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Using a PLC+Flowchart Programming to Engage STEM Interest

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Alka Harriger joined the faculty of the Computer and Information Technology Department (CIT) in 1982 and is currently a Professor of CIT. For the majority of that time, she has been actively involved in teaching software development courses. From 2008-2014, she led the NSF-ITEST funded SPIRIT (Surprising Possibilities Imagined and Realized through Information Technology) project. Since October 2013, she has been co-leading with Prof. Brad Harriger the NSF-ITEST funded TECHFIT (Teaching Engineering Concepts to Harness Future Innovators and Technologists) project. Professor Harriger's current interests include application development, outreach to K-12 to interest more students to pursue computing careers, applying IT skills to innovating fitness tools, and wearable computing.

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Brad Harriger has over 30 years of experience teaching automated manufacturing and has authored/co-authored several related articles. Professor Harriger has served in several leadership roles with Society of Manufacturing Engineers and the American Society for Engineering Education, and is a founding member of an international Aerospace Automation Consortium, serving on its steering committee for several years. He has invested over twenty-five years in the development and maintenance of a multimillion dollar manufacturing laboratory facility complete with a full scale, fully integrated manufacturing system. Professor Harriger has been a Co-PI on two NSF funded grants focused on aerospace manufacturing education and is currently a Co-PI on the NSF funded TECHFIT project, a middle school afterschool program that teaches students how to use programmable controllers and other technologies to design exercise games. Additionally, he co-organizes multiple regional automation competitions for an international controls company.

Using a PLC+Flowchart Programming to Engage STEM Interest

Abstract:

Attracting students to STEM remains an important goal in today's society. The first step involves educating students about opportunities and possibilities afforded to STEM graduates. Educational institutions that offer prospective students opportunities for interactive experiences that are enjoyable, memorable, and impactful can yield positive results.

One activity that has been used successfully by the authors involves teaching flowchart programming of a Phoenix Contact's nanoLine controller. The students ranged from middle school to high school as well as middle school teachers. The activities ranged from a one-hour demonstration, to a half-day interactive, instructional session, to a month-long or semester-long, immersive experience. Projects included developing a simple fitness game to innovating a self-contained, commercial-quality, automated system.

The paper and presentation will provide details about each of these varied approaches and share pluses and minuses of each. Information about how others can make use of this technology at low or no cost will also be shared.

Background

There is an insufficient number of youth pursuing STEM subjects, resulting in a large gap of qualified workers for STEM jobs. [1] Increasing access to hands-on learning to spark STEM interest and bridge the STEM attraction gap is a recommended strategy. [2] Numerous approaches have been taken by academic institutions to spark STEM interest in young people. Approaches range from one hour hands-on activities focusing on one aspect of STEM to multiple-day programs that devote small amounts of time to several STEM topics. Regardless of the actual approach used, all of the following concepts are covered:

1. Critical thinking
2. Programming
3. Engineering through the application of automation using programmable logic controllers to monitor and control physical devices.

In the following sections, the authors share three different approaches, all involving the same programmable logic controller (PLC).

Nanoline Microcontroller

There are a number of PLCs from different companies available in today's market offering a variety of features and functionality. [3] [4] The PLC used by the authors is a small, relatively inexpensive industrial controller called the Nanoline. [5] Figure 1 shows the 24-volt base unit which has eight digital inputs, two analog inputs, and four relay digital output channels. Extension modules can allow the developer to add more digital and analog channels to the automated system being designed.

The Nanoline PLC is manufactured by Phoenix Contact, a German-based controls company that manufactures products and solutions for all aspects of electrical engineering and automation. [6] The US headquarters of Phoenix Contact is in Harrisburg, Pennsylvania. The Nanoline offers functionality similar to PLCs available from companies that include Allen Bradley and Siemens; however, the Nanoline offers the option to develop programs for the controller through the creation of flowcharts, making it the easiest to learn tool for novices.

Input and output components can be easily wired through slots above and below the Nanoline controller. For instructional purposes, input and output simulation boards are available to demonstrate control of input and output without requiring additional time to discuss the intricacies of wring actual devices to the controller. The simulator boards are easily plugged into the input and output slots to aid testing. Although the Nanoline is a compact microcontroller, it has been used to create both simple and complex physical systems for a variety of domains.

Figure 1 Nanoline 24 volts base unit

There are two options for programming the Nanoline: ladder diagrams or flowchart programs. Although ladder diagrams are more common in industry, flowchart programming is more easily understood by younger and/or beginner programmers. A built-in simulator allows the student to watch the flow of control in the flowchart as well as see the changing states of input components, output components, registers, timers, counters, etc. Figure 2 illustrates this feature. According to Payne, unifying the programming environment reduces the learning curve and development time [7], and the authors' experiences show this to be true with the flowcharting software's integration with the built-in simulator.

Engaging Groups with the Nanoline Contest

The Nanoline contest is a free-to-enter competition that is open to middle and high school teams of two to six students. The contest provides the students with opportunities to acquire technical, STEM-related skills and showcase their talents and abilities in designing and fabricating an automated system. Applications are accepted in the fall of each year. Beginning in late August, student teams consisting of one mentor and up to six students are invited to submit their project ideas to Phoenix Contact for consideration. Teams accepted into the competition receive a toolkit valued at $550 and a gift card to help purchase other components and materials to construct their team's project. The toolkit includes a Nanoline base controller, an operator panel, two IO expansion modules, a power supply, DIN rail, circuit breakers, terminal blocks, and a few tools. If a team needs another component in the Phoenix Contact product line, all they have to do is explain how they will use it in their project to receive it.

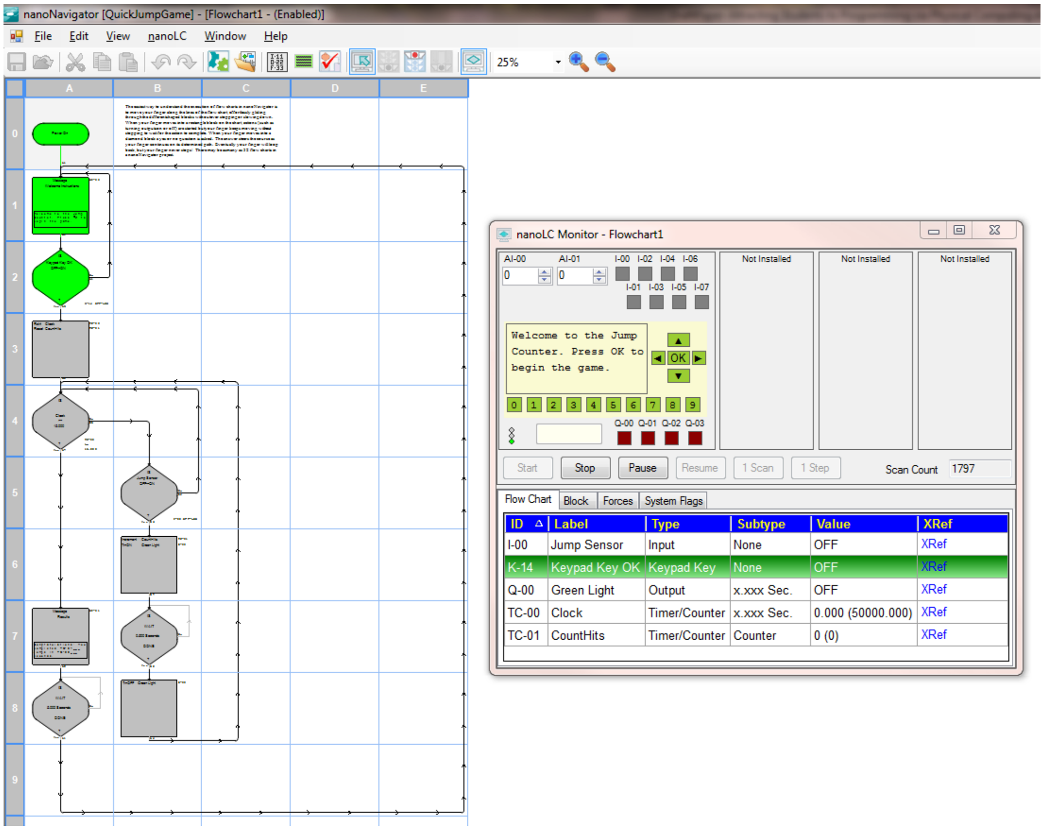


Figure 2 NanoNavigator showing flowchart execution with simulator

Each team has until early February of the following year to complete their project. Regular reports on their progress are required to pass several checkpoints and remain in the contest. Currently, there are three separate regional events for this contest: the original is in the Northeast (Elizabethtown, PA); the second added regional is in the Midwest (West Lafayette, IN); and the most recently added regional is in the Southeast (Charleston, SC). Teams that pass the January checkpoint are invited to compete in their regional event. The top two to three teams at each regional are named national qualifiers and earn the chance to compete in the national contest in Harrisburg, PA, at Phoenix Contact's US headquarters. Figure 3 shows the national winning projects from the past two years, both teams from the Midwest.

In order to give each team unfamiliar with the technology, the authors offer an optional, one-day training workshop for teams in the Midwest and Southeast regionals. Workshops provide teams with important information on basic electricity, safety, controller assembly and wiring, programming, program verification and controller operation. Before leaving the workshop each team will have assembled their PLC kit, wired in a pushbutton and a photo sensor input, and one light output. Additionally, each team will have written a program that uses sound programming concepts and logic that uses the devices they wired in as well as several embedded features including timers, counters, registers, and math functions.

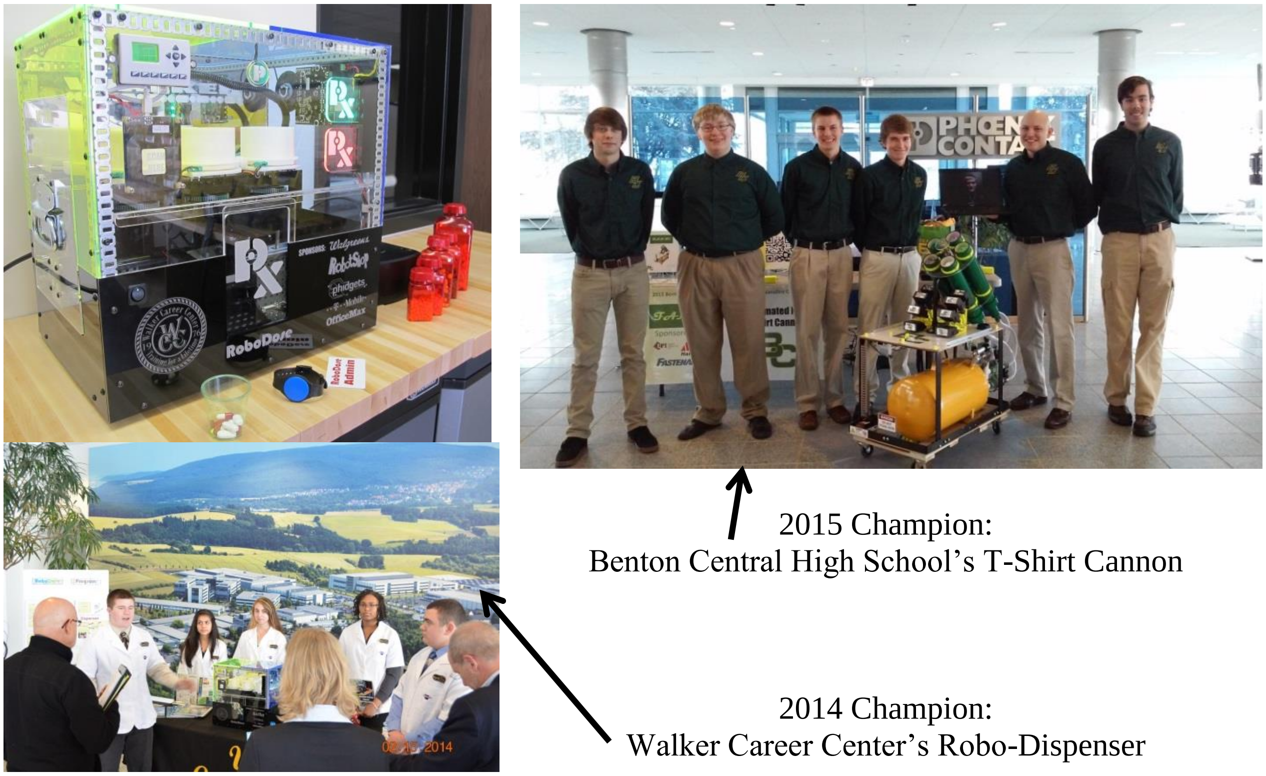


Figure 3 National Contest Championship Teams and Projects

Sparking Interest in Middle Schoolers through TECHFIT

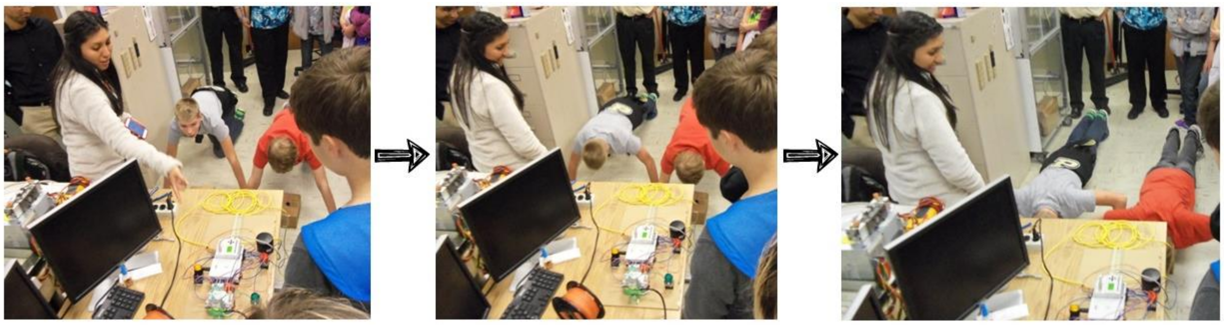
The second approach to engage student interest in STEM is through the NSF TECHFIT project. TECHFIT is an acronym for Teaching Engineering Concepts to Harness Future Innovators and Technologists. “TECHFIT includes a professional development program for teams of middle school teachers to equip them with technology, skills, and the knowledge needed to create their own exergames. They, in turn, run the equivalent of a ten-week afterschool program, under the guidance and support of the TECHFIT staff, in which they share the same lessons with their students to accomplish the objective of their students to innovate their own exergames. The experience is designed to inform, educate, excite, and reinforce the importance and value of STEM through team-based innovation. A side benefit causes the participants to engage in more regular physical activity.” [8]

TECHFIT participants use the same Nanoline controller; however, the toolkit they receive is valued at $4500 because it is supplemented with many additional electronic components by multiple vendors. In addition, in TECHFIT, the teacher participants complete an intensive, six-day educational program and a 230-page illustrated workbook with detailed instructions on programming, wiring, and construction of projects. The teachers then run a 10-week afterschool program for their students in which they teach the same things to their students.

TECHFIT is offered in two states: Indiana and South Carolina. Unlike the openness of the project ideas for the Nanoline contest, TECHFIT participants innovate projects that are considered technology-supported fitness games or exergames. The culminating activity of the afterschool program for each of the student teams is an opportunity to present and demonstrate the exergame innovations at the host institution. Figure 4 shows a demonstration exergame used during TECHFIT instruction and some exergames designed by the 2015 championship student teams.

Comparing the Approaches

Both approaches share some benefits. For example, by using the Nanoline controller, both approaches give students exposure to concepts and equipment used in industrial automation. Another shared benefit of both approaches is through their competitive nature, which seems to provide inspiration and motivation to the students. Phoenix Contact also provides no cost technical support in both instances. Nonetheless, there are advantages and disadvantages that are unique to each approach.



Students try out a pushup competition exergame

2015 Indiana Showcase Champion Demonstrates Playing their Exergame

2015 South Carolina Showcase Champion Explains and Demonstrates their Exergame: Escape from Alcatraz

Figure 4 TECHFIT Championship Teams' Exergames

An important benefit of the contest as an approach for engaging student interest in STEM is that it is open to any team of two to six middle or high school students who can find an adult mentor, such as a teacher or parent, and conceive of an automated system. Once this information is provided on the application, they are considered a registered team, which is sufficient to receive a basic toolkit and gift card. Although the contest sponsor places minor restrictions on the size of the project, primarily for shipping and display purposes, the function and purpose of the automated system is wide open, allowing the students to be very creative.

Even though the contest's advantages make this opportunity available to anyone, it does have distinct disadvantages. The toolkit is very basic and does not include input/output devices such as sensors, push buttons, lights, so these must be acquired. Additionally, there are very limited instructional resources to help new users get started. The authors have offered jump start workshops near the start of the build season for the contest; however, their experiences have shown that very few teams inexperienced with the system who do not attend the jump start qualify to compete at regional contests. Finally, each team is limited to no more than six students; however, there is no limit on the number of teams a particular school or organization could enter in the contest. In fact, one year a school had entered three teams.

The TECHFIT approach has several significant advantages. The selected schools receive a higher-end toolkit with a variety of input/output components, wires, and an illustrated instructional workbook. They also receive extensive, hands-on instruction on programming, building, and testing. Teachers design, build and test a functional proof-of-concept system to demonstrate their understanding of concepts taught. Thus, they are better prepared to mentor their students when they conduct the afterschool program. Additionally, multiple teachers from the same school must complete the training, so there are built-in backups for support at the school. Furthermore, like the contest, there is no cost for the TECHFIT schools, teachers, or students. In fact, each teacher can earn up to a $1200 stipend, and the school can receive modest financial support for afterschool snacks and transportation for the students.

The TECHFIT approach also has some disadvantages as an approach for engaging student interest in STEM. The nature of the program severely limits the number of schools that can participate in a given year. Additionally, TECHFIT requires a commitment by two to five teachers from the same school to complete a residential, six-day program during the summer. There have been several schools unable to participate due to schedule conflicts with the training, inability to be in residence for the program, or having only one teacher willing or available to attend the training. A final disadvantage of the TECHFIT approach is that the funding for the program is limited. After that, offering TECHFIT will involve a fee-based system unless additional funding is raised.

Conclusion

Everyone agrees on the importance of encouraging today's youth to consider STEM fields of study. Providing students with hands-on opportunities in which they learn about STEM and use the knowledge gained to build functional products is an ideal first step. This paper presented two no-cost opportunities that show students how STEM can be fun, impactful, and useful in solving problems and taking advantage of opportunities. Testimonials from TECHFIT participants are available online. [9] The presentation will share comments from contest participants about their experiences.

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