AC 2011-2224: WORKSHOP- ROBOTICS IN URBAN STEM EDUCATION: THE PHILADELPHIA MODEL

Velda V. Morris, M.S.Ed., School District of Philadelphia

Velda Morris is the Robotics Education Specialist in The School District of Philadelphia's Office of Secondary School Reform/Division of College Readiness, she functions as a results-oriented administrator who excels in science, technology, engineering and mathematics (STEM) initiatives, and brings research experience in the STEM areas and robotics. She designed and oversees the Secondary Robotics Initiative (SRI), one of the District's most promising initiatives. SRI is conducted in sixty-two schools; some of the neediest schools in The School District of Philadelphia, providing engaging, hands-on educational opportunities proven to enhance learning in STEM.

Velda was appointed as the nation's first African American Boosting Engineering Science and Technology (BEST) Hub Director. She was elected onto the BEST Robotics Board of Directors, in recognition of her expertise and sincere interest in the objectives of the organization; she is the District 6 representative for east coast Hubs now in Connecticut and Pennsylvania. She's the Co-Director of the Philadelphia FIRST LEGO League (FLL) Championship, on the leadership team of the Pennsylvania Girls Collaborative Project, Pennsylvania STEM Compact, and became one of the first African American elected officers of the Society Manufacturing Engineers, Chapter 15, (since its inception in 1936) with over 300 members; and reelected in 2011.

Ms. Morris has conducted STEM presentations nationally. She published a book on "Robotics a New Extracurricular Activity in the New Millennium", and published with teams of teachers two books with their students on technology and generational issues. She was a resource team leader for a Philadelphia middle school and instrumental in their receiving a partnership grant from NASA; making it the first school in the state to ever be named a NASA Explorer School. In 2009, Velda was the co-author and instrumental in launching a regional Workforce Innovation in Regional Economic Development (WIRED) grant bio program called "MARBLES", $107,000 grant. MARBLES served as a demonstration project for a regional mathematics, engineering and science initiative to accelerate achievement in life science domains for minority students ages 16 and older in DE, NJ and PA.

AT&T and NCCEP selected one recipient for the state of Pennsylvania and Velda was the solitary winner of the $50,000 grant to "prepare tomorrow's innovative leaders in technology". Yearly, Ms. Morris partners with the colleges of engineering at Villanova University and University of Pennsylvania; to host land and sea robotics competitions. All of her robotics tournaments have national or international platforms and she was instrumental in the development and national launch, of the Greater Philadelphia Sea Perch Challenge (underwater robotics) in Philadelphia, through the Office of Naval Research and the Naval Sea Systems Command (NAVSEA). In 2010, partnering with the Mechanical Engineering Department at Villanova University and Video Ray, they launched the Marine Advanced Technology Education (MATE) Pennsylvania Regional Remotely Operated Vehicle (ROV) Challenge, the first in the state of Pennsylvania.

Ten of Ms. Morris' robotics program schools were given commendations by the Mayor of the City of Philadelphia and BEST Practice Awards by the School District of Philadelphia. She's appeared on Philadelphia's WURD, Carole's Corner on Technology , presented at the National Council for Community & Education Partnerships (NCCEP) Conference, National Education Computing Conference (NECC), International Technology Education Association (ITEA) Conference, National Alliance of Black School Educators (NABSE) Conference , Boosting Engineering Science and Technology(BEST) Conference, the National Science Foundation (NSF) Data Conference, and the American Society of Engineering Education (ASEE) Conference .

Velda received the highest Pennsylvania Graduate Education Award for her thesis work on extracurricular STEM programs, West Chester University 3E Institute Director's Award for Educational Excellence and Entrepreneurship and also selected as a 3E Ambassador. Ms. Morris is a member of the PA STEM Initiative Network, National Society of Black Engineers (NSBE), Philadelphia Alliance of Black School Educators (PABSE), Society of Women Engineers (SWE), and associate member of the American Institute of Aeronautics and Astronautics (AIAA). Ms. Morris is on the Community College of Philadelphia School of Technology & Business Advisory Board and a member of the Pennsylvania STEM Compact.

As Founder/Co-Chair of the Urban STEM Strategy Group which is an advisory and advocacy coalition, assisted in leading group members (including representatives of Pennsylvania's regional and statewide

STEM Initiatives) toward the goal of strategically and intentionally increasing the participation of minority children and adults in Pennsylvania's various STEM pipelines.

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Rebecca A Stein, University of Pennsylvania

Rebecca Stein is the Associate Director of Research and Educational Outreach in the School of Engineering and Applied Science at the University of Pennsylvania. She received her B.S. in Mechanical Engineering and Masters in Technology Management from Villanova University. Her background and work experience is in K-12 engineering education initiatives. Rebecca has spent the past 5 years involved in STEM high school programs at Villanova University and The School District of Philadelphia. Additionally, she has helped coordinate numerous robotics competitions such as BEST Robotics, FIRST LEGO League and MATE.

James F Keller, University of Pennsylvania

James Keller is currently a part-time Ph.D. student in Mechanical Engineering at the University of Pennsylvania and a staff engineer in the GRASP lab. He received his Bachelor degree from Drexel University in 1981 and a Master degree from Stanford in 1986. He enrolled at Penn after a 20+ year career in helicopter flight controls and handling qualities with the Boeing Company. Over the years, he has supported design, simulation, and flight test of all Boeing rotorcraft products. At Penn, he has been active in GRASP Lab robotics outreach programs with local FIRST Robotics teams at the high school level since 2004 and at the middle school level since 2007. Jim has been a Summer Academy Robotics instructor at Penn since the program's inception in 2005. He is studying path planning for autonomous air vehicles in surveillance and reconnaissance applications.

Dr. Vijay Kumar, University of Pennsylvania

Robotics in Urban STEM Education: The Philadelphia Model

Abstract

Overcoming obstacles in urban education for over a decade, the School District of Philadelphia's Secondary Robotics Initiative and the School of Engineering and Applied Science at the University of Pennsylvania have transformed the way students learn STEM[1]. In fact, emerging evidence suggests that opportunities to learn through robotics can transform both the level of engagement and motivation of minorities to persist in STEM[1]. In a district composed of under-resourced learners (76% economically disadvantaged) and those typically underrepresented in STEM fields (62.4% African American and 17% Latino in the School District) [2] the challenges to implementing a structured robotics program are apparent. The University of Pennsylvania and School District of Philadelphia rely on a successful partnership in order to close the STEM equity gap, enhance learning, and increase access and awareness, for students, teachers, parents and community members.

Introduction

The collaboration between the Secondary Robotics Initiative (SRI) and School of Engineering and Applied Science (SEAS) serves as a model of a sustainable K-12 and university partnership. The Secondary Robotics Initiative provides pre-engineering programs for 6th -12th grade students. Linked with the GRASP[3] (General Robotics, Automation, Sensing and Perception) laboratory at SEAS, the SRI empowers both students and teachers while effectively increasing students' interest and excitement about STEM. SRI, with SEAS, teaches students how to problem-solve, design, and create in ways not commonly found in the classroom.

When properly structured, university partnerships can enhance how middle and secondary students are taught, challenging them to become more empowered performers. The partnership between the SEAS and SRI was designed to increase students' performance when competing nationally on Boosting Engineering, Science, and Technology (BEST)[4], FIRST LEGO League (FLL)[5] and Marine Advanced Technology and Engineering (MATE)[6] robotics competitions. Strategic partnerships such as this depart from traditional science education methods. The program design ensures that all students, regardless of learning hardships, have opportunities to work on independent projects, conduct experiments, solve open-ended problems, and be involved in activities that make connections between competition themes and coursework. At the 2006 BEST Robotics local competition, a team of special needs students from School District of Philadelphia High School won the highest award, BEST Overall, allowing the team to move onto the regional competition in Auburn, Alabama. In May of 2010 another School District of Philadelphia High School robotics team (97.2% African American, 83.6% Economically Disadvantaged[2]), under the mentorship of the Robotics Lab at the University of Pennsylvania, placed second in the MATE ROV Challenge and was sent to the international competition in Hilo, Hawaii where they tied for fourth in poster presentation.

Figure 1: BEST Robotics Champions (2006) and MATE ROV Champions (2010)

Importance of Robotics Education

The field of robotics is celebrating its 50th anniversary[7]. While the primary achievements of the field are primarily connected to increased accuracy and through input for automation in specific repetitive tasks, such as welding, painting, and machining, in hazardous, high volume manufacturing environments, the last five years have seen tremendous advancements enabling a new generation of applications in fields as diverse as agile manufacturing, logistics, medicine, healthcare, and other commercial and consumer market segments. In addition to contributing to the manufacturing and service sector, robotics is playing an extraordinarily important role in homeland security and defense by preventing highly trained soldiers from coming in harm's way and providing persistent surveillance in harsh environments, which ultimately minimizes the loss of human life. As the recently released Computing Community Consortium Roadmap[8] notes, "… these early, next generation products are a harbinger of numerous, large scale, global, robotics technology markets likely to develop in the coming decade." And "… next generation, "robotech" industry will eventually affect the lives of every American and have enormous economic, social, and political impact on the future of our nation." It is clear that our nation needs a workforce that is well trained in the basics of the robotic technology and the SRI with its many partners is training the next generation to fill those spots.

While one cannot deny the need for education and training in the science and technology underlying robotics, there is another significant benefit to focusing on robotics. Robotics, by definition, is an interdisciplinary field and it offers a broad-based education. In today's quickly changing technological environment, such a broad education is preferable[9]. A second benefit of teaching robotics is that as a subject, robotics lends itself to top-down education[10]. It is possible to start teaching robotics and injecting engineering and design content into a student's learning at a very early stage[11-14]. This provides perspective to beginning students[15], who currently perceive that engineering consists only of theoretical physics and mathematics.

Secondary Robotics Initiative Model

Founded in 2000 by a female minority science educator, SRI has grown from an after school robotics club to a district wide model for STEM education. As of 2011, the SRI continues to be managed by the founder. Over 60 elementary/middle and high schools participate in the initiative

with nine schools offering in-classroom robotics education as an elective course. As the district has struggled to address remedial tests scores, the focus on STEM has often taken a back seat to more immediate needs of basic education and literacy. In fact, prior to the *Rising Above the Gathering Storm*[16] report from the National Academies, STEM education was considered a luxury by some administrators and an exotic niche by others. The net result is limited access to funding and resources, requiring SRI to develop strategic partnerships to ensure the use of effective practices and programs. The SRI, in partnership with multiple universities and corporations, now supports three annual robotics competitions, multiple platforms, and ancillary exposure activities for under represented students in the nation's 8th largest school district. The SRI pyramid model shown in Figure 2 displays the major components of the initiative.

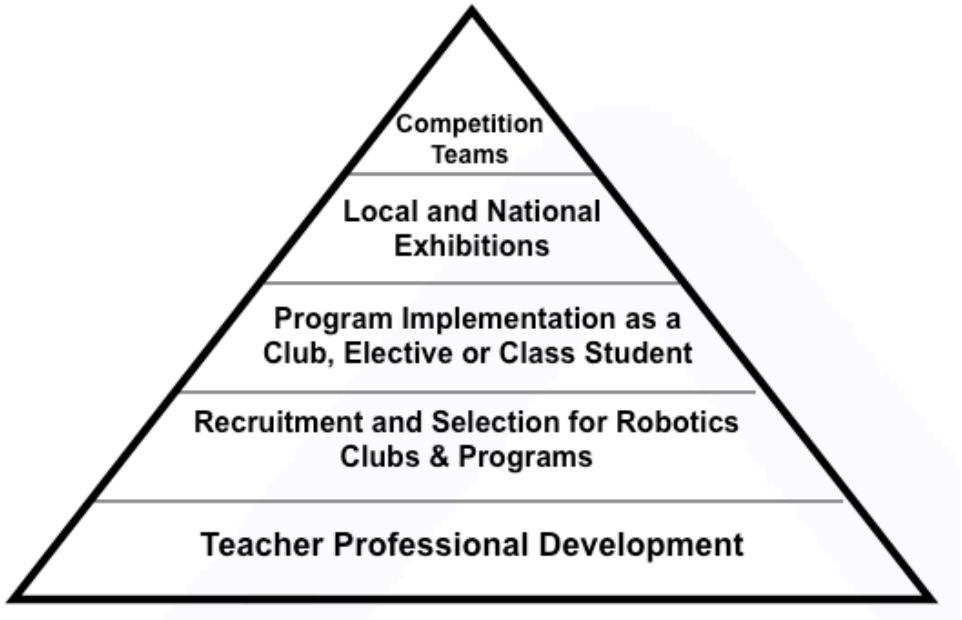

Figure 2: SRI Pyramid Model

The foundation of SRI lies in the successful development of robotics educators and the fostering of open communication channels between parents, students, teachers and administrators. The SRI is overseen by the robotics education specialist and a steering committee made up of stakeholders within the District and in the local community. While the Robotics Specialist for the District manages the program, there are many individuals who contribute to the program's success. An organizational chart of the SRI is shown in Figure 3. In order to strengthen program awareness in the District, the Robotics Specialist attends principal meetings, gives presentations at counselor meetings, publishes information about events in newspapers and bulletins, and hosts open houses. Program exposure is an essential element to ensuring continued support from the District administration and community.

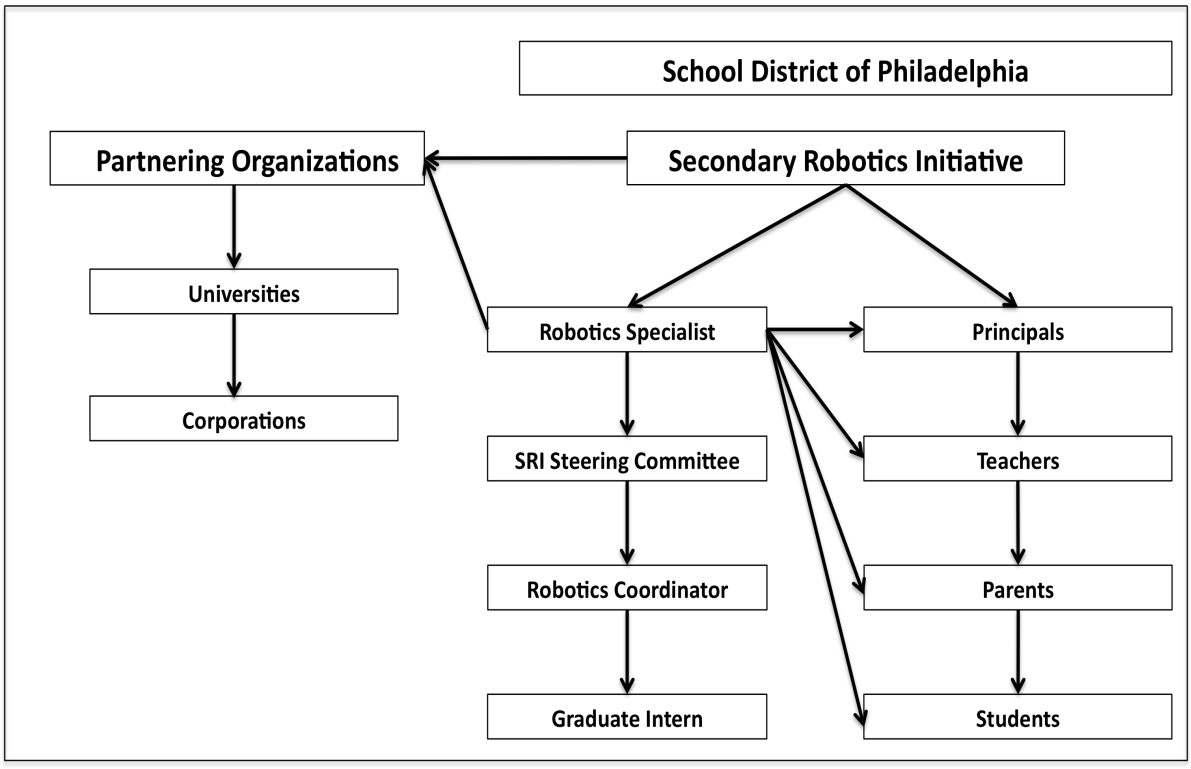

Figure 3: SRI Organizational Chart

SRI seeks to engage students in project based inquiry learning throughout the academic year and provides resources for students to stay involved in STEM programs during the summer months. Figure 4 shows a detailed schedule of SRI events and programs. While various skills are necessary to be successful in robotics, SRI separates the year into manageable learning units. In the fall robotics educators develop skills in manufacturing, mechanical design and computer-aided design to prepare their students for the Philadelphia BEST Hub Robotics Competition. In the winter, middle school robotics educators learn basic programming using the LEGO MINDSTORMS NXT system. The spring MATE Pennsylvania Regional ROV (remotely operated vehicle) Challenge test both middle and high school students to use skills leaned in previous competitions and apply that knowledge to the underwater environment. Figure 5 shows students participating in BEST, FLL and MATE competitions. Teams also have opportunities throughout the year to participate in workshops and conferences such as the Black Engineer of the Year Awards, Maryland Mathematics Engineering and Science Achievement (MESA), and the National Science Teachers Association. The SRI season ends with a preparing tomorrow's leaders' technology symposium, where STEM professionals from around the region conduct presentations and workshops for SRI students.

	Duration	Event	Participants
August	2 Days	Philadelphia BEST Hub Robotics Professional Development- Workshops on CAD, Robot Design and Construction, VEX System	M/H Educators
September	1 Day	Philadelphia BEST Hub Robotics Kick-Off and Workshops- Workshops on teamwork, oral and written communication, tool safety	M/H Teams
October	1 Day	Philadelphia BEST Hub Community Practice Day- an opportunity for teams to practice on the playfield and exchange ideas with other teams before the competition.	M/H Teams
November	1 Day	Philadelphia BEST Hub Robotics Competition	M/H Teams
November	5 Days	South's BEST Regional Competition	Winning Teams
December	1 Day	Philadelphia FIRST LEGO League Professional Development - Guided lessons on the LEGO MINDSTORM NXT system.	M Educators
January	1 Day	Philadelphia FIRST LEGO League Professional Development 2- Guided lessons on the LEGO MINDSTORM NXT system.	M Educators
February	1.5 Days	Pennsylvania MATE Regional ROV Challenge Professional Development- Educators build an underwater ROV from start to finish with the assistance of marine technologists.	M/H Educators
March-May		Pool practice sessions at local swimming pools for teams to test their ROV's.	M/H Teams
May	1 Day	Pennsylvania MATE Regional Underwater ROV Challenge	M/H Teams
June	5 Days	Pennsylvania MATE International ROV Competition	Winning Team

M-Middle School, H-High School

Figure 4: SRI Schedule of Events

Figure 5: Students participating in (from left to right): FIRST LEGO League, BEST Robotics, MATE ROV Competition.

Secondary Robotics Initiative Students

Data gathered regarding students who participate in robotics indicates that these students are achieving above average, based on a sample from each of the three main robotics platforms from schools years 2008-09 and 2009-10. This sample is based primarily on The School District of Philadelphia students, as the information is available through an internal data system[2], where information for students from non-District schools is limited to what is collected on sign-in sheets (this issue and gaps in internal system data influence sample size for each chart).

Demographically, SRI students tend to include slightly more white, Asian Pacific and Latino students than the district as a whole (eight percent higher for whites, two percent higher for Asian Pacific students, and four percent higher for Latinos) (see figure 6 left panel). Robotics students range from under 5th grade up to 12th grade students.

All students in Pennsylvania take Pennsylvania System of School Assessment (PSSA) exams in areas such as math. Figure 6 (right panel) shows the 2008-2011 math scores for SRI students. Figure 7 shows the high school GPA of SRI students for the 2009-10 school year. The District average is 2.00, a "C" average; 86 percent of SRI students are at or above this level.

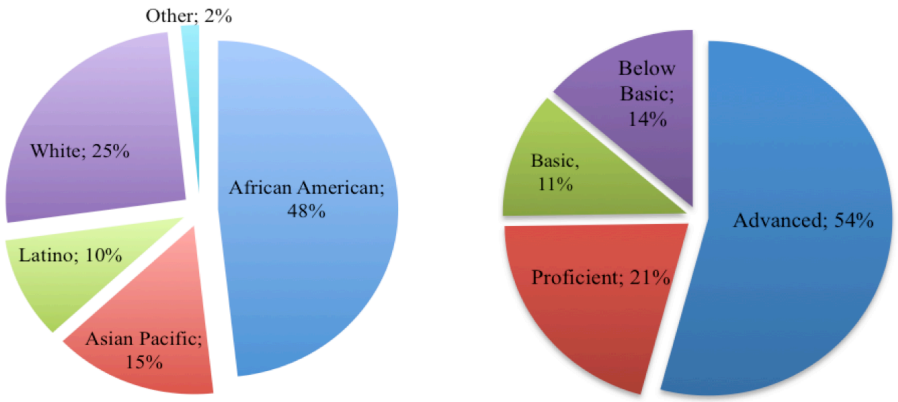

Figure 6: SRI students by race, n=489 (1), SRI students by PSSA math scoring group from the most recent test at the appropriate grade level, n=327 (r).

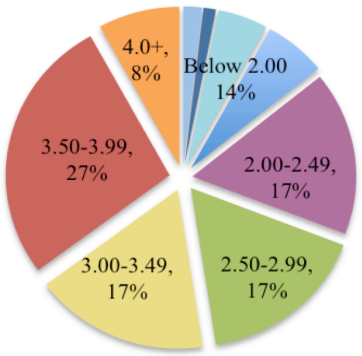

Figure 7: SRI high school student participants by GPA, n=162.

University and Corporate Partnerships

The success of Science, Technology, and Engineering and Math (STEM) programs relies heavily on authentic partnerships. True partnerships are not just a transfer of monetary resources, but a combination of time, effort, access to cutting-edge technology and world-class laboratories, etc. Partnerships require commitment from all individuals and groups involved, in the case of underrepresented minorities, an evolving level of social and institutional cultural competence is also required.

Why are partnerships so important to the continuation of these vital programs? One of the largest national deficits is the lack of STEM professionals, educators, and students currently studying in the science and technology fields. It is imperative that we combine our resources to provide a multi-faceted, culturally rich, unique learning experience, where students from all socio-economic backgrounds can flourish academically.

Over the years SRI has partnered with many organizations from various industries and backgrounds, but all related to the STEM fields. Society of Manufacturing Engineers, Society of Women Engineers, National Society of Black Engineers, National Alliance of Black School Educators, Video Ray, NASA, Atlantic Scuba Club, Navy League, and many universities in our region. These are just a few examples of vibrant partnerships that sustain an urban research-based robotics initiative.

Robotics Educator Professional Development

Today's technological leaps and bounds mandate all chief executive officers, chief academic officers, associate superintendents, directors of instruction, supervisors and specialists to professionally develop all educators responsible for imparting technological knowledge upon our future workforce. Quiet as it is kept, educators do want to enhance their knowledge, incorporate best practices in teaching, share with others their strengths, and want rostered additional time to just be better instructors. A whole professional paradigm shift had to occur in the past decade, and into the next, to assist educators in responsibly preparing students for current and future post secondary pursuits and workforce internships.

Robotics is presented as a trans-disciplinary approach to learning. Professional Development sessions are designed in alignment with Pennsylvania's math, science, technology and engineering standards.[17] Teachers are encouraged to understand the world of robotics and provide a framework for applicable 21st century practices. The following list describes SRI professional development activities:

1. Developed technology rich learning environments: University of Pennsylvania provided 12 sessions on C++ instruction, 3 sessions on hands-on sensor applications, and 6 on NXT programming and field tested robotics curriculum.
2. Utilized information resources and innovative methods to support learning: Community College of Philadelphia provided 2 nanotechnology hands on laboratory lessons (yearly national robotic themes change as do the professional development content focus).

3. Demonstration of innovative professionals: Drexel University provided students and teachers 3 sessions on VEX design and construction.
4. Created learning environments for diverse learning styles: Villanova University provided 6 lessons on computer-aided-design and programming.

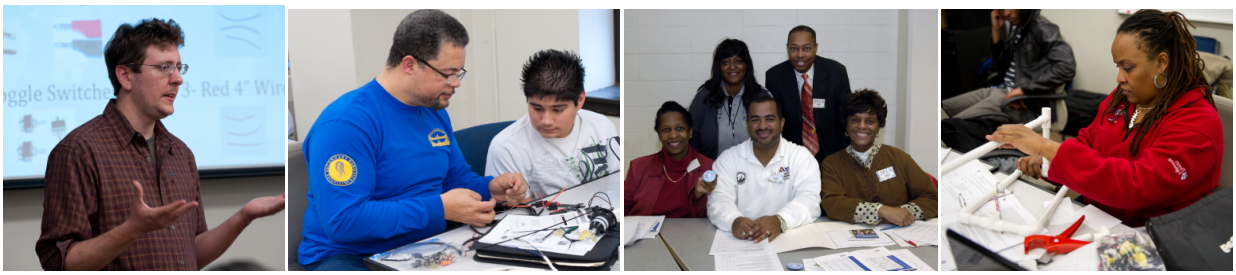

Figure 9: Professional Development Session Pictures

After each professional development there is an immediate witnessing of the integration, application and mastery of deeper conceptual knowledge about intelligent systems/robotics. The robotics educators bridge the digital divide thereby creating students who were not just technology consumers but producers.

FIRST LEGO League Support and Mentoring

To prepare students and teachers/coaches for the FFL competition, each year the SRI and SEAS provides two formal Lego NXT training sessions sponsored by the GRASP Lab. approximately 50 and 25 days prior to the match. These are hands-on workshops developed for the teachers/coaches to enable them to fully understand how the Lego system works in the context of the actual FLL challenge. Teachers are provided with educational presentation material and software they can then use with their own respective teams. In this regard, the SRI does not provide solutions that can be duplicated but rather provides the expertise so that students can then tailor their own ideas to the FLL challenge. The workshop includes a primer on how to use mathematics to determine the motion of a generic robot based on motor commands. Lego software developed by the GRASP Lab is also provided so students can experimentally verify the parameters derived mathematically in the primer. At this stage many teams then try to jettison design calculation in favor of trial and error approaches. To maintain a STEM focus, the GRASP Lab also provides examples where the use of mathematics can actually make the design and testing of a robot easier than if calculations were avoided. This is considered to be a key for success at the middle school level. Students are generally ready to believe that mathematics can be applied to robot design but they would still prefer to avoid it because it can appear too daunting or diminish the fun. When they are shown it is actually easier and faster to implement motion commands when some basic math is applied, they are then more likely to keep mathematics in their proverbial toolbox and use it to increase the fun they have by gaining a stronger sense of achievement. The range of material presented in these workshops is presented in the figure below. Following the workshops, the SRI provides an email help-line for teams to forward their questions. Each year, by request, the

GRASP Lab also makes "house-calls", especially to directly tutor teams competing for the first time. Since some schools run their Lego robot clubs throughout the school year, after the FLL season, the SRI continues it engagement by visiting these schools to show them other cool projects they can design.

FIRST Lego League Teacher Familiarization Workshop Curriculum

- Basic Lego NXT programming
- Basic motion commands: driving and turning – theory and practice
- Lego NXT programming and hardware tips:
  - Sensors – how they work and how they are calibrated
  - Advanced motion commands – sensor enabled motion
  - Advanced program structures
- Data-logging and display techniques
- FLL Challenge tips
  - Rules overview
  - Assessment of level of difficulty of each FLL mission
- A guide to engineering design process
  - A guide for translating FLL challenge missions into NXT programs

Figure 10: SRI/GRASP FIRST LEGO League Workshop Curriculum

RoboMentors Program

The RoboMentors program was developed by the GRASP Lab to support SRI programs and teams. The program engages 15 undergraduate and graduate students yearly to support four School District of Philadelphia high school robotics teams participating in the BEST and MATE competitions. Figure 11 shows the percentage of students at the mentored schools who are considered typically underrepresented in STEM fields. Students join the program from many different engineering disciplines and volunteer three to five hours per week with their team. The RoboMentors program was designed to support the university students, teachers and teams through the process of mentoring. RoboMentors spend the beginning of the semester training for their experiences in the classroom. Additionally, robotics teams are invited to campus prior to each competition for engineering workshops taught by the robotics mentors.

Elverson-PMA	63.1% African American 30.9% Hispanic	83.2% Economically Disadvantaged
Overbrook	97.2% African American 1.5% Hispanic	83.6% Economically Disadvantaged
Paul Robeson	97.2% African American 2.4% Hispanic	73.5% Economically Disadvantaged
George Washington	30% African American 11.9% Hispanic	57.7% Economically Disadvantaged

Figure 11: Demographic Information of Mentored Teams[2]

The robotics teams develop strong bonds with their mentors. As a result, the impact on both university and high school students is apparent. During the 2010 BEST Robotics competition, two of the four teams who were mentored by the University of Pennsylvania advanced to the regional competition. University of Pennsylvania students also mentored the second place wining team in the 2010 MATE competition. Figure 12 shows one of the undergraduate student mechanical engineering mentors with his team. He has since gone on to pursue teaching with Teach for America.

Figure 12: RoboMentor and Team

Conclusion

The SRI model is a partnership driven approach to STEM education that is empowering and engaging for the SRI students and teachers. The partnership's design ensures students will have the opportunity to exchange their ideas about STEM, understand how they are being used in the world today, and realize the effects upon their future lives. SRI students' attitudes towards education and belief of what they can achieve academically have changed dramatically. SRI and its many partners strive to close the equity gap in urban STEM education through developing lessons and materials that finally cross ethnic, socio-cultural and gender barriers.

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