Training Cost Analysts, a Cohesive Pedagogical Framework for Success

Authors:

Danielle Lainez, Senior Consultant, Herren Associates

Katharine Mann, Senior Consultant, Herren Associates

Correspondence concerning this paper should be addressed to Danielle.Lainez@jlha.com and Kammy.Mann@jlha.com

Abstract

How do we train cost analysts? This paper will take a critical look at peer-reviewed academic research regarding pedagogy, or the method of teaching. Leveraging existing knowledge, current best practices and resources available, a framework for teaching and training will be proposed to the cost community. By establishing a consistent methodology for educating our professional workforce we can ensure that new members of the cost analysis field have the tools and skills to succeed.

Keywords: Communication, Program Management, DoD, Training, Pedagogy, Teaching, Education

Introduction

How does one learn how to be a cost analyst? There are no current "cost analysis" degrees offered by any major undergraduate university. Most members of the current cost analysis community have a varied background including economics, engineering, finance, accounting, political science, public policy, or for some, something completely different. In a 2013 survey by the International Cost Estimating and Analysis Association (ICEAA) out of the 497 respondents to the question asking about their field of undergraduate education the following fields of education were identified as seen below in Table 1 below. Most respondents identified Business/management and engineering as their field of education, however there is a large diversity when it comes to the educational background of cost analysts.

Table 1: ICEAA 2013 Survey Results (n=497)

Field of Education	Percent
Business/Management	20%
Engineering	28%
Math/Statistics	11%
Economics	11%
Accounting/Finance	15%
Operations Research	5%
Computer Science/Information Systems	1%
Physical Sciences	2%
Other	7%

What all cost analysts have in common is a desire and a passion for applying data-driven analysis to solve complex problems and inform decision makers on the best way to utilize their resources. Cost analysis is defined by the International Cost Estimating and Analysis Association's (ICEAA) Cost Estimating Body of Knowledge (CEBoK) as "the process of

collecting and analyzing historical data and applying quantitative models, techniques, tools and databases to predict the future cost of an item, product, program or task" (ICEAA CEBok, 2013). This paper will take a critical look at the current state and challenges currently facing the cost analysis community. Specifically, the training of new analysts, and make recommendations for a cohesive training framework using current education research.

Understanding: The Importance of Training

Training employees costs time, money and materials. Failed training comes at a high cost, and businesses often don't want to take that risk. However, not training employees also comes at a cost because untrained employees can be unhappy employees (Lipman, 2013). If the employee feels inadequate, underachieving or unsupported, they are unhappy. Not being satisfied at work can cause the employee to underperform, make mistakes and lose interest in the final work product. Time and money can be lost when untrained workers make mistakes, or even worst, the inadequate product is delivered to the client. This is why an investment in the employee's skills should be of interest to the company. When an individual improves their skill and overall attitude, it positively affects the company as a whole.

Performing high-quality and credible cost estimates requires a great deal of technical skill and knowledge. Cost estimating involves collecting and analyzing historical data and applying quantitative models, tools, techniques, and databases to predict a program's future cost (GAO, 2009, p. 31). Cost Estimating combines art and science to predict the future cost of something based on history that is then adjusted to reflect upgrades, new materials and new products. Cost estimating is complex and sophisticated, requiring the analysts to combine many disciplines and concepts. Without incorporating a variety of methods costs can be under or over estimated.

Specialized training is needed, because it is beyond the basic training of many analysts (Sewell & Marczak, 2016).

Basic and intermediate training can be obtained through reading and referring to the Government Accountability Office (GAO) Cost Guide. It not only includes best practices for the development of costs estimates in government acquisition programs, but outlines generally applicable best practices in a variety of circumstances. In order for a cost estimate to be comprehensive, well-documented, accurate, and credible, the Cost Guide provides great detail for the best practices from the private and public sectors. Current best practices will be discussed in detail below.

In the 2013 ICEAA member survey it showed 65% respondents over 45 years old and twelve percent under 30 years old. It's anticipated that with this age distribution there will be a continued influx of young talent into the cost community. With little, to no experience, it's important to provide the appropriate training to equip cost analysts with the tools to succeed. With 79% of respondents working in the government and defense markets, we asked the question, what is the current climate as it relates to training?

Understanding: Current State

The current training in the cost estimating community is inconsistent and there are no common requirements to train workers. The Federal Government has defined training requirements and courses; however, these trainings are often not offered for contractors working in either government support roles or private companies. Also, there is a discord that is often present between the members of the "cost shop" and the rest of the organization they support; especially the engineers, technical Subject Matter Experts (SMEs), program/project managers, etc. Often times the other members of the team or organization see cost analysts as "bean

counters," or that the only solution that they can offer is creating a Life Cycle Cost Estimate (LCCE) which is used for budgeting and funding strategy, as well as a tool to help decision makers. So why this mistrust between cost analysts and the program/product team they are supporting? In informal discussions, the term "weather man" has often been presented, but not in a good connotation! Cost analysts and estimators can be perceived as overly conservative, and "breaking budgets and adding additional risks" without having data or facts to support the position. There is a very common misconception that cost analysts don't understand the technical aspects of the project. The cost estimate/LCCE is not the only product they offer, and the analysts are more than a "one trick pony" focused around a single product. Instead they are a suite of comprehensive services made up of methods, tools, analysis, evaluations, advice, process improvements, and strategy.

Understanding: Challenges

Challenges that cost analysts face in today's current political and economic client are discussed in detail in the Government Accountability Office's Cost Estimating and Assessment Guide (2009). Figure 1 below taken from the GAO Guide demonstrates the "balancing act" required by members of the community; on the left side are requirements needed to create a good cost estimate (as defined by GAO). On the right side of the see-saw are the challenges or obstacles that can create roadblocks or issues with creating a credible and defensible cost estimate. Notice that the top of the pile of blocks is "inexperienced analyst." While all of these issues need mitigation strategies; the issue of inexperienced, or untrained analysts, and how to train them, will be the topics examined by the authors in this paper.

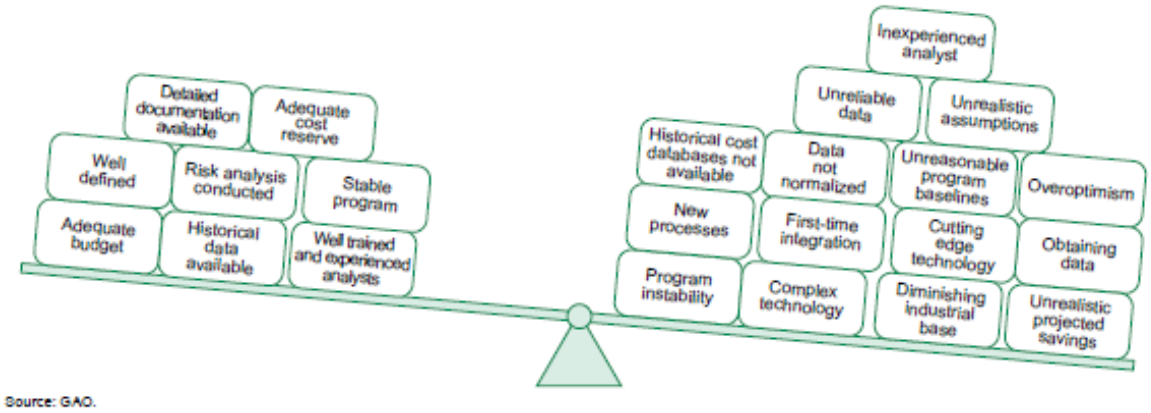

Figure 1: Challenges Cost Estimators Typically Face (GAO, 2009, p. 17)

Understanding: Academic Research

To look at the current landscape and academic research regarding how students learn, the authors of this paper turned to the field of engineering education, focusing on pedagogy, or the study of how we teach and learn, and the art/science that lies behind being an effective teacher and the intellectual development of students. Usually, when pedagogy is used it is in the traditional classroom sense, researchers are referring to their subjects as grade, middle, high school or undergraduate/graduate level collegiate students. However, in this paper, we are using the construct that the students are members of the cost analysis community (usually new to field in need of training); and their "classroom" is the complex and ever changing environment of the professional workplace, usually within the United States Department of Defense sector where the majority of members of the cost analysis community are employed (ICEAA, 2013).

Engineering education is an emerging academic research field that has grown significantly in the past 10 years. An increase in the desire to improve Science, Technology, Engineering and/or Mathematics (STEM) education in the early 2000's has led to a massive increase in federal funding, especially from the National Science Foundation (NSF). With the

technical and analytical nature of cost estimating the engineering field seemed to provide the strongest comparison for academic literature review purposes. Looking at Table 1 in introduction section above, one can also see that 28% of respondents to the ICEAA survey self-identified as having an engineering educational background. Other educational disciplines could have been studied as well, however for the purpose of this paper, and for the similarities between the engineering disciplines and cost analysis, only engineering education research was considered. Researchers in the engineering education field are focusing on the best way to teach undergraduate students to be successful problem solvers and preparing them to be members of the work force. The latest academic research supports the idea that the focus of undergraduate education needs to be concentrated more on preparing students to develop their engineering/critical thinking and professional judgement for the ever changing landscape of the United States work environment and focus less on a transmission of skills or concepts (Adams & Felder, 2008).

Research has shown that students learn better when exposed to the creative nature of engineering through hands-on labs, design projects and open-ended problem solving (Sheppard & Jenison, 1996). Design is a critically important skill, especially in the engineering field and although cost analysts are not “designing” a product, there is still a creative process and the need to design tools and models to fit the data. From his 1992 paper Bordogna adds, "In essence, engineering is the process of integrating knowledge to some purpose. It is a societal activity focused on connecting pieces of knowledge and technology to synthesize new products, systems, and sciences of high quality with respect to environmental fragility." This quote could also be equated to cost analysis, in where the analyst is connecting knowledge and technology to create an accurate, comprehensive, repeatable, traceable, credible, and timely cost estimate (ICEAA

CEBoK, 2013). Larry Leifer in 1995 offers three provisional notions of design education: that design education is a social activity, that learning (to design) requires becoming comfortable with ambiguity, and that all education is re-education.

Educational theory supports the importance of design education along with studies being conducted by engineering programs around the United States and the world (Brereton et al., 1993, Teslow et al., 1994). An educational school of thought called constructivism states that knowledge is learned from experience (Perkins, 1992). Instead of the student being something to fill up with theoretical knowledge by the teacher, the student learns from experiencing different activities, especially in a realistic context, and is especially meaningful when it's a collaborative or team experience.

Research shows that continuous feedback to and from the student and an assessment of students to understand their learning style will allow the instructor to tailor the lessons to their specific needs and will result in higher retention (Sonwalker, 2013). There are five learning pedagogies which during research have found to be effective for learning and retention; apprentice (learning through mentor–student interaction), incidental (learning through case study), inductive (learning through example), deductive (learning through application), and discovery (learning through experimentation) (Sonwalker, 2004 & Sonwalker, 2009). Studies have also shown that continuous feedback to students and engaging the students versus a typical "sage on the stage" or "chalk and talk" lecture method has proven more effective and produces a higher rate of retention of knowledge. In their paper from 2000, Felder et al. cites several instructional methods to improve the engineering education experience for undergraduates including; balancing concrete (facts/practical applications) and abstract (theories, mathematical

formulas and models) information, use active learning and cooperative (team) learning, and discuss clear objectives and relevance of subjects.

In pedagogy, a common terms used for STEM education is "purposeful design and inquiry" (PD&I). In his 2009 article, Mark Sanders discusses the application of PD&I for STEM students as the integration of technological design and scientific inquiry, especially in cross functional teams. Sanders, who runs the STEM education graduate program at Virginia Tech, speaks to the importance of collaboration, and cross-discipline training and teams which has also been reflected in other research investigations. This can be applied to the cost analysis field where analysts need to combined design with data collection and analysis. Below, we will discuss data collected from current cost analysts, who emphasis the need for cross-functional/disciplinary teams.

Academia has begun to focus on the importance of continuing education post undergraduate education when the engineer has entered the workforce (Wulf, 1998). The time in which half of what an engineering student learned during their undergraduate degree has become obsolete (often referred to as "half-life of knowledge") varies between fields, but is commonly estimated to be between 2.5 to 7.5 years (National Science Foundation, 1995). When it comes to discipline such as cost estimating and analysis where these specific concepts are not studied in a collegiate environment there is even a greater need for a robust training and development program, as well as a focus on continuing education for members of the community.

Assess: Best Practices

With a high influx of young new talent emerging into the cost community, the current industry best practice is to teach them the basics through Defense Acquisition University (DAU) and the ICEAA Professional Cost Estimator/Analyst (PCEA) or Certified Cost Estimator/Analyst

(CCEA) certification, while incorporating specific, on-the-job training. Cost analysts are encouraged to find their niche, especially within the DOD, whether it be shipbuilding, electronic warfare, radars, or aircraft. Once they find their niche, stake-holders will find them value-added and a source of knowledge in improving the Federal Government's allocated budget dollars.

The Government Accountability Office is known as the Investigative arm of Congress and exists solely to support Congress in meeting constitutional responsibilities. The GAO oversees the federal government in the stewardship of public funds, and seeks to avoid cost overruns, performance shortfalls, and missed deadlines. In order to meet these requirements, the GAO created a standardized approach that was officially documented in March 2009. Other foreign governments such as Japan, Canada, Great Britain, India and Peru have all embraced these standards and procedures, adding to the validity of the document (2015 Richey). The twelve step process of creating a cost estimate and the ten best practice are captured in the lists below:

The Twelve Steps (2015 Richey)

(1) Define the estimate's purpose (well documented)
(2) Develop the estimating plan (comprehensive)
(3) Define the program (well documented)
(4) Determine the estimating approach (comprehensive)
(5) Identify ground rules and assumptions (well documented)
(6) Obtain the data (well documented)
(7) Develop the point estimate and compare it to an independent cost estimate (accurate)
(8) Conduct sensitivity analysis (credible)
(9) Conduct risk and uncertainty analysis (credible)
(10) Document the estimate (well documented)
(11) Present estimate to management (well documented)
(12) Update the estimate to reflect actual costs and changes (accurate)

Ten Best Practices (2015 Richey)

(1) Capturing all activities
(2) Sequencing all activities
(3) Assigning resources to all activities
(4) Establishing the duration of all activities

(5) Verifying that the schedule can be traced horizontally and vertically
(6) Confirming that the critical path is valid
(7) Ensuring reasonable total float
(8) Conducting a schedule risk analysis
(9) Updating the schedule using actual progress and logic
(10) Maintaining a baseline schedule.

Further basic and intermediate training can be obtained through an ICEAA training program, Resources exist such as the Cost Estimating Body of Knowledge (CEBoK), and attending CEBoK training and knowledge transferring sessions. The Certified Cost Estimator/Analyst (CCEA) program allows the cost analyst to master the basic and intermediate cost knowledge, and strengthens the individual's organizational ability to produce a high quality cost estimate. There are more than 10 exams scheduled in the U.S. for 2016, and a one-week Professional Development and Training Workshop where the cost analyst can learn about a myriad of topics.

On the job training is a large part of current best practices, as real-world problems are hard to test in training. Knowing what good data looks like is important for any credible cost analyst, and mentorship improves your understanding of data. In ICEAAs 2015-2019 Strategic Plan, their strategy for success noted the importance of analyzing and understanding data collected along with the performance measures. Much of the cost analyst's time is spent obtaining and normalizing data, and too often untrained individuals are thrown into data collection without the necessary skills. A common saying in the industry – "garbage in, garbage out," referring to the idea that if you create a cost estimate with bad data, the results will be non-value added, and in some cases, could detriment the program/product being supported. In determining data reliability, GAO states the analyst must verify that the input data used to create the estimate are valid (GAO, 2009,, p. 17). What training exists in the cost community for to ensure this validity of data collection? What data sources are available to an analyst?

Assess: Survey Feedback

After interviewing eleven NAVSEA 05C cost estimators some common threads started to come up. The intern program was highly praised, as it provides the employee with a road map, and specific training opportunities with the goal to equip them with the knowledge and skills to exceed in their career. However, while the classes offered by the Defense Acquisition University, are a good foundation, a majority of students commented that classes do not train specifically for the day-to-day tasks of performing costs. There are a few, such as the regression analysis and learning curve theory that are directly applicable to cost analyst as a whole. The DAU classes are lacking appropriate training in scheduling, data collection, building a cost model, Crystal Ball and ACEIT training, and continued learning once basic training is completed.

Advanced training required pertaining to data collection can be studied and learned in the CEBoK and the GAO cost guide. They outline specific examples of primary and secondary data and what good data looks like. However, this requires the cost analyst to proactively teach themselves how to collect good data. Many times data is collected in a time-crunch and the result is quick, instead of quality data. Most people wouldn't instinctively know to check to see if cost segregations are clear, so that recurring data are separable from nonrecurring data, or if the data has been analyzed for performance variation over time, including technological advances.

Below, Table 2 is taken from the GAO Cost Estimating and Assessment Guide (2009) that shows the mandatory training and experience to achieve the first and second level of cost estimating certification for Federal Government cost analysts. While some of the basic courses are available for non-Government employees (i.e. Support contractors who have Common Access Cards (CACs)) if you are in the private or commercial industry these trainings are not

available to analysts in these organizations. This is why it is even more important that these individuals have access to a comprehensive, cohesive and complete training program that will prepare them for the challenges associated with the cost analysis career.

Table 2: Certification Standards in Business, Cost Estimating, and Financial Management in the Defense Acquisition Education, Training, and Career Development Program (GAO, p. 54-55)

Level		Education	Experience	Training
I	Desired	Baccalaureate		
	Mandatory		1 year of acquisition in business, cost estimating, or financial management	ACQ 101: Fundamentals of Systems Acquisition Management and 2 of the following: BCF 101: Fundamentals of Cost Analysis BCF 102: Fundamentals of Earned Value BCF 103: Fundamentals of Business Financial Management

Level		Education	Experience	Training
II	Desired	Baccalaureate	2 additional years in business, cost estimating, or financial management	
	Mandatory		2 years of acquisition in business, cost estimating, or financial management	ACQ 201: (Parts A & B) Intermediate Systems Acquisition and BCF 205: Contractor Business Strategies and, if not taken at Level I, BCF 101: Fundamentals of Cost Analysis or BCF 102: Fundamentals of Earned Value Management or BCF 103: Fundamentals of Business Financial Management and one of the following: BCF 203: Intermediate Earned Value Management or BCF 204: Intermediate Cost Analysis or BCF 211: Acquisition Business Management
III	Desired	Baccalaureate or 24 semester hours among 10 courses[a] or Master's	4 additional years of acquisition in business, cost estimating, or financial management	
	Mandatory			BCF 301: Business, Cost Estimating, and Financial Management Workshop

The GAO Cost Estimating and Assessment Guide (2009) also recommends eight functional areas for a highly trained cost analyst to be well versed and skilled in. While economics, statistics, and engineering might seem like an easy assumption of skills to have, one might be surprised to see computer science, public and government affairs and interpersonal skills as important components of a cost analyst's education and training. Figure 4 below from the GAO guide is a visual representation of these eight functional areas of study and emphasis and these should be an integral part of the training methodology as will be discussed in the next section.

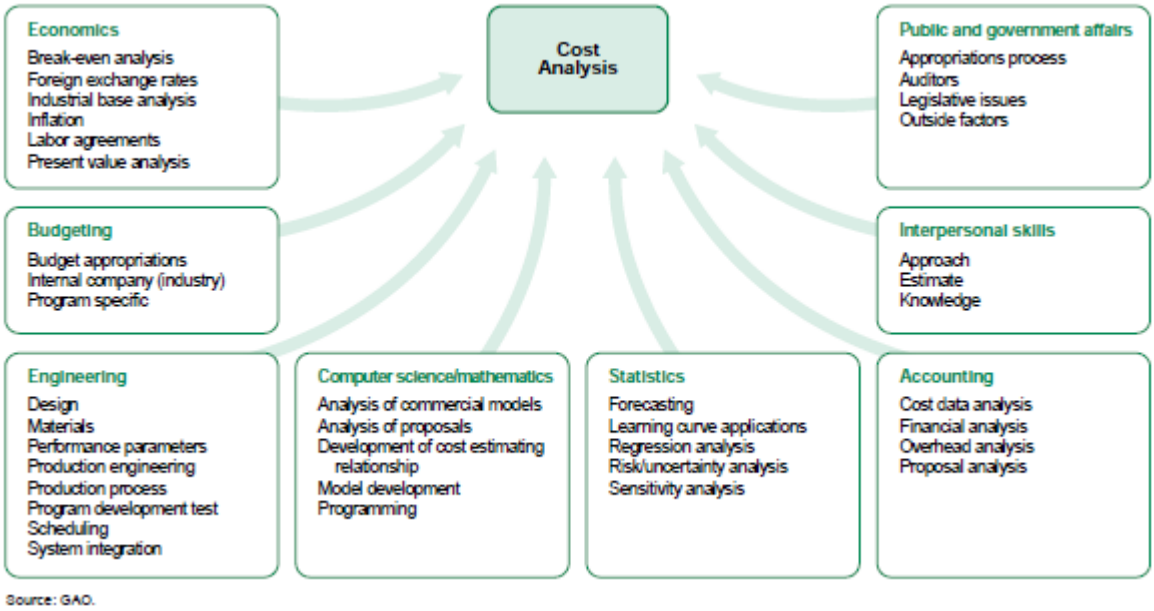

Figure 4: Disciplines and Concepts in Cost Analysis (GAO, 2009, p. 51)

The authors conducted interviews and a brief anonymous survey to gather more data regarding current cost analysts' experiences regarding training. We began the process with interviewing 15 cost analysts at NAVSEA 05C and Herren Associates. They ranged from 2 months to 46 years of experience. The sample was chosen because of already established interpersonal relationships and the willingness to be vulnerable and candid with their responses.

From this sample, a 9 question survey followed, the in person survey can be found in Appendix A and the online survey for Washington Area Chapter ICEAA members can be found in Appendix B. Demographics included gender, years of experience, employer and educational background was also collected.

When conducting the one-on-one interviews, a major trend for junior, mid-level and senior professionals was that basic training is available, but continued learning was a less viable option. The majority agreed courses offered by the Defense Acquisition University (DAU) were beneficial in providing a foundation on acquisition management, learning curve theory, program life cycle cost estimates and earned value management. One respondent with over 45 years of experience commented on how DAU courses were refreshing, and useful for getting back to basics, but added unless you start in the government's intern program there is a real need for a formal roadmap in regards to training and career advancement. One respondent, who is currently enrolled in the NAVSEA intern program, commented how the OSCAM training was good, but it doesn't apply to day-to-day tasks. Another respondent with 13 years of experience completed all certifications and DAU training, but since then hasn't had any formal continued education, and when asked about what keeps them loyal to their job, they responded "my paycheck". One respondent, who came from Raytheon, commented how most of their training occurred there, and their next step was to enroll in the Master's program through the Naval Postgraduate Institute, where they are currently in their second year.

From the survey, the major take away was that 58% of the respondents benefitted the most from on the job training and mentoring. This was especially true with new analysts with 0-5 years of experience who chose on the job mentoring as the most profitable form of training they have received. However, it wasn't only just young analysts, new to the field, who profited

from mentoring; respondents with 20+ years of experience chose on the job mentoring as the most profitable training tool as well. Respondents who profited most from on the job mentoring also agreed it is one of the greatest areas for improvement. Another major trend from the interviews was that new challenges and learning opportunities was a driving force behind job satisfaction. There was a common thread of civic responsibility to provide honest analysis for key decision makers. The conclusions that can be drawn from the qualitative and quantitative data collected during these interviews and surveys is there is a compelling and critical need for knowledge transfer and mentorship, especially as our workforce ages. The new generation of analysts are hungry for knowledge and experience and a wealth of this knowledge can be gained from those who are experts in the field. More experienced cost analysts also get the benefit of mentoring less experienced members of the field, ensuring their institutional knowledge and work is passed on to continue the community they have worked so hard to build. Figures 5, 6, and 7 below are graphical representations of the survey data collected regarding mentorship and help demonstrate the cost communities desire to incorporate a more structured and formal mentor program into the training process.

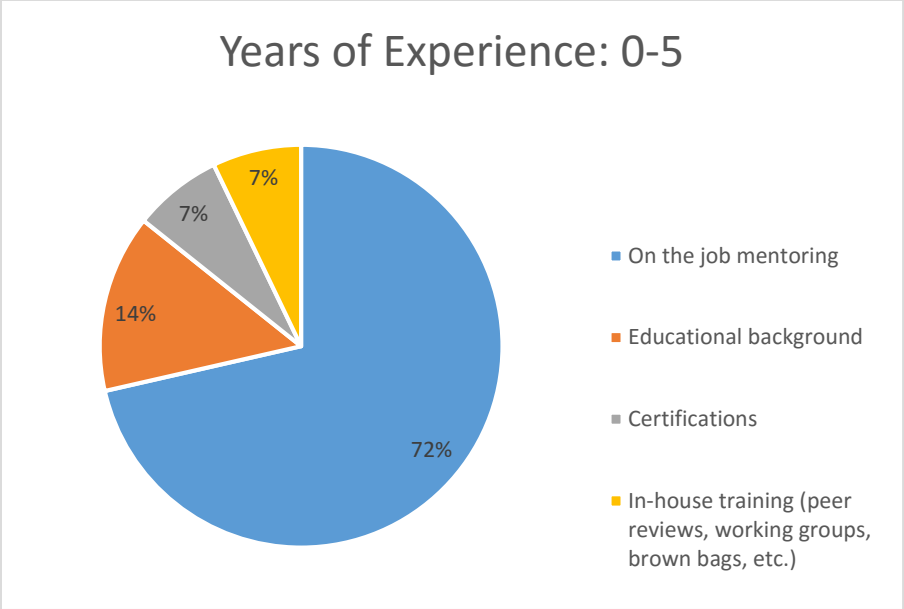

Figure 5: Training Preference for Analysts with Experience 0-5 years

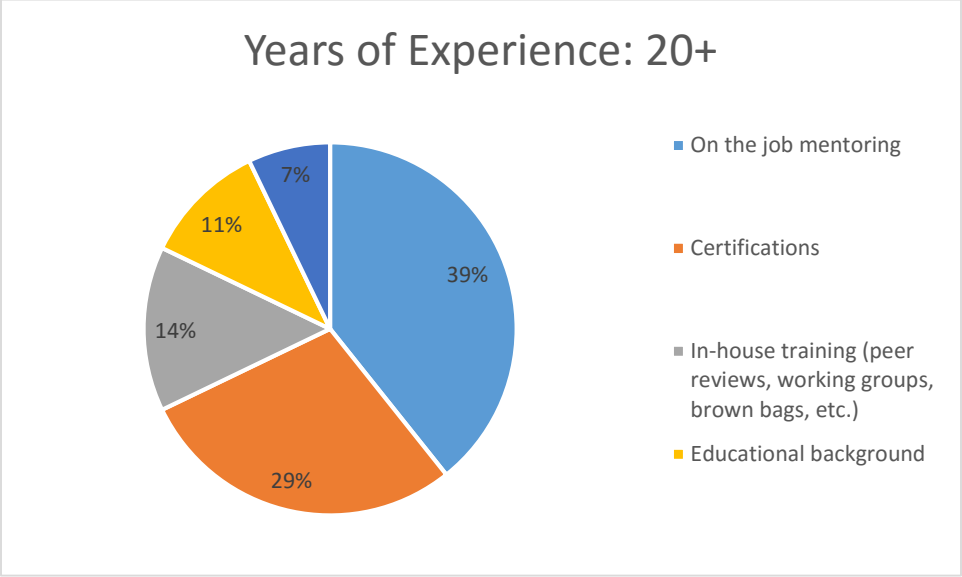

Figure 6: Training Preference for Analysts with Experience 20+ years

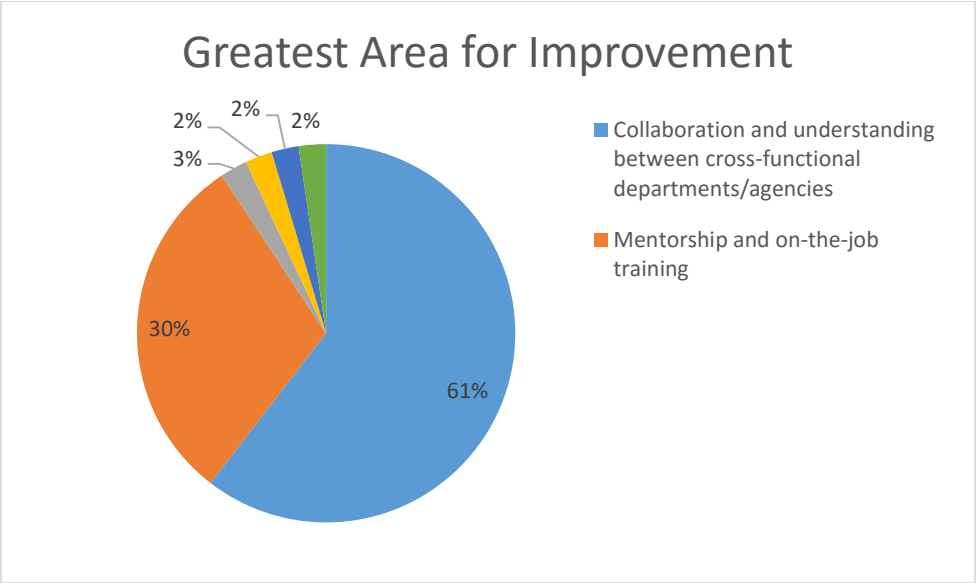

Figure 7: Greatest Area for Improvement Survey Responses

Recommended Pedagogical Framework

Using all of the knowledge presented in the sections above the authors created a pedagogical framework for training cost analysts incorporating the current industry best practices and the most applicable research from cognitive research and how educators in engineering are instructing their classes to prepare students for the professional workforce. Figure 8 below is the framework that was developed. The basis of the framework leverages the Understanding by Design (McTighe & Wiggins, 1998) backwards design three step process. The first step, identifying the results that the instructor wants the student to possess, the authors chose the eight disciplines and concepts in cost analysis as defined in the GAO Cost Estimating and Assessment Guide (2009). These eight disciplines were selected as the authors wanted to emphasis the cross-discipline nature of cost analysis and the necessity to be well versed in all eight areas and have an arsenal of tools and skills, not just the typical "LCCE creation" ability as common believed by other members of the organization. Stage 2 is defined as determining acceptable evidence or assessing the analyst's ability to operate in the eight functional areas from Stage 1. Some outputs that were determined by the authors as necessary functions of a highly trained and skilled cost analyst include: creating quality estimates, performing detailed and accurate data analysis, thorough data collection and research, active team participation and collaboration, especially cross-discipline with other members of the organization, and mentorship and knowledge transfer to others. While there are other desirable outputs of a highly trained analyst these were the main ones determined by the authors. For future research and considerations, the authors plan to have discussions with other members of the cost analysis community, and SMEs, to determine if other outputs or other evidence should be collected for assessment purposes. Finally, stage 3 is the development of the learning experience or training.

Within Stage 3, the authors proposed additional steps for more granularity and structure based on the literature reviewed. First, we recommend an assessment of the students' preferred learning style so that the interactive/design portion of the lesson could be tailored to fit specific needs and requirements. There are several free assessments available on the internet to assist the student in determining their individual learning style such as the VARK assessment (http://vark-learn.com/the-vark-questionnaire/) and the Index of Learning Style Questionnaire by Soloman and Felder (https://www.engr.ncsu.edu/learningstyles/ilsweb.html).

After the analyst has a better understanding of how they learn and the best method for retaining knowledge, the authors recommend a three step learning process. This is probably best done over an intensive 2-week in person course to get the new member of the field up to speed and functioning at a high level, especially since this will be their first exposure to the discipline if they are new college graduates. First, we recommend a short classroom section of the training where the analysts will acquire the basic vocabulary, math formulas/equations, processes and introductory information about cost estimating. The authors recommend using material already available and created such as ICEAA CEBoK, Defense Acquisition University courses (if available), and the GAO Cost Estimating and Assessment Guide. This part of the training will be on the lower tiers of the Bloom's Taxonomy pyramid (remembering, understanding, and applying). The second portion of the training which should encompass the majority of the time will utilize the five versions of pedagogy including: apprentice (learning through mentor–student interaction), incidental (learning through case study), inductive (learning through example), deductive (learning through application), and discovery (learning through experimentation). As discussed in the literature review section, current research has shown that students retain and comprehend knowledge better when it is applied, especially in a project-based or design based

situation (Mills & Treagust, 2003). This also relates to the educational theory of constructivism, or that the individual learner relates things they learn to experiences, therefore creating a strong case for activity/hands-on based learning (Hein, 1991, Jonassen & Ronrer-Murphy, 1999). This will require additional effort and planning by the instructors to create projects/case studies for the new analysts, however, research has proven the investment to create these simulations of the professional work environment will pay off by having well trained and qualified analysts who can sell to other members of the organization their skill set to solve complex problems for decision makers.

Finally, the authors recommend the last step of transferring knowledge learned in the intensive training course by becoming instructors for the next cohort of incoming analysts and mentoring the next group of the team. Mentorship is a wonderful way to achieve this knowledge transfer, and as proven in the survey to current members of the community, it is highly desired and considered to be the greatest training tool currently available. In their 2008 book Spurlin, Rajala, and Lavelle speak to the important of iterative assessment during educational design. With an iterative cycle of reflection and assessment the organization implementing this pedagogical framework can ensure continuous improvement and incorporation of lessons learning and best practices for each new group of incoming analysts requiring training.

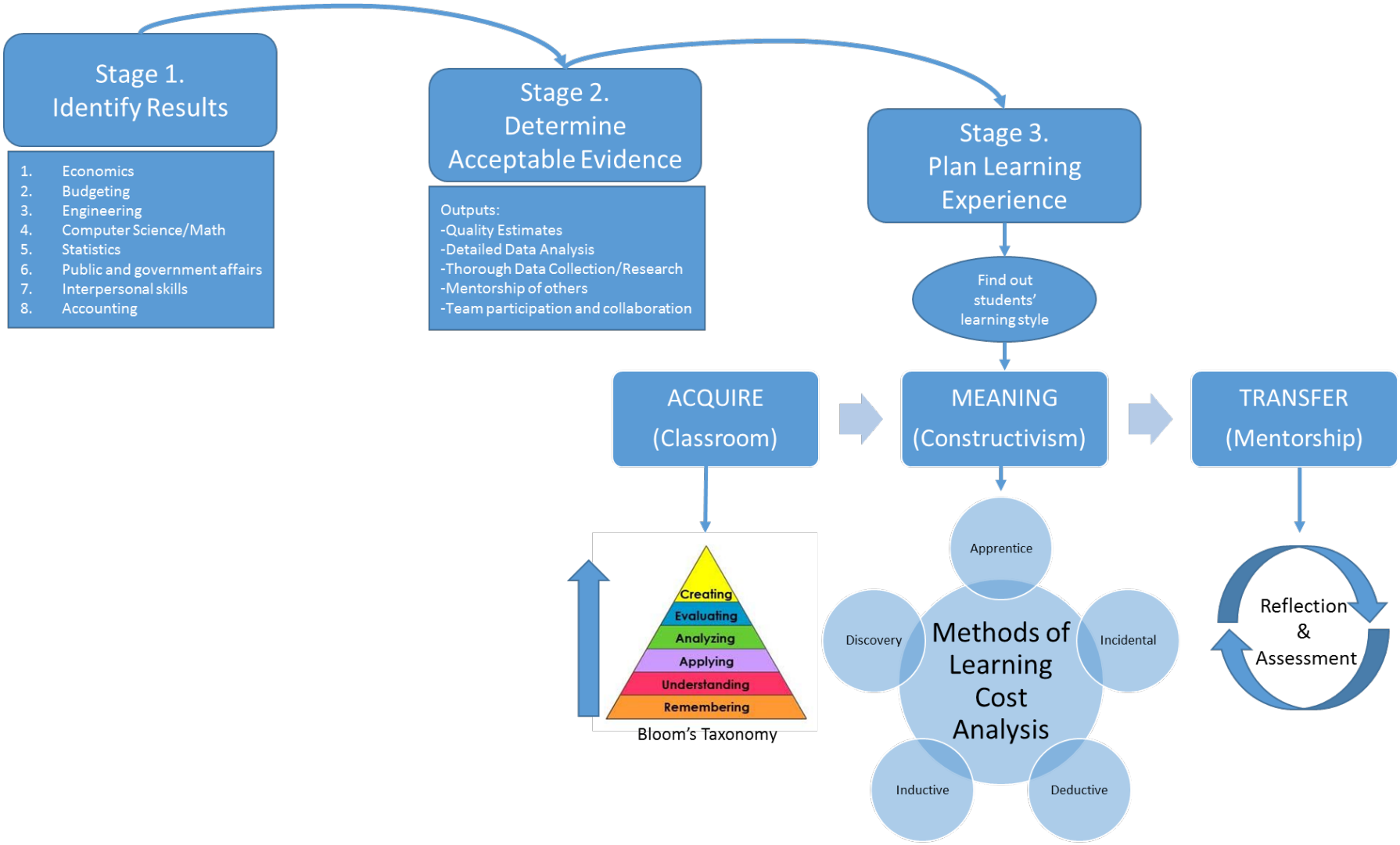

Figure 8: Proposed Pedagogical Framework for Training Cost Analysts

Recommended Training Framework

A pedagogical framework is a structured method or approach for teaching that guides the instructor in a systematic way to instruct the students. There are several well-known and researched pedagogical frameworks that have been around since the 1950's and new frameworks continue to be introduced and refined in current literature. The most important framework that is the "backbone" of pedagogy and teaching theory that is still to the day very commonly referenced is Bloom's Taxonomy which was first introduced in 1956 (Bloom et al., 1956). The taxonomy defines six levels of learning in a hieratical structure that shows an increase of understanding as the student progresses up the pyramid. The six levels can be defined as (Felder et al., 2000, p. 3):

1. *Knowledge* — repeating memorized information
2. *Comprehension* — paraphrasing text, explaining concepts in jargon-free terms
3. *Application* — applying course material to solve straightforward problems
4. *Analysis* — solving complex problems, developing process models and simulations, troubleshooting equipment and system problems
5. *Synthesis* — designing experiments, devices, processes, and products
6. *Evaluation* — choosing from among alternatives and justifying the choice, optimizing processes, making judgments about the environmental impact of engineering decisions, resolving ethical dilemmas (p. 3)

The six cognitive levels were updated into a new model in the 1990's and were translated into more contemporary language and a visual representation as seen in Figure 2 below which was created to demonstrate the progression from rote memorization at the base of the pyramid, to creating new ideas at the pinnacle of learning (Forehand, 2010):

Figure 2: New Model of Bloom's Taxonomy (Forehand, 2010)

Along with Bloom's Taxonomy, another major pedagogical framework that has become popular with researchers, especially in the engineering education field, is Understanding by Design (UbD) developed by McTighe and Wiggins in 1998. This framework focuses on using a backwards design to develop training and curriculum by thinking first about the desired results, then determining the evidence necessary to assess the desired results, and finally developing the learning plan to accomplish the stage 1 goals and stage 2 assessments. Figure 3 below is a visual representation of UbD backwards design (Newton-Conver's Online Newsletter for Educators, 2016):

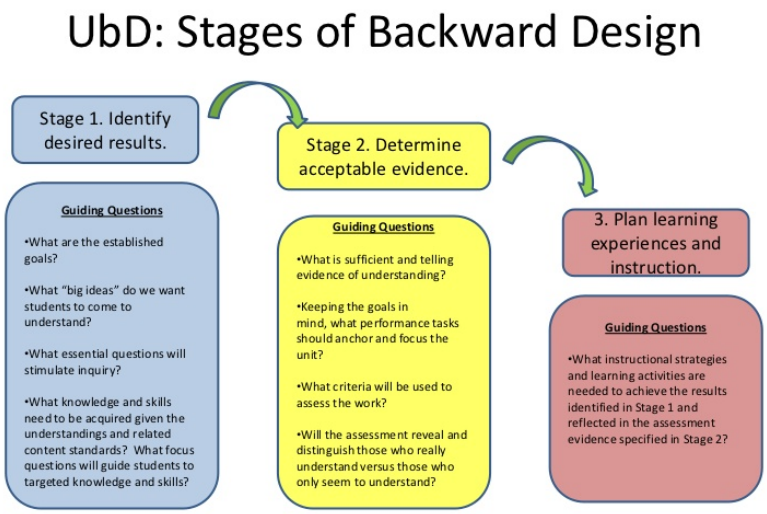

Figure 3: UbD Stages of Backward Design (2010)

Additional pedagogical frameworks that are used in educational research includes Whole Brain Paradigm (Herrmann, 1988), VAK Model – Visual, Auditory or Kinesthetic (Ward & Daley, 1993), Dimensions of Learning (Marzano & Pickering, 1997), DEEP Pedagogical Framework (White, 2003), and Teaching for Understanding (Freestone, 2007) along with many others. These frameworks will be used as a basis for creating the pedagogical framework for training cost analysts below, but the authors especially drew heavily from Bloom's Taxonomy and Understanding by Design.

Final Recommendations

The best path forward for organizations looking for a successful way to train new cost analysts is an established, systematic and well planned method and schedule for training. The organization should leverage the literature and trainings that are already available through DAU, GAO, ICEAA or any other entity. However, they should not rely solely on classroom training ("sage on the stage") or the baptism by fire method of training, but should consider the proposed pedagogical framework presented here for a design/project based approach to training. The field

of engineering education is embracing hands-on activities and design based learning; the cost community should think of the work we do as design as well (it is an art and a science!). By putting in the effort into creating well thought out trainings, the organization or company will return their investment by retaining a pool of well training, experienced, and engaged analysts ready to solve the challenging problems presented by our profession. Assessment, reflection, mentorship, and continuous improvement are crucial to ensure that the training programs are always evolving and previous students are becoming the teachers/mentors to the next "class" of incoming analysts.

This paper was only the beginning of this discussion regarding training and creating a pedagogical framework for success. This methodology is still untested, so future work includes a case study of implementing this framework to see the results and benefits of having a cohesive structure and implementing project/design based learning would improve knowledge retention and move the student's up Bloom's Taxonomy to higher levels of learning. Other future research could include more fields of educational research outside of the engineering education discipline such as mathematics, political science, business, etc. Research could also be considered from the workforce development field and what current best practices are recommended in this discipline. Finally, the authors hope that this paper will spark a conversation within the community and members can discuss the best ways to train analysts who have had no formal training in their undergraduate field (and maybe have never heard of cost analysis before job searching!) Subject Matter Experts who have been in the cost community and have trained multitudes of analysts will have important information and tips to add to this conversation and the authors look forward to incorporating feedback into the next iteration of the framework.

Conclusion

In conclusion, the field of cost analysis is exciting and ever changing. Those of us who are in this profession have come to know and love the challenges and opportunities we face every day in the current political and fiscal environment. As resources shrink, the demand for high quality cost analysis and data-driven decisions will continue to increase. It's our responsibility to ensure that new members of the community are getting the best training and hands on experiences possible to continue the quality and reputation of our profession. We need to think of ourselves not as just a producer of an estimate, but problem solvers and members of a cross-functional team to support the organization and the larger strategic goals. By guaranteeing success for new members of the field with a comprehensive and cohesive strategy for training we safeguard our profession for the future.

Acknowledgements

The authors would like to acknowledge the support of the cost team at Herren Associates for their guidance and review. The authors would also like to thank the cost analysts that were interviewed at NAVSEA-05C and to those anonymous estimators who responded to our survey. Thank you! To Megan Jones at the ICEAA National Office thanks for working with us to find a slot to put this paper, even if it doesn't exactly fit into a paper track. Finally, to Melissa Teicher for her insight and initial research she did on the topic of training cost analysts and for her willingness to share her thoughts with us!

Citations

Adams, R.S., & Felder, R.M. (2008). Reframing Professional Development: A Systems Approach to Preparing Engineering Educators to Education Tomorrow's Engineer. *Journal of Engineering Education*, 239-240.

Berry, J., & Asiello, D. (2011). *Department of Defense Sustainability Planning: The View from the Second Year*. New Orleans, LA: Noblis.

Bloom, B. S.; Engelhart, M. D.; Furst, E. J.; Hill, W. H.; Krathwohl, D. R.(1956). *Taxonomy of educational objectives: The classification of educational goals*. Handbook I: Cognitive domain. New York: David McKay Company.

Bloom, B.S. & Krathwohl, D.R. *Taxonomy of Educational Objectives. Handbook 1: Cognitive Domain*. Addison-Wesley, New York, 1984.

Bordogna, J. "Engineering—The Integrative Profession," NSF Directions, May/June, Vol. 5, No. 2, (1992).

Brereton, M.F., J. Greeno, J. Lewis, C. Linde and L. Leifer, "An Exploration of Engineering Learning," Proceedings of the 5th International Conference on Design Theory and Methodology. Held: Albuquerque, NM, USA. American Society of Mechanical Engineers, Design Engineering Division (Publication) DE v 53, Published by ASME, New York, NY, USA. p. 195-206, (1993).

Cost Estimating Body of Knowledge *(CEBoK)* (1.2 version). (2013). Vienna, VA: International Cost Estimating and Analysis Association.

Estimated Impacts of Sequestration-Level Funding. (2014). Washington, D.C.: Department of Defense. <http://www.defense.gov/pubs/2014_Estimated_Impacts_of_Sequestration-Level_Funding_April.pdf>.

Felder, R.M., Woods, D.R., Stice, J.E., & Rugarcia, A. (2000). The Future of Engineering Education, Teaching Methods that Work. *Chemical Engineering Education, 34(1)*, 26-39.

Forehand, M. (2010, July 6). *Bloom's Taxonomy - Emerging Perspectives on Learning, Teaching and Technology*. Retrieved March 23, 2016, from http://www.roe11.k12.il.us/GES%20Stuff/Day%204/Process/Blooms/Mary%20Forehand%20discussion-Bloom%27s%20Taxonomy.pdf

Hein. G.E. (1991). Constructivist Learning Theory. Proceedings from: *International Committee of Museum Educators Conference*, Jerusalem, Israel.

ICEAA. (2013). Survey of Members. Vienna, VA: International Cost Estimating and Analysis Association.

Jonassen, D.H. & Ronrer-Murphy, L. (1999). Activity Theory as a Framework for Designing Constructivist Learning Environments. *ETR&D, 47(1)*, 61-79.

Leifer, L. remarks made at the *International Workshop on Project-Based-Learning*, Stanford University, Aug. 7-10, (1995).

Lipman, V. (2013). "Why Employee Development is Important, Neglect and Can Cost you Talent." Forbes. Retrieved from: http://www.forbes.com/sites/victorlipman/2013/01/29/why-development-planning-is-important-neglected-and-can-cost-you-young-talent/#60dd33e62ce0

Mills, J.E. & Treagust, D.F. (2003). Engineering Education – Is Problem-Based or Project-Based Learning the Answer? *Austrailasian Journal of Engineering Education*, 2-16.

National Science Foundation (NSF). (1995). Restructuring Engineering Education: A Focus on Change. Report of an NSF Workshop on Engineering Education, June 6-9, 1994, Arlington, VA.

Perkins, D.N. "What Constructivism Demands of the Learner," *Constructivism and the Technology of Instruction: a conversation*, LEA Associates, Hillsdale, NY, p. 161-165, (1992).

Richey, Karen. (2015) GAO Cost Estimating & Scheduling, Best Practices and Audit Findings. Washington, D.C.

Sanders, M. (2009). STEMmania. *The Technology Teacher*, 20-28.

Sewell, M. & Marczak, M. (2016). "Using Cost Analysis in Evaluation", The University of Arizona, retrieved from http://ag.arizona.edu/sfcs/cyfernet/cyfar/Costben2.htm

Sheppard, S. & Jenison, R. "Freshman Engineering Design Experiences: an Organizational Framework" International Journal of Engineering Education. 1996.

Soloman, B.A. & Felder, R.M. (2016). Index of Learning Styles Questionnaire. NC State University. https://www.engr.ncsu.edu/learningstyles/ilsweb.html

Sonwalkar N. ''Changing the Interface of Education with Revolutionary Learning Technologies: An Effective Guide for Infusing Technology Enabled Education for Universities and Corporations.'' Presentation at iUniverse, New York, September 2004.

Sonwalkar N. The sharp edge of the cube: pedagogically driven instructional design for online education. Syllabus December 2001, pp. 12–16(www.campus-technology.com/article.asp?id = 5858);

Sonwalkar N. Changing the Interface of Education with Revolutionary Learning Technologies. Syllabus November 2001, pp. 10–13, (http://www.campus-technology.com/article.asp?id = 5663).

Sonwalker, N. (2013). The First Adaptive MOOC: A Case Study on Pedagogy Framework and Scalable Cloud architecture – Part 1. *MOOCs Forum*, 22-29.

Spurlin, J. E., Rajala, S. A., & Lavelle, J. P. (2008). *Designing better engineering education through assessment: A practical resource for faculty and department chairs on using assessment and ABET criteria to improve student learning*. Sterling, VA: Stylus Pub.

Teslow, J.L., L.E. Carlson and R.L. Miller, "Constructivism in Colorado: Applications of Recent Trends in Cognitive Science," *ASEE Annual Conference Proceedings,* Session 1602, (1994).

The Compass. (2016). Understanding by Design: A Framework to Support Effective Teaching and Learning. Newton-Conover's Online Newsletter for Educators. Retrieved from: http://nccscurriculum.org/2014/01/22/understanding-by-design-a-framework-to-support-effective-teaching-and-learning/

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice*. San Francisco: Jossey-Bass.

Wiggins, G., & McTighe, J. (2005). *Understanding by Design* (Expanded 2nd ed.). Alexandria, Virginia: Association for Supervision and Curriculum Development.

Woods, D.R. *Problem-based Learning: How to Gain the Most from PBL*. Woods Publishing, Waterdown, 1994. Distributed by McMaster University Bookstore, Hamilton, ON.

Wulf, W. (1998). The Urgency of Engineering Education Reform. Proceedings from: *Realizing the New Paradigm for Engineering Education*, Baltimore, MD.

VARK Questionnaire. (2016). Retrieved on 29 March, 2016 from:

https://www.engr.ncsu.edu/learningstyles/ilsweb.html

U.S Government Accountability Office. (2009) GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs. Washington, D.C.: Applied Research and Methods.

Appendix A
One-on-One Survey Questions

1) What are your individual training needs?

2) What are the overall training needs?

3) What training has equipped you?

4) What keeps you enthusiastic and loyal to your job?

Appendix B
Training Survey to Washington Area Chapter ICEAA Members

1) Training that has profited me the most as a cost analyst:

    a. Education Background
    b. DAU Courses
    c. In-house training (peer reviews, working groups, brown bags, etc.)
    d. On the job mentoring
    e. Other

2) I want further training and knowledge in:

    a. Accounting: cost data, financial, overhead and proposal analysis
    b. Budgeting: appropriations, industry, program specific
    c. Computer science/math: development of model and CERs, programming, handling mega data
    d. Economics: labor agreements, inflation, break-even analysis, foreign exchange rates, inflation
    e. Engineering: design, materials, performance parameters, production engineering and process, scheduling
    f. Interpersonal Skills: approach in presenting estimate, managerial and leadership
    g. Public and gov't affairs: appropriations process, auditing, legislative issues, outside factors
    h. Statistics: forecasting, learning curve, regression, risk/uncertainty, sensitivity analysis
    i. Other

3) DAU classes are applicable for day-to-day tasks

    a. 0-5 Scale (strongly disagree-strongly agree)

4) The greatest area for improvement in the cost community is:

    a. Collaboration and understanding between cross-functional departments/agencies
    b. Mentorship and on-the-job training
    c. Diversity in education and skill
    d. Other

5) What do you enjoy most about your job?

    a. New challenges and learning opportunities
    b. Known standard processes
    c. Making a difference
    d. People I work with
    e. Analysis

f. Other