**Apprenticeship: A Pathway for the Cost Estimating Profession and the Greater STEM Workforce**

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**ABSTRACT**

This article spotlights the cost estimating and operations research profession, and a STEM apprenticeship program that currently offer opportunities to both the learner and sponsor. While government and school systems scramble to align themselves with the current initiatives, apprenticeship remains an attractive learning model in gaining STEM competencies while advancing in a promising career. This article explains the current STEM movement and shows how apprenticeship, through legitimate peripheral participation, enhances the STEM learning process.

**INTRODUCTION**

Producing a citizenry that is workforce ready is a primary objective of the education system in the United States (National Panel, 2002; Symonds, Schwartz &Ferguson, 2011). In particular, preparing a workforce with knowledge in science, technology, engineering, and mathematics (STEM) has the greatest potential to contribute to the innovation and technological growth of the United States’ needs for the 21st century (Carnevale, Smith & Melton, 2011; National Academies, 2010; PCAST, 2011). As reported by Change the Equation and Business Roundtable (2014), 97 percent of CEOs see the U.S. STEM skills gap as an issue. The report further explained that nearly 1 million employees with basic STEM competency and over 600,000 STEM knowledge workers will be needed over the next five years. This article spotlights one occupation rooted in STEM, cost estimating, and an apprenticeship program that currently offers opportunities to both the learner and sponsor involved in this critical occupation.

**STEM and STEM Education**

Carnevale, Smith & Melton (2011) explained the US needs more STEM talent across the board – not only just traditional STEM workers, but throughout non-traditional occupations as well. Of course, the acronym STEM stands for four very important disciplines in their own right. The National Science and Technology Committee (2011) stated the need for high quality STEM education “has been touted by numerous reports that link our nation’s future economic success and security to a highly skilled STEM workforce” (p. xi). US economic competitiveness does not stop at merely educating and creating a highly specialized STEM workforce. The National Governors Association (2007) believes that STEM education should be integrated into schools holistically – to increase student interest in math and science, but also to promote a STEM literate workforce.

According to Carnevale, Smith & Strohl (2010), technological innovation accounted for almost half of U.S. economic growth over the past 50 years, and almost all of the 30 fastest-growing occupations in the next decade will require at least some background in STEM, including cost estimating, often grouped with operations research or data analytics. The President’s Council of Advisors on Science and Technology (PCAST, 2011) conveyed great hopes in an ability to produce such a community citing that the United States has the most productive STEM community in the world, illuminating research on how to teach STEM, and bipartisan consensus where efforts are currently underway in reforming education with a STEM initiative.

According to Thomasian (2011),US states are combining their own resources with those of the private sector, philanthropic community, and federal government to push such actions as the creation of STEM-focused schools. Governors have been working to increase the proficiency of all students in the areas of STEM primarily because STEM occupations are among the highest paying, fastest growing, and most influential in driving economic growth and innovation. As individuals employed in STEM fields enjoy low unemployment, prosperity, and career flexibility, variables that clearly strengthen state economic performance, states and their educational institutions have commonly adopted more rigorous math and science standards and improved assessments; recruited and retained more qualified classroom teachers; provided more rigorous preparation for STEM students; used informal leaning to expand math and science beyond the classroom; and established goals for postsecondary institutions to meet STEM job needs. “Through new schools and instructional designs – STEM specialty schools and academies, early college programs, linked learning, and online courses – states and schools are providing students with more focused and rigorous STEM curricula with real-world application” (p. 6).

Teaching STEM as a meta-discipline offers students opportunities to make sense of the world and take charge of their learning (Satchwell & Loepp, 2002). Rather than learning isolated bits and pieces of content, STEM education provides a platform allowing students to use science, technology, engineering and mathematics to engage in real world problems, exactly like the problems presented to cost estimators or operations researcher, and experiences through inquiry-based and problem-based strategies leading to higher level thinking required. Laboy-Rush (2011) explained the use of problem-based learning in STEM education through the use of reflection, research, discovery, and application. Students who learn in this capacity have shown greater understanding of content and concept acquisition than students learning through expository learning (Gallant, 2010; Hill, 2006; Wang, Moore, Roehrig & Park, 2011).

Teaching STEM in this integrated format while using problem-based strategies, allows students a contextual understanding that leads to innovative solutions, (Stohlmann, More & Roehrig, 2012; Gallant, 2010). Laboy-Rush (2011) stated “The project approach to STEM, or *learning by doing*, is grounded in constructivist theory that is shown to improve student achievement in higher-level cognitive tasks such as scientific processes and mathematic problem solving” (p. 4). Such quantitative skills are the same processes and problems that are needed in the cost estimating profession and are promoted through cost estimating and operations research training and certification (ICCEA, 2015).

**Cost Estimating Profession**

The Bureau of Labor Statistics (2015) frames the duties of a cost estimator as someone who collects and analyzes data to estimate operating resources, such as time, money, materials and labor. These resources are required to manufacture products or provide services. Cost estimators typically specialize in a particular industry or specific product. They often travel to jobsite locations to gather information for operations research and collaborate with other professions such as engineers, architects, clients and contractors on their operations estimates (Bureau of Labor Statistics). It is exactly this cross disciplinary, quantitative environment that makes broad STEM education so important in training cost estimators and operations researchers (National Governors Association, 2007).

Cost estimators are workers who heavily rely on digital literacy to calculate estimates and evaluate a product’s potential profitability (Burning Glass and Capital One, 2015). According to the Bureau of Labor Statistics, a cost estimator’s responsibilities can include recommending ways to make a product more profitable and work to prepare bids for clients. “Accurately predicting the cost, size and duration of future construction and manufacturing projects is vital to the survival of businesses.” The profession is expected to grow by 26% from 2012 to 2022. This expected growth significantly outpaces the future demand of 11% across all professions in the United States during the same time period.

The Bureau of Labor Statistics’ website goes on to mention a few qualifying criteria for most cost estimating jobs. The “Work Experience in a Related Occupation” section of the Bureau of Labor Statistics states, “Increasingly, employers prefer that cost estimators—particularly those without a bachelor’s degree—have previous work experience in the construction industry. For example, experienced electricians and plumbers can become construction cost estimators if they have the necessary construction knowledge and math skills. It can be challenging for some students to gain the necessary experience if they have not participated in the trades involved in their estimating fields. Opportunities to gain the necessary experience are very valuable to candidates hoping to become cost estimators and operations researchers.

Candidates interested in becoming cost estimators also can gain experience through internships and cooperative education programs. One such cooperative education program, in the form of an apprenticeship sponsored by Huntington Ingalls Industries, will be addressed in this article.

The Bureau of Labor Statistics states in its “Licenses, Certifications, and Registrations” section that “voluntary certification can show competence and experience in the field. In some instances, employers may require professional certification before hiring. The International Cost Estimating and Analysis Association offers a variety of certifications. To become certified, estimators generally must have at least two years of estimating experience and must pass a written exam.”

International Cost Estimating and Analysis Association (ICEAA) can best be defined by its mission statement, “a 501(c)(6) international non-profit organization dedicated to advancing, encouraging, promoting and enhancing the profession of cost estimating and analysis, through the use of parametrics and other data-driven techniques.” More specifically, ICCEA’s website states that the association exists to promote excellence in the profession of cost estimating. It does this by enabling professional development of its cost estimating members and sharing of experience and knowledge gained in real-world applications (ICEAA, 2015). A number of other cost estimating associations exist, though a cursory review of existing cost estimating associations would suggest that ICEAA is widely up held in the profession. ICEAA mentions on its webpage that they cooperate with other organizations of related purpose to further public interest. The purpose of all cost estimating associations, however, is to foster the professional growth of its members and to develop professional standards, often by creating professional certifications such as ICEAA’s Certified Cost Estimator/Analyst (CCEA).

The Bureau of Labor Statistics has framed the requirements to become a cost estimator in three overarching requirements. A person wishing to pursue a career in cost estimating should achieve a relevant four-year degree (strong math or quantitative field), pursue relevant experience, and achieve a cost estimating certification. It may, however, prove difficult to get experience without the opportunity to get hired. Without the necessary experience, cost estimating certifications such as ICCEA’s CCEA may also be unachievable. So it would seem that beyond completing a bachelor’s degree in a mathematical or quantitative field, a key component to pursuing a career in cost estimating would be professional experience in cost estimating.

The question to be addressed is how can a person pursue the requirements for experience and education for a career in cost estimating or operations research? The authors of this article offer one possible solution for those who wish to pursue the growing cost estimating profession and other STEM professions -- apprenticeship.

In a time when the US is spending more on education than any other country (National Center for Educational Statistics, 2012), why are we not producing the finest STEM competent workers in the world? The answers vary, but at a high level, most students are kept too tucked away inside cinderblock walls of an academic arena and never given the chance to become legitimate in a career pathway (Halpern, 2009). Research identifies critical thinking and problem solving skills as the primary need, for which academic classes without context add only minimal value (Symonds, 2011). Pathways to Prosperity (Symonds, 2011) pinpointed 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. Teachers in the United States try to provide relevancy, realness, and meaning to the curriculum, however, what our students really need is a level of access to real scenarios. While learning science, technology, engineering and mathematics, they should be practicing legitimately within an occupation that will eventually lead to a career. Apprenticeship is a model of learning that has traditionally provided a transparent connection between learning and tangible opportunities.

**Apprenticeship**

According to the National Governors Association (2007), “STEM literacy is an interdisciplinary area of study that bridges the four areas of science, technology, engineering, and mathematics. A STEM classroom shifts students away from learning discrete bits and pieces of phenomenon and rote procedures and toward investigating and questioning the interrelated facets of the world” (p. 7). The phenomenon that occurs with STEM education, however, has more to do with curriculum integration than the content knowledge that resides within each discipline. It is more than just the presentation and dissemination of information and knowledge of techniques.

Roberts and Cantu (2012) explained STEM instruction as having varying levels of curriculum integration. Morrison (2006) quoting from Rosenblatt (2005) pointed out that “for too long we have collapsed teaching in STEM to the presentation of information and cultivation of technique and therefore student understanding has fallen short” (p. 3). In its approach, STEM education attempts to transform the often used teacher-centered environment to one that is student-centered by encouraging a curriculum that is driven by exploration, problem-solving and discovery (Fairweather, 2008). The STEM curriculum as a meta-discipline often requires students to actively engage in real situations in order to find real solutions to real problems, such as in cost estimating, which is a learning method that naturally occurs in apprenticeship.

Apprenticeship offers a new definition of what it means to be a student. As not all students benefit from the traditional route of attending college full-time, almost entirely separated from the realities of a career, many businesses are finding ways to partner with their local community college to offer apprenticeships that are helping close the skills gap. According to the Association for Talent Development (2015), community colleges and businesses are a perfect match in helping to alleviate the skills gap because of the relationships and lines of communication that already exist. Although it has been around since the founding of the US, the apprenticeship concept is gaining in popularity. According to the Office of Management and Budget Communications (2015), the Obama administration in its 2016 budget proposed investments to double the number of registered apprenticeships in the United States over the next five years.

Opposite of the “prepare-then-place” model of development, apprenticeship is a “place-then-prepare” process that calls to first place or imbed the learner in an occupation. Once placed with an employer, the learner receives his or her formal education and specialized training that articulates the educational concepts and makes them more legitimate within the occupational community. Historically, apprenticeships have been seen as a form of education where a master craftsperson provides direct instruction to a student or an apprentice by passing on the skills and knowledge of the particular occupation (Brewer, 2011). According to Cantor (1997), modern apprentice schools are learning institutions often sponsored by employers that provide a complementary blend of college-level academic courses, specialized theory or training, while employing learners in relevant occupational areas. According to Soares (2010), these areas work complementary to one another in a way that develops and benefits both the learner and sponsor involved.

The theoretical framework supporting the apprenticeship model of development is based on what Lave and Wenger (1991) coined as legitimate peripheral participation. The theory draws on social learning where newcomers learn better in legitimate environments while being allowed to observe more experienced and legitimate others within a community of practice. It contends that when newcomers join a community of practice (i.e., an occupational community) and become acquainted with the tasks, vocabulary, and organizing principles of that community, and if the newcomer experiences positive signals from the community of legitimacy, they will move further into the community seeking more knowledge for even greater legitimacy and eventually become full-participants. Lave and Wenger further reported the value stems from membership in a real community of practice where learners can observe, model, and reflect in a safe – but legitimate – environment. As Lerman (2015) explained, throughout an apprenticeship, real situations often arise that allow the participant to act legitimately. Simultaneously, the learner can assess how well he or she is doing through self-evaluation, often encouraging or motivating the participant to “want” to learn even more.

Legitimate peripheral participation is used to describe the engagement in social practice found within the apprenticeship model of development. Certainly, this model includes the inquiry- and problem-based strategies often found in STEM education – although, in this case, it is being applied in a real context. Much of the phenomenon brought by integrating STEM into a meta-discipline is about contextual learning leading to a higher level of knowledge than the sum of its parts. Apprenticeship does the same; however, it provides 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 often seek it. They realize that learning will translate into more legitimacy within the community (Lave & Wenger, 1991).

**Cost Estimating Apprenticeship**

Huntington Ingalls Industries (HII) designs, builds and maintains nuclear and non-nuclear ships for the U.S. Navy and Coast Guard and provides after-market services for military ships around the globe. The company has well-established apprenticeship programs at each of its primary business divisions -- Newport News Shipbuilding in Virginia and Ingalls Shipbuilding in Mississippi. The programs have operated for centuries and provide opportunities in various trade and professional occupations leading to associate and bachelor’s degrees. The cost estimating apprenticeship currently resides at Newport News Shipbuilding.

The mission of the Contracts and Pricing department at Newport News Shipbuilding is to develop cost proposals, identify risks, formulate and negotiate proposals, administer contracts following award, and function as a liaison between the company and its customers regarding contractual compliance and contract closeout. Cost estimators perform primary roles within the Contracts and Pricing organization and are responsible for developing material and man-hour estimates, analyzing and comparing cost information for proposal variances, projecting funding progress, and compiling estimate documentation to support contract negotiations. To meet its unique needs for a competent workforce, Newport News Shipbuilding funds and operates an apprenticeship program in cost estimating.

The Apprentice School at Newport News Shipbuilding was spotlighted in a recent *New York Times* article (Schwartz, 2015) as the “gold standard” approach to training student apprentices. The article centered on the recent resurgence of the apprenticeship model and the recent momentum apprenticeship has gained among employers, politicians and the news media as a solution to address the skills gap facing employers and the opportunities it provides workers for a path to a fulfilling occupation. Although the school offers apprenticeships in 27 unique occupational areas, the cost estimating apprenticeship is one of the newer programs that has recently gained popularity with students.

Cost estimating apprentices typically spend their first 18 months working in an industrial trade before being transferred and designated as a cost estimating apprentice. Each apprentice serves three additional years rotating within the Contracts and Pricing department, as well as the Engineering Scoping area. Specific duties during the cost estimating portion of the apprenticeship include evaluating customer requirement documents, developing material and labor estimates, participating in job scope development and budget distribution, assisting with planning workflow for trades departments, and analyzing performance to the budget. The cost estimator apprenticeship is registered with the Virginia Apprenticeship Council, and upon program completion, graduates are classified as cost estimating analysts and have the knowledge and skills necessary to develop quality estimates, possessing a well-rounded background that is favorably suited for future growth opportunities.

Like any other apprenticeship with the company, students are employed full-time with the company upon matriculation to the school and receive pay for a 40-hour work week, which includes two days per week (16 hours) in the college classroom and the remaining three days of the week (24 hours) on the job. While serving their work-related component, apprentices receive occupational training and serve in essential areas within a specific occupational area – in this case, cost estimating. Apprentices receive all benefits and resources that other employees receive e.g., medical and 401k. The employer covers the cost of tuition and the textbooks. Through partnerships with Thomas Nelson Community College, Tidewater Community College and Old Dominion University, apprentices complete an associate degree in either engineering, engineering technology or business administration, all while receiving a full-time salary.

**CONCLUSION**

Why is there a growing gap in so many industries and skill sets – especially in STEM? The secret of capturing and growing an interest in STEM lies in a student’s motivation to “want” to learn STEM. Through the implementation of STEM education and the problem-based strategies it promotes, school systems and teachers are creating a learning environment where students want to learn STEM (Fortus, Krajcikb, Dershimerh, Marx & Mamlok-Naamand, 2005). They are being given the opportunity to experience and debate real-world situations, design and build solutions, and ultimately discover knowledge; and this describes the phenomena surrounding STEM education and the success it brings to the learning process.

Many theorists, however, have argued that greater development occurs through apprenticeship where students learn through experience and engage in discourse through real situational problem solving like the cost estimating apprenticeship program highlighted in this article (Lave and Wenger, 1991; Frykholm, 2005). The contention is that participating in multiple disciplines while being embedded in a real career, learning happens instinctively through shaping arguments and solving problems. These are attributes promoted through apprenticeship with an integrated STEM curriculum.

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