school, possibly indicating a lack of rigor in earlier grades or a failure to consider the developmental needs of adolescents (Smith & Darflur, 2012). Also, "the low level of science achievement among U.S. high school students appears to be affecting youth in higher education" (Heck, Carlos, Barnett, & Smith, 2012, Background section, para. 4).

As early as 2003, National 4-H work groups were identifying the science, engineering, and technology (SET) mission mandate to help address the shortage of U.S. workers in SET fields. After-school and extracurricular opportunities, such as those offered through 4-H SET programs, can reinforce the cross-cutting concepts of the Next Generation Science Standards and improve youth exposure to and interest in SET fields and, moreover, have resulted in documented improvement in testing scores (Next Generation Science Standards, 2013; Sneider, 2013; Yager & Falk, 2008).

Heck et al. (2012) suggested, ". . . 4-H may have a longitudinal impact on science interest and participation. Exposure to 4-H science-related programming in particular appears to be significantly associated with higher-level science coursework taken in high school" (Discussion section, para. 1). Research by the University of Nebraska on youth's learning STEM through 4-H robotics and geospatial technologies programming suggested a significant increase in youth's mathematical scores and understanding of programming concepts and engineering concepts (Barker, Nugent, & Grandgenett, 2008).

4-H and Robotics

Robotics projects seem to have become a natural fit for 4-H clubs to use to address some of these national needs. Small-group robotics projects and clubs offer opportunities for youth to exercise self-determination and to explore critical thinking and science-related inquiry skills (Papert, 1993). As with other 4-H programming, such 4-H club and project environments also provide suitable emotional and intellectual support. Positive learning impacts associated with robotics in education include better response to high-order knowledge assessments, increased creative thinking and problem solving, increased mathematics skills (Beer, Chiel, & Drushel, 1999; Mauch, 2001; Mukai & McGregor, 2004), and affective by-products, such as improved cooperation and teamwork (Barker & Ansorge, 2007). Even when assessment focused on the impacts of designing and competition with robots, findings suggested that students participating in robotics-related programs learned critical thinking skills beyond the technological orientation of the study (Harmon & Gleason, 2009; Norbakhsh et al., 2005).

Many initial 4-H robotics projects promote and use Lego® Mindstorms® robotics kits and iterations of national curricula (Barker & Ansorge, 2007; Mahacek, Worker, & Mahacek, 2011; Marsh, Miller, & Kerman, 2006). However, more advanced robotics engineering opportunities—effective at engaging and retaining high school–aged 4-H members and helping them enhance their SET skills through the design, engineering, and programming of robots made from raw building materials—also exist. As Barker, Grandgenett, and Nugent (2009) pointed out, ". . . many individual states have undertaken SET initiatives with innovative programs dealing with relatively complex content topics" (Introduction section, para. 2). It is important to point out that youth who are implementing more advanced projects benefit from working with volunteers who have expertise in engineering and science. However, such volunteers do not necessarily have to be involved unless the project skill level makes their engagement necessary. As with other 4-H programming, passionate volunteers having less expertise can learn alongside youth, using numerous beginning-level resources.

A Model Robotics Club

An example of one relevant 4-H club that has been operating for over a decade is the Skagit Exploration and Marine Technology (Sea-Tech) 4-H Club of Washington State. Sea-Tech is a science and technology 4-H club started in January 2001 in Skagit County, Washington. Sea-Tech now creates elaborate custom-designed remotely operated vehicles (ROVs), but the club began with a few power tools, some PVC, and circuit boards. The National Oceanic and Atmospheric Administration (n.d.) offers the following explanation of underwater ROVs:

> [ROVs] are unoccupied robots linked to an operator by a group of cables. Underwater ROVs are usually controlled by an operator aboard a surface ship. Most are equipped with one or more video cameras and lights, and may also carry other equipment such as a manipulator or cutting arm, water samplers, and measuring instruments to expand the vehicle's capabilities. (Remotely Operated Vehicle section)

Sea-Tech was founded to inspire home-school students to pursue STEM-based studies by capturing their imaginations with the excitement of underwater exploration. The hands-on experience provided the students an opportunity to learn and apply basic engineering skills essential to solving complex problems. After the home-school students aligned with 4-H, their opportunities and the popularity of and requests for membership in the club increased substantially.

Club activities encourage the development of critical thinking skills and creative problem solving, advancing members' understanding of a variety of technical areas and the underlying physical principles behind them. Interclub competitions promote teamwork and opportunities for collaboration between members involved in the same technical endeavor. The 4-H approach of promoting teamwork, encouraging public speaking, and providing public educational opportunities is designed to reinforce life skills.

Sea-Tech teams have designed and built at least 40 ROVs for the purposes of demonstration and competition in regional and international events. Each ROV includes video cameras, lights, manipulators, and sensors. The students have assembled and staffed interactive displays for at least a dozen county fairs and numerous school science fairs, and they developed and staffed a showcase display for the Annual Conference for the National Association of 4-H Agents in Seattle, Washington. Also, the club has hosted field trips focused on topics related to science and marine technology.

Since 2007, Sea-Tech has competed in regional and international competitions hosted by the Marine Advanced Technology Education Center. Every competitor is required to use a custom-designed ROV to complete a predetermined set of mission tasks, create a poster display summarizing the ROV project, and present the project to a panel of judges through written and verbal communication. Sea-Tech has won numerous awards and is considered a top competitor, placing even higher than university teams, such as those from the Massachusetts Institute of Technology.

Sea-Tech has remained a high-tier science and technology 4-H club for over a decade and has been a powerful influence in the lives of its members. For the study discussed in this article, educators evaluated current and past members to determine whether the club had influenced youth interest in, knowledge of, and pursuit of science education and careers in science, engineering, and technology. Another measure evaluated was the development of life skills associated with participation in the club.

Instrumentation, Data Collection, Population, and Sample

A web-based survey instrument, using an online survey tool constructed at www.surveymonkey.com, was developed to collect data for the study. Eight items on the survey involved a 5-point Likert scale, with response options ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). These items were relative to interest in science subjects at school and science as a possible career. Another five items on the survey involved a 3-point Likert scale, with response options ranging from 1 (*very comfortable*) to 3 (*not comfortable*). These items were relative to the acquisition of positive work attributes and life skills. The demographics section of the instrument collected information about gender, education, age, and other characteristics.

The instrument was validated for content and face validity by a panel of experts consisting of 4-H faculty and a program leader. The study was approved by the Institutional Review Board of Washington State University. A post hoc reliability analysis was conducted to estimate the reliability of the instrument. Cronbach's alpha coefficient was measured and revealed all subscales to be above 0.80, proving good to excellent internal consistency. Cronbach's alpha reliability for items 1–8 was 0.84 and for the five subscales of item 9 was 0.81.

An email explaining the study and ensuring confidentiality of the answers was sent to prospective study participants. The email also contained the web link for the survey. The population for the study consisted of all those who were past or current club members from 2000 until 2012 (N = 80). Names of and contact information for the prospective study participants were obtained from a list maintained and updated by the club leader. Of the 80 past and current club members contacted, 35 responded.

Results

Educational Engagement

- Eighty-eight percent of respondents agreed or strongly agreed that science and math at school became more interesting after they joined Sea-Tech.

- Sixty-six percent reported doing better in science and math at school as a result of joining Sea-Tech.

- Ninety-one percent reported feeling that involvement in Sea-Tech had helped them have a better understanding of science.

- Seventy-one percent reported that they were motivated to take more science classes in school after they joined Sea-Tech.

Careers in Science

- Eighty-five percent of respondents agreed or strongly agreed they had a greater understanding of the importance of science.
- Eighty-six percent agreed or strongly agreed that they had a better understanding about what scientists and engineers do.
- Seventy-four percent agreed or strongly agreed that they either had gone into or were planning to go into a science, engineering, or technology field in college.
- Seventy-six percent reported that they planned to pursue a science-related career in the future.
- Of the 31% of respondents who had finished their educations, 26% reported that they had gone on to science-related careers.

Life Skills Development

Respondents were asked to reflect on how participation in Sea-Tech improved their leadership, teamwork, public speaking, decision making, and time management skills. Among both male and female respondents, 95% or more reported that they were comfortable or very comfortable exercising each life skill.

Discussion

The evidence that participation in Sea-Tech increased interest and participation in science-related careers is strongly inferred from the reports by 76% of respondents that they plan to enter science-related fields. Thirty-one percent of those respondents reported having finished their educations; 26% of the same group of graduates progressed into science-related careers.

Compared to the finding by Intel Corporation (2011) that only 34% of youth have even considered science careers, responses from the survey discussed here indicate notable success in creating sustained interest and a career path for three quarters of project participants. This result corroborates the statement by Heck et al. (2012) that "the 4-H program has the ability to influence science interest and participation in the long term among its members" (Conclusions section).

Extension is founded in science and research, and faculty frequently serve to educate the public in the arena of science literacy. To the extent that we are inculcating youth in the values of STEM, we are reinforcing the value of the Extension service. Additional research regarding the effectiveness of science-based clubs would be useful evidence of Extension's success. Suggestions for improving the efficacy of program outcomes include pretesting youth entering a project and then comparing initial interest with interest after 1 or 2 years of project participation. One vetted tool for measuring youth interest in science, adapted from the Interest in Science Scale (Paciorek, 1997) and the Competency in Science scale of the Process Skills Inventory (Arnold & Bourdeau, 2009), is available to Extension professionals on the cyfar.org evaluation website. Additional measures that could be explored in future studies include the influences of the adult mentors and teen peer groups that are essential elements of successful program delivery (as compared to the effects of independent project work involving self-guided instructional kits).

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