Addressing STEM Education: The U.S. Defense Industry and Legitimate Peripheral Participation

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***Abstract*—The U.S. workforce faces a number of STEM workforce educated challenges as many employees are not prepared to meet the needs of the U.S. economy. The theoretical framework of the article is based on legitimate peripheral participation stating that participants join a community of practice and become acquainted with the tasks, vocabulary, and organizing principles of the community, then they move further into the community seeking more knowledge for greater legitimacy, and eventually become full-participants. This article highlights examples at how partnerships with the U.S. defense industry are addressing STEM education and offering valuable learning experience for preparing the U.S. defense workforce.**

***Index Terms*—STEM defense industry, STEM partnership, apprenticeship, aerospace STEM, defense industry education.**

I. Introduction to the STEM Education Issue

Science, technology, engineering, and mathematic (STEM) education, according to the National Academies [1], advisors to the U.S. on science, engineering, and medicine, is a matter of ensuring the U.S.'s position as a prosperous member of the global community into the near future. In his State of the Union Address, former U.S. President Bush [2] stated, "The bedrock of America's competitiveness is a well-educated and skilled workforce." U.S. President Obama [3] referenced post-secondary attainment as an answer to the need to compete globally and urged all Americans to "commit to at least one year or more of higher education or career training, this can be community college or a four-year school; vocational training or an apprenticeship".

According to Clagett [4] workforce preparation programs can be found both in and outside schools. General educational programs are typically found in schools where a segment of the curriculum is used to address skills and traits needed for careers. Upon graduating or leaving an educational institution, work-based programs allow students to work at job-sites requiring the knowledge and skills attained from the institutions of learning. Efforts that attempt to partner such programs rest on the assumption that work and school successes are interrelated and interdependent [4].

Many U.S. employers provide remedial training in an attempt to upgrade the new entrants to work standards, only to find difficulty keeping up with the widening gap [5]. There are various programs established in academic institutions to address emergent needs in the work environment (i.e. leadership, teamwork skills and information technology); however, there are still inadequacies in applied skills, which are the most essential according to the employers [5]. According to the National Center for Education Statistics [6] U.S. students ranked lower compared to other nations in problem-solving skills in a real-world context. As stated by Casner-Lotto [5], more than 40 percent of employers have a 'high need' for applied skills, but do not adequately offer them to the new entrants. Firms also fall short of programs for encouraging creative skills of the new entrants. This is disturbing, given the fact that creativity brings about innovation which can in turn bring about success in business. This is especially true in the modern competitive global marketplace [7]. This is not to imply that the basic skills currently being taught in U.S. schools are not relevant. They are extremely essential in developing the critical skills; however there still remains a lack of basic skills of writing, comprehension and mathematics — which is the main responsibility of the schools [7].

With billions of dollars being spent in the education sector, there is a call for a change in educational programs. There have been concerted calls from many to increase the focus of career and technical education within the secondary curriculum [8]. The workplace needs people who are strong enough to adapt to the tough environment. Oftentimes, these people are those that have undergone vocational or career and technical education, and possess the resiliency needed to benefit them in the competitive working environment [9].

II. Answering the Call

A. STEM Focus

According to National Academies [1] the United States is in need of science, technology, engineering and mathematics (STEM) secondary and post-secondary graduates. These graduates are needed to supply the U.S. economy with workers who are technologically proficient. However, U.S. secondary institutions graduate too few of such graduates. On the post-secondary level, "the United States graduates more visual arts and performing arts majors than engineers" [1, p.8]. Many authors advocating for STEM education show that having these skills increases success after post-secondary and ultimately in the larger labor pool [1]. Of the high school students that do graduate, some simply do not get enrolled for postsecondary education. This is a swelling challenge, and students should be helped and guided to get skills and knowledge required to deal with the challenges of the modern workforce [10].

National Academies [1] expressed promoting education in this way would help graduates join or access post-secondary schools and greater productive employment. Perhaps, the greatest recommendation from the Learning System included rethinking and changing the learning paradigms. This will help in promoting new ideas critical in capturing the emerging needs in the academic sector [11].

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B. Business-Education Partnerships

The largest efforts answering the call of the ill-prepared workforce today appears to be coming from partnerships between business and education. According to Casner-Lotto [5] companies realize how important it is to focus on partnering with post-secondary institutions in developing workforce readiness skills. In the research report based on 217 employers, five model programs were surfaced as having exemplary workforce training programs – each of which involved extensive partnerships where entry-level employees attended post-secondary institutions while transitioning within the operations in their workplace.

III. Theoretical Foundation

The theoretical framework supporting partnerships is based on social learning theory from Albert Bandura and what Lave and Wenger [12] have coined as legitimate peripheral participation [13]. Drawing on Vygotsky's work showed that people learn better when they have a support system. Bandura describes social learning theory as a way of learning from others in a social context that included observation, modeling, and reflecting [13]. As the learner gains competence, scaffolding occurs until the apprentice completely masters the task. In an attempt to understand situated learning, Lave and Wenger [12] explain legitimate peripheral participation (LPP) while observing apprentices. Their salient point was when newcomers (participants) join a community of practice and become acquainted with the tasks, vocabulary, and organizing principles of the community, they move further into the community seeking more knowledge for greater legitimacy, and eventually become full-participants. Lave and Wenger [12] report that membership in a community of practice is often determined by the possible forms of participation to which newcomers have access, both physically and socially. If newcomers have the opportunity to observe the practices of an expert, they gain greater understanding. Conversely, newcomers that are not afforded the expert have limited access to their tools and community and therefore have limited growth. Through participation, situations arise that allow the participant to assess how well they are contributing through their efforts, thus LPP provides a means for self-evaluation that often encourages or motivates the participant to "want" to learn more. Although LPP does not define specific models; it does describe the engagement in social practice that entails learning when utilizing the models similar to those discussed in this article. Partnerships provide much more than simply learning with context. When learners are being educated and trained while actually participating in their occupation of choice, they not only absorb knowledge, they seek it. They realize that learning the tricks-of-the trade (education and training) will translate into more legitimacy within the community.

IV. Business-Education Partnership Issues and Examples

Much of the literature is pressing for partnerships between colleges and industry. The following are two examples where such partnerships are thriving. The first example examines the aerospace industry where the Aerospace Academy for Engineering and Teacher Education teamed with post-secondary educational institutions and government agencies such as NASA to demonstrate and provide solutions to the problem. The second example spotlights apprenticeship in the U.S. and examines a unique relationship between Newport News Shipbuilding and Thomas Nelson Community College as well as Old Dominion University in Virginia.

A. Aerospace Defense and Education Partnership

The aerospace and defense industries face a bleak outlook due to a number of variables. In a survey conducted by the Aerospace Industry Association (AIA), college students in engineering showed very little interest in pursuing careers in the Aerospace industry. According to the survey the students rated the industry low in opportunities for development and low in encouraging management. This is a problem for an industry where 43% of its workforce is comprised of engineers and scientists. The industry is suffering from an attrition rate of 14% for employees with zero to five years of work experiences [14], with some studies suggesting that this attrition rate could be even higher [15]. The attrition of employees with zero to five years of experience is higher than the industry average at 10% for all experience levels. This statistic is even more concerning when one considers that 58% of the U.S. aerospace workforce is over the age of 50. What this means is that there are a large number of aerospace employees that are going to be eligible to retire soon and there will be fewer qualified people to replace them [14].

The aerospace industry relies heavily on Science, Technology, Engineering, and Mathematics (STEM) professionals. STEM professionals make up a large part of the aerospace industry which is a necessary part of our nation's mobility and defense [16]. There is currently a shortage of STEM focused and trained people in America, and this is proving to be a serious problem for the aerospace industry [14].

Although the defense aircraft sector is facing budget cuts globally; with the biggest cuts in spending in the United States and Europe, it is predicted that the commercial aircraft sector will experience growth in the near future. This is due to the need for more fuel efficient next generation aircraft, where increasing fuel prices have made fuel efficiency a more important aspect of aircraft production and acquisition [17].

There is no question that the aerospace industry is in need of more engineers. Some post-secondary administrators attribute the lack of engineers to a lack of capacity of state engineering colleges. In 2010, the University of Washington had to deny admission to 370 qualified applicants to their college of engineering due to lack of capacity. In addition, factors like the rising rate of tuition keep some applicants from pursuing even high-paying, high-demand fields such as engineering. It falls to the state legislators to keep tuition prices and college capacity at levels that will meet the demands the nation has for its aerospace industry [18].

In the post-secondary system it is important to maintain and grow the retention of students in STEM majors. There are a larger number of students that express interest in STEM

majors than those completing the degrees in STEM fields. Hands-on research opportunities in these fields could support STEM oriented major participation in the post-secondary [14].

Some government and industry organizations are attempting to take steps to address the nation's shortage of engineers, high technology workers, and other STEM professionals. One such example is the Aerospace Academy for Engineering and Teacher Education. This organization has teamed with post-secondary educational institutions and government agencies such as NASA to demonstrate and provide solutions to the problem. This unique collaborative nationwide effort resulted in the training of over 800 math and science teachers, and provided teachers with the opportunity to job shadow in the aerospace industry. The project involved, and was recognized by the Texas state legislator and received the Governor's Council Award for Exemplary Partnership [19]. Other successful collaborative efforts can be seen in the System Architecting and Engineering (SAE) program at the University of Southern California (USC). USC has developed successful partnerships with two of the most well-known companies in aerospace, Boeing and Lockheed Martin, and with Missouri University of Science and Technology to develop programs to meet the needs of those companies' industry. The program is sought after by students from across the US because it facilitates graduates in their entry into the systems engineering workforce. The partnership has graduated 750 Boeing employees since its inception and has been ranked highly by students and employers. Other aerospace companies and universities have begun to follow the successful partnership's example [20].

The United States remains the world's leader in aerospace technology and industry. However, that advantage has shrunk in recent years. Aerospace manufacturing has offered a positive foreign trade balance for the U.S. for many years. That balance has seen a drop. In order to maintain pace with its global competitors the US must make investments in its educational institutions to support its engineering workforce [18].

B. Shipbuilding Apprenticeship

The Pathways to Prosperity document [18, p.11] pinpoints a deep rooted cause of student attrition by suggesting that too many students do not have a clear or transparent connection between what they are studying and tangible opportunities in the labor market. Apprenticeship provides a model of learning that has traditionally provided a transparent connection between learning and tangible opportunities. As reported by Halpern [21] the prevailing method of developing the US workforce is one that requires all students to spend a maximum amount of time and energy in a common school experience mainly focused on advancing learners to college then keeping them there for as long as possible. Often void of anything real, the learner is not truly expected to participate legitimately in an occupational field until after graduating. For decades, the idea of asking a young adult to identify a career area has been foreign to the way of thinking in the United States [22]. According to Downing [22], identifying "who" or "what" to become is not part of the equation of many college programs, and the statistics are telling. According to Noel-Levitz [23] approximately 36.6 percent of those students enrolled in four-year public colleges will graduate within five years. Of the high school graduates that start college, only a fraction complete, and when they do, it may not be in a field applicable to the current economy such as STEM [18].

Modern apprentice programs in the United States are learning institutions sponsored and funded by employers that choose to do so, and often provide 1) a complementary blend of college level academic courses, 2) specialized theory or training, while 3) employing learners in relevant occupational areas [24]. According to Soares [25], these areas work complementary to one another in a way that develops and benefits everyone involved. Although not well publicized, apprenticeships exist across the country at very high levels and are providing much of the middle-skill demand needed for the U.S. economy. Besides the more than 19,000 programs registered with the U.S. Department of Labor (DOL) [26], Lerman [27], citing a recent National Household Education Survey, explained that over a million apprentices could potentially be in programs not registered with the federal government. Extrapolating Lerman's figures to the programs already registered with the DOL, there may be more than 65,000 apprenticeship programs throughout the United States. Unlike the traditional model, where students sit in a classroom wondering why they need such academic courses, apprenticeships offer participants employment and a salary while receiving specialized training while taking college courses towards an associate's or bachelor's degree. If done correctly, apprentices are launching into their careers with an employer, allowing that employer to pay for their college education, while learning the logistics of the organization and gaining seniority all along the way. Obtaining a post-secondary education in this fashion provides a focused and structured style of mentorship that benefit the employer and employee. One such program that provides an excellent example of the apprenticeship model of development is The Apprentice School at Newport News Shipbuilding.

Newport News Shipbuilding builds, modifies, repairs, refuels, and overhauls ships for the U.S. Navy and some commercial companies. The Apprentice School, associated with Newport News Shipbuilding, operates as a department within the company and offers an opportunity for its students to earn an income while taking advantage of a four to eight-year, post-secondary technical education. Students are employed full-time with the company upon matriculation to the school and receive pay for a 40-hour work week, which includes time spent in the classroom and laboratory training. An apprentice basically spends two days per week (16 hours) in the college classroom and the remaining three days on the job. While serving their work-related component, apprentices receive occupational training and serve in essential areas within any one of the 27 apprenticeship programs offered. Apprentices receive all benefits and resources that other employees receive e.g., medical and 401k. Tuition is free and the textbooks are supplied by the company.

Regardless of the discipline in which they are enrolled, all apprentices are required to complete a standard academic curriculum consisting of 36 credits of college coursework in the subject matter areas of technical mathematics drafting,

engineering, and design; naval architecture and marine engineering; business processes; physical science; and technical communications. The school also offers optional, advanced apprenticeship programs in Shipyard Operations, Marine Design, Production Planning, Cost Estimating, Nuclear Test Technician, Modeling & Simulation and a professional Development Program in Engineering. Through partnerships with Thomas Nelson Community College, Tidewater Community College, and Old Dominion University, apprentices complete an associate degree in engineering, engineering technology, technical studies, business administration, or a full four-year bachelor's degree in engineering, all while on-the-clock.

According to Jordan [28], the program has paid off in dividends as it provides the leadership throughout the company. Impressive statistics reveal that over 82% of its graduates are still with the company after 10 years; and the majority of the company's mid to upper-level leadership are graduates of the program.

V. Conclusion

The U.S. defense industry faces potentially major issues in the near future in the form of a lack of qualified STEM educated workforce pool. The U.S. defense aerospace and shipbuilding industries face large attrition rates. Both industries rely on STEM education professionals to maintain their edge and remain competitive. As described, collaboration efforts by industry and educational institutions have shown success. The problem remains that there is a lack of STEM focused and trained professionals in educational institutions to meet future demand. There may be repercussions to a lack of a STEM educated workforce pool and the effect that it could have on the ability of the U.S. defense industry to stay globally competitive.

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