

## **AC 2008-454: STEPS ALONG A ROBOTICS TECHNOLOGY CAREER PATHWAY**

### **David Landis, The Technology Collaborative**

Dave Landis received the BS EE degree from Carnegie Mellon, MS from the University of Pennsylvania, and PhD from the Pennsylvania State University. His industry experience includes work in reliable and fault tolerant computer / chip design for RCA and Honeywell. He has been an Electrical Engineering Professor at the University of South Florida and at Penn State, doing research and teaching on the subjects of embedded systems, chip design and test. He is currently Vice President, Education and Training at The Technology Collaborative where he is responsible for career pipeline, professional and workforce development, and University education programs.

### **Stan Komacek, California University of Pennsylvania**

Stan Komacek earned a BS from California University of Pennsylvania, MEd from Miami University, and EdD from West Virginia University. He served as the Project Director for the PA State System of Higher Education in PA's Nanofabrication Manufacturing Technology Partnership and for the PA Governor's Institute for Technology Education. A Professor of Technology Education and Chair of the Department of Applied Engineering and Technology at California University of PA, Dr. Komacek is currently PI and Project Director for the NSF ATE Advanced Manufacturing in PA Project.

### **Carol Adukaitis, PA State System of Higher Education**

Carol Adukaitis received a BSED degree from the University of Delaware, an MSED from Bloomsburg University, and a DED from Temple University. She has been a faculty member at Reading Area Community College, Temple University, an adjunct at Montgomery County Community College, and has held the position as Industry/Curriculum Coordinator at several Career and Technology Centers. She has served as a PA Department of Education Evaluator for ten Governors Institutes and was a consultant for NOCTI Assessment Development and Test Preparation for the Massachusetts DoE. She is currently employed by the PA State System of Higher Education on a Department of Community and Economic Development funded position as statewide Program Manager for 2+2+2 Workforce Leadership Grants, and is co-PI of an NSF-ATE Advanced Manufacturing Project in PA.

### **Robin Shoop, Carnegie Mellon University**

Robin Shoop is a lifelong teacher who was identified as teacher of the year in 1999. Currently he is the director of Carnegie Mellon's Robotics Academy; the preeminent educational robotics curriculum development center in the world. Before he came to Carnegie Mellon he taught in the Pittsburgh Public School System for 28 years where he helped lead the district in the transition from Industrial Arts Education to Technology Education. Mr. Shoop is PI on the NSF funded Robotics Corridor project. The Robotics Corridor project's mission is to create pathways for students entering the new economy.

# Steps Along a Robotics Technology Career Pathway

## Abstract

This paper describes an evolving Robotics Technology career pathway. The project began with a study commissioned by a regional robotics industry group that surveyed both local and national robotics companies to determine their workforce needs. Continuing industry input guided the development of an “agile robotics” technician and technologist career pathway from high school through associate and bachelor degrees. The steps along this path are chronicled through the description of the meta-steps of creating a project partnership, developing a program, implementing a curriculum, determining industry workforce requirements, and adjusting the project plan and expectations in order to stay aligned with evolving industry needs.

## First Step: a need identified

The US robotics industry, which has a strong presence in Pennsylvania (PA), is experiencing market growth from healthcare to manufacturing, with large growth in defense and homeland security. Industrial automation is an important robotics market segment; however, significant regional growth is occurring in service robots or “agile robotics” applications. These are the emerging generation of intelligent and/or mobile devices and vehicles that interact with humans, with other robots, and with their surroundings. Agile robotics utilizes rapidly advancing sensor, processing, communications, and software technologies and thus blends traditionally distinct engineering disciplines including electronics, computers, embedded systems, software, networking, mechanical systems, manufacturing, information management, and artificial intelligence. Because educational programs do not traditionally blend these areas, there appears to be a gap where new curriculum and corresponding teacher development / laboratory enhancement are required.

The workforce development needs of PA’s growing agile robotics industry are important to The Technology Collaborative (TTC), a not-for-profit technology-based economic development organization focused on starting, attracting, and growing robotics, cyber-security and digital technology companies. In July 2004, TTC engaged an independent marketing consultant to study what, if any, baseline training was needed for end-users and service technicians in the Robotics industry. Survey respondents included Carnegie Mellon University Robotics Institute researchers involved in technology training with military and government clients; 13 robotics companies (9 of which are located in Pennsylvania); and 4 military/civilian contractors who purchase robots and plan for training. This study identified a growing need to create formalized training for the robotics industry.

Significant training needs were identified for military and civilian bomb disposal units as the number of military and civilian robots being deployed continues to increase. Military and homeland security Explosive Ordinance Disposal (EOD) robots have demonstrated the ability to save lives, and beginning in 2009, robots will be on the list of required items for all accredited bomb squads.<sup>1</sup> In addition, PA companies are developing robotics technologies and selling robotic equipment into a variety of industries, including healthcare, water, waste water,

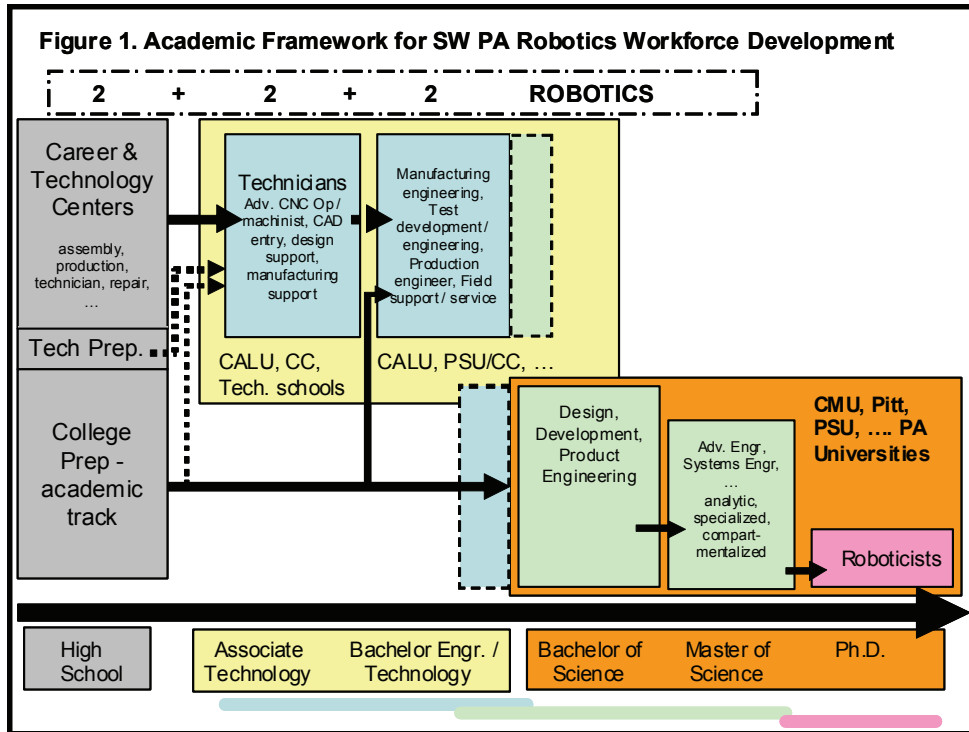
transportation, materials handling and even fast-food. According to the 2004 study, these companies reported current and future training needs which may go unmet. The study also concluded that while many vendors provide end-user and service technician training, most would eventually prefer to de-emphasize or exit this aspect of their business.

In late 2004, TTC began working with educational partners to identify formal ways to address skill gaps in the Robotics technician and technologist career pipeline. The partners found close alignment between their needs and the opportunities presented by a state-funded “2+2+2 Workforce Leadership Grant” program operated by the PA Department of Community and Economic Development (DCED).<sup>2</sup> DCED funds the development of seamless, articulated 2+2+2 (i.e. secondary school + community college + 4-year institution) curricula driven by business partnerships in emerging programs in bio-technology, information technology, and advanced manufacturing and materials. The development of these high-tech, high-skill, programs supports the Commonwealth’s need to increase the supply of potential employees for jobs that have been, or will be created, or made more technical by the rapid advancement of technology, research, new processes and production techniques.

The DCED 2+2+2 model is unlike articulated programs operating in other states. It is not limited to a single curriculum articulated statewide, nor a single college or university offering articulated courses at all of their statewide campuses. The model encourages the development of a program in any region where the labor market identifies an emerging skill need in one of the three curricula areas. DCED 2+2+2 projects may be led by an educational institution, a non-profit economic development organization, or a private business. The applicant and partners collectively decide how to best meet the DCED guidelines which include:

- A score of ‘Proficient’ or ‘Advanced’ on the required statewide Pennsylvania System of School Assessment (PSSA) for English and math by all secondary program completers,
- At least 15 credits articulated from the high school to a two-year institution, and another 15 credits articulated from the two-year institution to a 4-year institution
- A Guarantee/ Warranty is given to graduates upon exiting the program at any of the three educational levels as an assurance of academic and technical competence. In the event of employer or institutional dissatisfaction, the Guarantee/ Warranty provides up to 12 credit hours of instruction at no cost to the student.
- Industry input determines curricula, exit requirements, certifications, and standards.

The working partnership began with TTC, the A.W. Beattie Career Center (Beattie) at the secondary level, California University of Pennsylvania (Cal U) at the associate / bachelor degree level, and Carnegie Mellon University (CMU). CMU’s Robotics Institute (RI) is nationally recognized for its research and technology development work in agile robotics, most recently for winning the DARPA Urban Grand Challenge autonomous vehicle race in November 2007.<sup>3</sup> The RI offers doctorate and masters degree programs in robotics and has pioneered the development of agile robotics education curriculum for middle and secondary schools up through bachelor degree programs through its Robotics Academy (RA). A goal of the RA is to provide industry-driven professional development programs for teachers. From 2001 through 2007 the RA has offered a summer Research Experience for Teachers at CMU’s National Robotics Engineering Center. Over the summers of 2004-2006, the RA worked specifically with high school and vocational school teachers to develop robotics educational materials for systems



integration, programming, electronics and mechanics. This curriculum is currently being tested and implemented by the partner high schools. The partnership is committed to iteratively improving the teaching tools based on feedback from all stakeholders: industry, teachers, and students.

Success for the growing agile robotics industry will be enhanced by a skilled workforce at training levels from secondary school through post-graduate degree. The 2+2+2 robotics program options and pathways, and their place within the existing educational infrastructure, is illustrated in Figure 1 above. Secondary students begin at regular high school or specialized Career and Technology Center high schools, and articulate to Cal U programs at the associate and bachelor levels. The 2+2+2 program is complementary to existing bachelor, masters, and PhD programs that focus more on the research and development track, and helps fully cover the range of technological skills required by the agile robotics industry.

### Second Step: a pilot program to serve the need

The robotics education partners collaborated to write a 2+2+2 robotics proposal that was submitted to DCED in December 2004. The proposal was funded for the 2005-06 academic year, and the partners began development of an articulated Robotics curriculum during Fall 2005.<sup>1</sup> The initial secondary school partner was Beattie, with Cal U serving as the two-year/four-year degree partner. Washington County, where Cal U is located, as well as the adjacent counties of Fayette and Greene, do not have a community college. Thus Cal U serves a community college role by providing associate degrees in addition to its bachelor and masters degree programs. Beattie pilot-tested the CMU-developed robotics curriculum in 2005-06 in their existing electronics and computer science program with assistance from a CMU intern. In 2006-07, Beattie formalized a robotics engineering technology program and produced its first 2+2+2 robotics graduates in June 2007.

At the time the 2+2+2 robotics partnership was initially established, there was a synergy of related partner activities. CMU, Cal U, and TTC began a cooperative investigation of the need

for robotics technical training materials to support robotics industry growth regionally and nationally. This effort evolved into the Robotics Corridor Project. At the same time, CMU was solicited by RadioShack to develop training materials around a new educational robotics platform named VEX, and Cal U was investigating the potential for a Manufacturing or Mechanical Engineering Technology (MET) degree. Cal U held “Designing A CURriculum” (DACUM) meetings to solicit industry feedback on what should be included in the MET curriculum. The DACUM committee included representatives from companies involved in advanced manufacturing and automation as well as from CMU and TTC. DACUM results were used to guide the development of the high school robotics curriculum by CMU.

During this period Cal U and Beattie developed an articulation agreement that met the DCED 2+2+2 requirements: provide opportunities for Beattie students to earn 15 credits of advanced standing in a Cal U associate degree, verify student proficiency on the PSSA exams, and provide a guarantee/warranty of academic and/or technical competence. To create the agreement, Cal U and Beattie faculty compared courses, curricula, and assessment systems to ensure that Beattie’s robotics students would attain competencies equivalent to entry-level associate degree courses. A competency list for the Beattie Robotics Technology program was created that mapped onto five Cal U courses required in an existing associate degree, including automation, robotics, circuit analysis, digital electronics, and computer science. Full details of the articulated curriculum are available on the 2+2+2 program website.<sup>2</sup> The agreement requires students to earn a B average or better and to be recommended by the Beattie robotics teacher. Credits only, not grades, will be recorded on the transcript when a student enters the Cal U associate degree program.

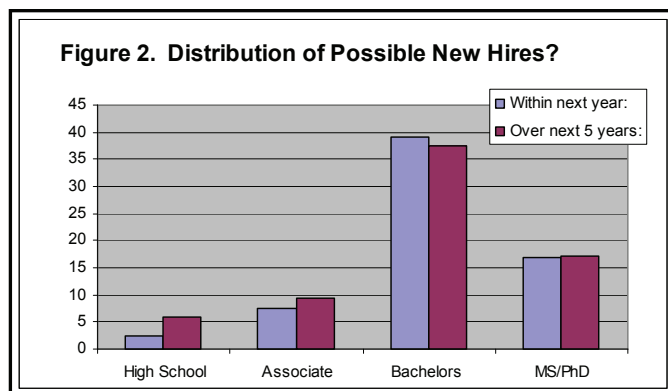
### **Third Step: expansion and needs validation**

In the 2006-07 academic year, DCED funded expansion of the 2+2+2 robotics partnership. McKeesport Area Technology Center (McKeesport) was added as a secondary school, and the programs moved from pilot phase into operational mode at Beattie and Cal U. In Summer 2006, CMU conducted an NSF-funded Research Experience for Teachers (RET) with faculty from Beattie, McKeesport, and Cal U participating. The VEX curriculum, with improvements made in the 2006 RET, was tested at Beattie and McKeesport during the 2006-07 school year. A Cal U graduate student intern assisted the high school teachers with testing and iteratively improving the curriculum. The intern worked with Beattie and McKeesport teachers to ensure alignment among robotics hardware, curriculum, pedagogical approaches and authentic assessment techniques. The Intern also acts as a mentor and role model for the secondary students in the program. Robotics competitions have been used to stimulate student interest, provide opportunities for students to demonstrate their engineering and technological capabilities, and to rally community support. CMU and Cal U developed a series of short-duration competitive events for the VEX robotics platform. Students from Beattie, McKeesport, and Schenley High School participated in five VEX competitive events during the Applied Engineering & Technology Spring Conferences at Cal U in April 2006 and 2007. Also, Beattie and McKeesport participated in the US FIRST (For Inspiration and Recognition of Science and Technology) High School Robotics Competition in March 2007. It was Beattie’s initial experience in FIRST, but McKeesport’s third. Previously the McKeesport team was part of the winning alliance at the Pittsburgh FIRST regional and also received a Rookie team award.

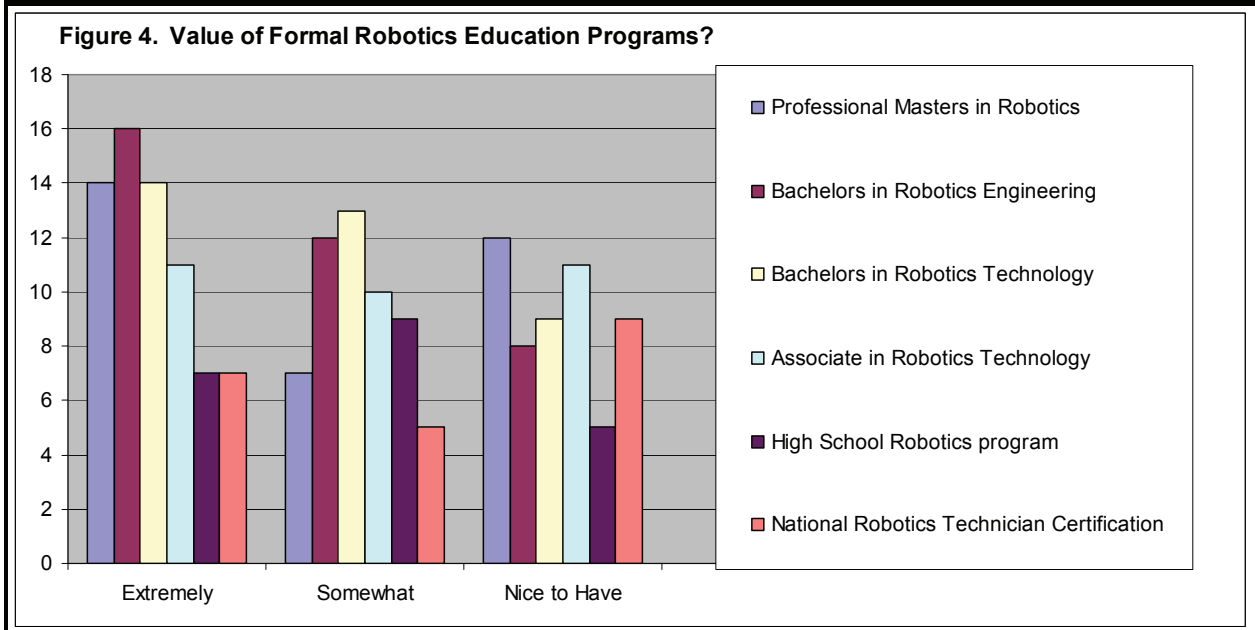
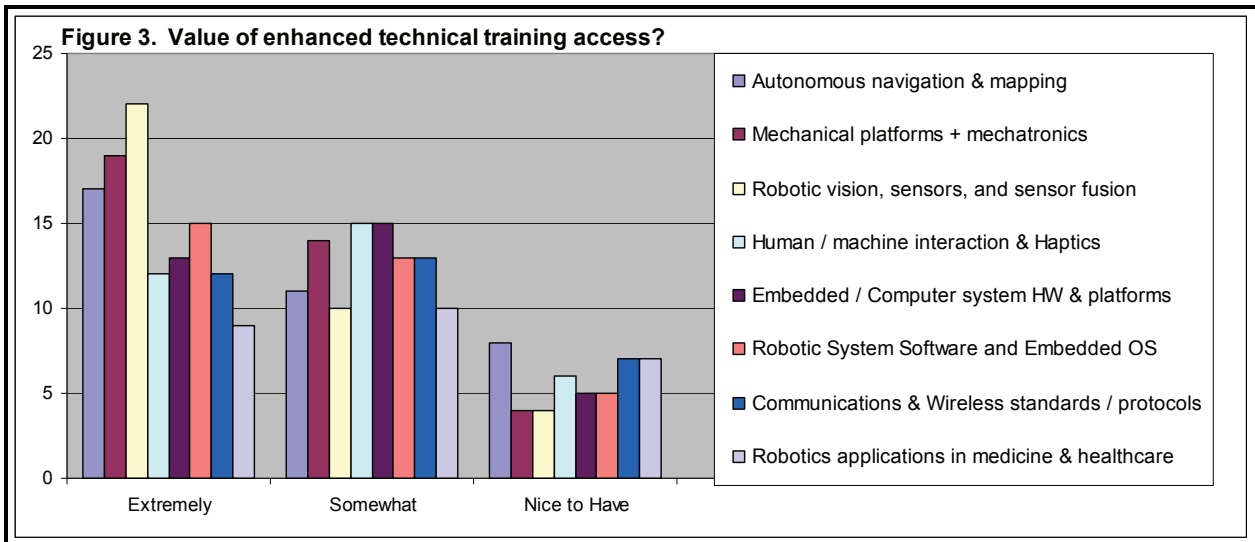
At Beattie the Robotics Technology program is now fully underway, and they have turned their attention to marketing and recruiting. Open House events, operation of a Robotics Industrial Advisory Board, and a successful Robotics Camp for Middle School students in Summer 2007 have been key marketing/recruiting efforts to date. At McKeesport, Robotics has sparked a growth in their Engineering Technology program and has become the content organizer for the Engineering Program. Following the same model used with Beattie, Cal U and McKeesport developed an articulation agreement that meets DCED's 2+2+2 program requirements. The McKeesport-Cal U 2+2+2 Agile Robotics Articulation provides a clear pathway for McKeesport students that will allow them to enter high-tech careers in robotics and advanced manufacturing. Due to the successes and growth, the program was moved to a larger classroom and laboratory that is providing more freedom and space to grow this opportunity for the students.

During this period, TTC began working cooperatively with the Three Rivers Workforce Investment Board to form a Southwest Pennsylvania Agile Robotics Industry Partnership. This partnership was funded by the PA Department of Labor and Industry as a forum for local industry to share workforce needs and issues, and collectively address impediments to regional industry growth.<sup>1</sup> Under direction from the Agile Robotics Industry Partnership, a national robotics workforce needs assessment survey was distributed at the 2006 RoboBusiness Conference. Survey respondents included 23 robotics companies (the majority early stage) as well as 6 educational institutions, and a number of interesting results were observed. The largest

needs identified were for experienced engineers, especially at the bachelor and masters level as indicated in Figure 2. The survey also confirmed that the Agile Robotics Industry needs enhanced training and technical skills across a wide range of technology areas (see Figure 3). A surprising result of the survey was the relatively low interest by early-stage robotics companies in technicians and technologists (see Figure 4). Survey follow-up revealed robotics start-up companies choosing a different growth and product delivery strategy than projected by the 2004 study. As they grow to scale, R&D intensive start-ups are likely to outsource manufacturing, installation, repair, and tech support. Thus, the need for robotics technicians more closely aligns with the need for regional supply chain resources, and a significant 2+2+2 project value is to provide workforce resources needed along the robotics supply chain.



One gap in the current robotics education/industry model is the lack of recognized national robotic workforce certifications. Certification could be offered at the high school or associate degree level or through incumbent worker training. The Robotics Corridor Project, which has been intertwined with the 2+2+2 project since its inception, is working to develop this certification. Phase I of the Robotics Corridor began as a partnership between Cal U and CMU to support western PA robotics industry growth in military and commercial applications. In 2007 the Robotics Corridor project secured funding from the National Science Foundation to develop a Robotics Intelligent Systems Certification, and added three community college partners to their



team. Working with the National Occupational Competency Training Institute (NOCTI), an assessment was developed to determine if potential entry-level employees have the requisite skills to gain employment as a robotics technician.

#### **Fourth Step: continued expansion and needs assessment**

DCED will fund 2+2+2 partnerships that are achieving their objectives for up to six years, and partnerships are expected to increase student enrollment by 50% each year. For the 2006-07 academic year, the partners agreed to bring two more secondary schools on board: Connellsville High School and Mercer County Career Center. The schools were selected because they had very good robotics-related curriculum / programs in place with good administrative support. The models of curriculum development, teacher professional development, and articulation

agreement building used previously are being repeated at Connellsville and Mercer in the current school year (2007-08).

Given the previously successful experience with a Cal U intern, a second intern was added in 2007-08 to better support all four high school partners. McKeesport and Beattie student teams will both participate in the FIRST Robotics Pittsburgh regional competition in 2008, with support from Cal U interns. Figure 5 illustrates some of this activity at Beattie and McKeesport. Connellsville and Mercer have decided to participate in another robotics competitive event, BotsIQ, which involves student teams in designing, producing, operating, and analyzing the performance of a battling robot. Industry partners provide mentors, technical advisors, and financial support. There are two BotsIQ consortiums operating in western PA; both are supported by industry, governmental, and educational partners. The southwestern PA BotsIQ group expects to host more than 30 teams at their March 2008 competition.



Cal U is continuing to develop robotic courses for engineering technology and technology education programs. Cal U, CMU, and the National Center for Defense Robotics are working together on robotics training under the umbrella of Cal U's National Center for Robotics Engineering Technology Education (NCRETE). This multi-year effort, funded through a Department of Defense appropriation, is developing a comprehensive robotics education program that includes post-secondary curricula as well as K-12 teacher professional development in robotics-related STEM (science, technology, engineering, and math) fields. NCRETE and the 2+2+2 partnership are collaborating on several fronts and sharing resources and capabilities.

The NCRETE group's initial study of future workforce needs produced findings different than the previously described RoboBusiness conference workforce needs survey. In particular, the group heard from local companies that PA robotics industry growth will continue, but a limiting factor could be the lack of a technologically proficient workforce. As the emerging agile robotics industry moves from proof-of-concept into production, the need for highly skilled technicians will grow. These technicians do not exist as yet, but need to be created through rigorous academic programs at the associate degree level. This finding is more consistent with the Robotics Industry Partnership supply chain study results that appear later in this section. The Robotics Corridor project is working to address these needs through curriculum development and dissemination and through work towards a national robotics technician certification.

Under the auspices of the Robotics Corridor project, a series of robotics courses are being developed and tested to form the foundation of a Robotics Engineering Technology Associate degree. Phase II of the Robotics Corridor, which is a National Science Foundation funded program to provide wide-scale dissemination of Phase I developed materials, is being lead by



CMU, Cal U, and Butler County Community College. Other Phase II team members include the Community College of Beaver County, Westmoreland County Community College, the University of Pittsburgh's Learning Research and Development Center, the Pennsylvania Department of Education, and high schools and Career and Technical Centers across western PA. The team's mission is to provide programs for students and teachers designed to grow a technically-trained, mathematically-competent workforce in a region with a rich manufacturing history and a steadily emerging robotics industry. Over a three-year period, the Phase II plans are to expand across PA, develop a Robotics Technician Certificate, offer a Robotics Engineering Technology associate degree that articulates into baccalaureate degrees, provide K-12 STEM teacher professional development, and develop advanced placement opportunities with a "college in the high school" program. The largest gains will come from improving teacher competency, which will increase both the quality and quantity of students successfully pursuing robotics technology and engineering degree programs.

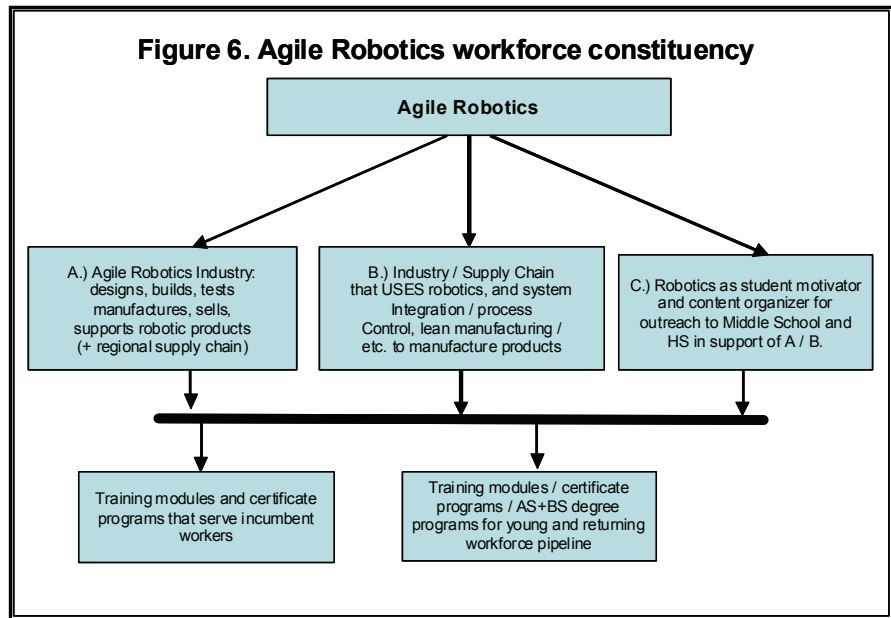
As previously discussed, the Agile Robotics Industry Partnership identified robotics technician and technologist needs as important within the robotics supply chain. Further information was provided through a Robotics Industry Partnership study performed by the Keystone Enterprise Manufacturing Alliance (KEMA).<sup>4</sup> The study identified regional companies that can function as component suppliers to advance the overall regional growth of the robotic industry. It also addressed the questions: How do robotic companies identify their suppliers and/or teaming contractors? Are they using regional suppliers? In a competitive environment, how do you establish a regional group of suppliers to support developing robotic firms? These questions set the roadmap for the next step in the study. Eight companies were identified to be included in the survey, representing the spectrum of agile robotic manufacturers. They range from small to large production, from commercial to military application, and also one that currently produces robots for their own inspection services. The companies' needs varied, depending on their approach to design, development, manufacture, testing, and field support. However, the study further determined that: "almost all of the companies limit themselves to keeping the design, development, and prototyping, in-house. The production and assembly are typically outsourced. Sometimes they team with suppliers, other times it is a formal source selection relationship. Even the companies that may keep the final assembly in-house often use contract personnel for those operations. Although it is difficult to generalize, it is evident that this group of spin-off robotic companies may no longer be considered 'R&D'-type firms; however, they certainly have not moved into the realm of standardized products with established standardized components and repeatable processes. It is evident that these companies prefer to remain as design/development companies and often 'subcontract' the production/assembly."<sup>4</sup>

In the workforce development part of the study, most companies report they have been able to find the personnel they need and that turnover is minimal. The companies report that in their opinion this is because work in robotics is exciting and state-of-the-art, and good employees are drawn to this challenge. Also, the region produces many trained engineers who prefer to stay in the area upon graduation, or are anxious to return after gaining experience through employment outside the region. Most companies reported limited short-term hiring needs, but much higher long-term expectations. They believe that since they often hire for specific skill areas, they need to do considerable in-house and on-the-job training to broaden each individual's capability. Very little is standardized in robots, and thus the engineers and technicians need experience to

become “systems” personnel. Experienced multidisciplinary personnel have to be developed. Companies want people with “hands-on” talent, for example, someone who has “changed their own oil.” Interview responses, however, indicate that almost all the companies currently report little communication with local technical schools on training personnel to meet their needs. Most report some continuing contact with robotics research projects at Carnegie Mellon University (CMU), but not with robotics education and curriculum development. This is another gap that 2+2+2 and the Robotics Corridor project can work to fill.

The 2+2+2 robotics project began with the goal to support growing technician and technologist needs of the Agile Robotics Industry, represented by Branch A in Figure 6 below. As the project matured and additional industry needs assessment was conducted, it was determined that the robotics industry supply chain and advanced manufacturing workforce needs of Branch B were quite significant as well.

The partners also acknowledge that the hard-to-quantify, yet possibly most important, aspect of robotics education is that it serves as a student motivator and STEM content organizer as identified in Branch C. It is fortuitous that the teacher training and instructional materials developed under the auspices of this program can well serve all three of these constituencies.



### Fifth Step: and beyond

The 2+2+2 robotics partnership continues to work successfully, and the partners plan to request a DCED expansion grant for 2008-09. As reported by DCED: “The overall success of more maturely-funded statewide 2+2+2 Workforce Leadership projects can be expected with TTC project partners. Based on yearly Final Reports submitted by Project Managers to DCED, no 2+2+2 high school student who has articulated into a community college or 4-year program who has scored a ‘Proficient’ or ‘Advanced’ on the PSSA has had to take remediation courses for entry-level Math or English. In addition, a 2007 Study of Project Employers indicates that no employer has had to utilize the Guarantee/ Warranty because of dissatisfaction with a student’s technical skills. Asked if they would hire another graduate of the 2+2+2 Program, 100 percent of the employers responded positively.”<sup>5</sup>

The Robotics Corridor and National Center for Robotics Engineering Technology Education are continuing to disseminate curriculum, to work with NOCTI to validate assessment of robotics technician training needs, and to create a Robotics Technician (Intelligent Systems) certification.

This is important notwithstanding the robotics workforce needs surveys that place more interest in bachelor degree new hires and are less interest in high school or associate degree graduates. Consider that every post-secondary engineering graduate began as a middle school or high school student interested in technical studies, and that the quality and depth of the technical workforce career pipeline is a valuable asset for both robotics companies and their supply chain. There are currently 52 secondary students and 30 post-secondary students participating in the 2+2+2 robotics program. No one has completed the end-to-end program, as it is only in its third year of operation. One Cal U graduate who completed agile robotics courses as part of his degree also completed an internship at a local manufacturing company (Hamill Manufacturing, Trafford, PA). In January, 2008, it was reported that the company planned to hire the graduate as an engineering technology associate.

In conclusion, agile robotics companies are competing in a knowledge-based world economy, with both products and enterprise driven by technology. A highly skilled workforce is needed in all areas of high-technology enterprise, not just research, product design and development. In reports by the National Science Board (NSB) and the American Electronics Association<sup>6,7</sup>, a bleak picture is painted of US K-12 system failure to provide adequate Math and Science skills. According to the January 2006 NSB report<sup>6</sup>, US 15-year-old student performance in math and science knowledge was at or near the bottom of the 29 countries participating in the study. The 2+2+2 project focus on robotics skills and workforce needs puts the partners in a unique position to impact student career choices, by using robotics to help capture student interest and increase competency in Science, Technology, Engineering, and Math.

## Bibliography

1. National Bomb Squad Commanders Advisory Board, "National Strategic Plan for U.S. Bomb Squads", AEL / SEL Number: 11RE-00-BSSP, December 2006
2. 2+2+2 Workforce Leadership Grants, Pennsylvania Department of Community and Economic Development website, <http://www.222wlg.org/>
3. DARPA Urban Grand Challenge web site, <http://www.darpa.mil/GRANDCHALLENGE/>
4. Keystone Enterprise Manufacturing Alliance, "Agile Robotics Workforce Manufacturer / Supply Chain Analysis", report to TTC and the Three Rivers Workforce Investment Board, Pittsburgh, PA, December 2006
5. DCED 2+2+2 Workforce Leadership Program employer and partner survey, results presented at PACTA 222WLG Project Managers Meeting, February 6, 2008
6. National Science Board, "America's Pressing Challenge – Building A Stronger Foundation", A Companion to Science and Engineering Indicators 2006, NSB-06-02, National Science Foundation, Arlington, VA, Jan. 2006
7. American Electronics Association, "We Are Still Losing The Competitive Advantage, Now is the Time to Act", Washington, DC, March 2007

---

<sup>1</sup> **Acknowledgements:** Funding for the 2+2+2 robotics career pathway project, which supports curriculum development, instructor release time, and instructional equipment acquisition was provided by the Commonwealth of Pennsylvania Department of Community and Economic Development, under grants C000026827, C000019135 and C000013153. Funding for the Agile Robotics Industry Partnership, which supported robotics industry and supply chain workforce needs surveys, was provided by the Commonwealth of Pennsylvania Department of Labor and Industry under contract TRWIB164 managed by the Three Rivers Workforce Investment Board.