Overview

In early 2013, Director of the Washington State Community College Center of Excellence for Aerospace and Advanced Manufacturing (CoE) Mary Kaye Bredeson met with representatives from The Boeing Company to learn about its need for calibration technicians. This meeting led to a collaborative research event involving several other manufacturing companies. The findings confirmed the broader labor market need for people with the knowledge, skills, and abilities (KSAs) commonly required of calibration technicians. To develop foundational curriculum in Measurement Science that would meet this declared skills gap, the CoE sought and received funding from the National Institute of Standards and Technology (NIST).

Introduction

As part of the State’s Community and Technical Colleges (CTC) system, the CoE for Aerospace primarily acts as a broker between statewide aerospace/manufacturing companies and the two-year college system. Like many long-established industry leaders, Boeing is keen to replace and replenish an aging and highly skilled workforce. At the time of this research, Boeing needed approximately twenty calibration technicians and, not surprisingly, other large Northwest manufacturing companies reported similar requirements.

Based on these findings, Bredeson and her staff conducted a qualitative research study—Design a Curriculum (DACUM) workshop—as the first stage in preparing instructional courses and modules for calibration technician training. A DACUM workshop begins with an in-depth discussion with subject-matter experts on the specific job tasks. The second stage of a DACUM is to map out the KSAs required to perform this job. The results—a detailed profile of the work involved and the KSAs associated with it—become the foundation for curriculum development and modification.

The DACUM took place in May of 2013 with attendees from Fluke Manufacturing Corporation, Lockheed Martin Company, Puget Sound Naval Shipyard, Northrop Grumman, The National Conference of Standards Technologies, CIMtech Inc., Grayson Industries, and The Boeing Company. Representatives from these companies and others were asked to continue their relationship beyond the DACUM by joining an Industry Advisory Group to provide guidance and support as the project proceeded. All agreed to assist in this way.

The Labor Market Demand

In exploring the labor market demand, we found the requirements, responsibilities, and KSAs varied a great deal among industries. For example, in the medical field, correct calibration of equipment used to monitor a medical condition could have life-or-death consequences. Following standard operating procedures for equipment calibration and documentation of the work completed are essential work tasks. Similarly, in a manufacturing setting, failure to follow calibration steps according to the prevailing standards and procedures can have equally momentous implications. However, several common skills were found across many job descriptions and industries. These include the ability to:

1. Inspect for accuracy and indications of noncompliance with a required standard
2. Recognize noncompliance in machine or process performance
3. Clearly and accurately document
   a. Inspection findings
   b. Calibrations performed
   c. Problems identified
4. Apply basic math functions to solve problems
5. Use rigorous logic and methods to solve problems
6. Employ basic statistical concepts into problem analysis and reporting
7. Deal with problems involving several concrete variables
8. Write accurate and complete reports
9. Maintain tools and equipment in accordance with established standards
10. Read and interpret technical drawings and documents

Our research found over 400 manufacturing-related positions advertised in the area, although many of those were at the ‘operator’ level, and little reference was made to the KSAs seen more frequently in positions involving calibration. However, it was clear that the manufacturing sector was very active, and new, entry-level employees were in great demand.

When we searched labor market sources for open calibration and/or metrology technician positions, it was clear the demand was extensive. In the Northwest alone, there were 50–100 open positions that involved some level of calibration work. In addition to manufacturing, we also found the demand in medical research labs, hospitals, warehouses, and food processing plants. And this need is not unique to the Northwest—our industry partners are trying to fill these technical positions across the nation.1

In the fall of 2013, the CoE for Aerospace wrote, submitted, and received a grant from NIST to continue this project and create instructional certificates in Measurement Science. In August 2014, the CoE received the $65,000 grant and began the project.

Technical Project Approach, Methodology, and Project Management Plan

The grant proposal stated the case for funding as follows:

1 The main sources for this labor market information included company websites, Monster.com, Indeed.com, and Simply Hired
A training gap exists in measurement science between what is typically taught at community and technical colleges, and KSAs required to effectively perform job requirements within the advanced manufacturing industry. Measurement science is a critical tool in manufacturing and has traditionally been under-addressed in higher education and should be included in technical training. Technicians need an understanding of the fundamentals of measurement science, including traceability, standards, and standardization processes, as each applies to the use of measurement and test equipment in an advanced manufacturing environment. Including measurement science courses in community and technical college technical training programs will allow technicians to gain both theoretical and practical, hands-on experience as they focus on design and production processes within the manufacturing sector. There is a distinct lack of standards education in advanced manufacturing in the state of Washington. In fact, no community or technical college offers a certificate or degree in measurement science or metrology. Only a few colleges in the state offer courses at all and those courses are not standardized to common criteria. To meet today’s industry needs a curriculum must be developed for courses and stackable certificates that integrate measuring devices, techniques, analysis, and plan development. This curriculum needs to be incorporated into college manufacturing programs throughout Washington.

Project Goals

Under the leadership of the CoE, five colleges—North Seattle College, Everett Community College, Lake Washington Institute of Technology, Olympic College, and Shoreline Community College—joined the project and worked closely on the curriculum design team. Support was provided by the State Board for Community and Technical Colleges in Olympia, Washington. The goals of the project for which the Center was funded were:

- Develop course curriculum with industry subject matter experts’ input that can be embedded into advanced manufacturing/aerospace programs;
- Develop a series of courses that can be included in a short-term certificate that can be adopted at any of the state’s colleges;
- Create curriculum that will be easily recognizable (common certificate with course titles/objectives) so that industry hiring managers are able to clearly identify the training when it appears on resumes;
- Increase the number of community college students that are qualified to fill job openings in measurement science/precision measurement/metrology within local companies; and
- Provide professional development opportunities for Design Team faculty to attend industry-led conferences and seminars for exposure to workplace best practices.

Possible Future Scenarios

In the grant proposal it was suggested that future project expansion could:

- Provide a pathway to incumbent workers who have experience in Measurement Science. Such a pathway would allow them to earn a certificate or degree to validate that work experience;
- Develop two to three stackable certificates leading to a two-year AAS or AAS-T degree to be implemented at Washington community or technical colleges;
- House a Bachelor’s of Applied Science in Metrology at a community or technical college in the greater Seattle region after research determines that it would be viable; and
- Provide training that with the 2014-NIST-SSCD-01 Everett Community College/Center of Excellence for Aerospace and Advanced Manufacturing required experience would assist workers in successfully passing the ASQ Calibration Technician Certification.

Project Implementation

As the project began, the CoE for Aerospace hired three outside consultants: a lead for the Curriculum Design Team; an external project evaluator; and a project manager. The Design Team, which included six technical faculty from the participating colleges, met weekly for four months. As preparation for the grant work, members of the Curriculum Design Team attended the 2015 Measurement Science Conference in Anaheim, California. Their travel and conference expenses were covered under the grant.

In addition, CoE staff provided extensive logistics support to the whole project. This support included arranging meeting space, notifying industry partners and college faculty, arranging meeting refreshments, managing the project budget, and providing monthly updates to the NIST project consultant. Bredeson kept local agencies, colleges and the legislature informed about the project. She also represented and reported on the project nationally at several conferences.

Shifts in Focus

Following the DACUM in May 2013, the grant’s advisory panel shifted the focus from calibration engineering to technician level training in measurement science. The latter, it was felt, was a more foundational level of training and promised a broader base of support from industry.

A launch meeting in November of 2014 was attended by company subject-matter experts (SMEs), Bredeson and her staff, the three consultants, the Workforce deans from the five participating colleges, and a policy analyst from the State Board of Community and Technical Colleges. A very important second shift in focus occurred at that meeting. Up until that time, the thinking had been to organize and guide resources and planning toward creating a certificate in measurement science that would eventually grow into a degree in measurement science. This shift expanded the context beyond manufacturing to nearly every industry sector.

Digital technologies, be they in production systems, instruments and sensors, communications, tracking and monitoring security systems, or LEAN manufacturing methodologies are ubiquitous across most industries. Consequently, the systems within these systems depend on measurement accuracy with implications for safety, quality, competitive advantage, profitability, and business planning among others. At the root of it all lies measurement science, a wide range of measurement standards and technologies.

With this shift in context the project potential became statewide. Not only were all manufacturing-related programs at the
Standards Engineering

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thirty-four colleges impacted, but many other professional technical programs as well. We had stumbled on the fact that the liberal arts community had reached earlier—that standards, particularly standards of measurement, were fundamental knowledge and skills for citizenship in the technically dense civilizations of the 21st century.

With this in mind, the curriculum design team began their discussions and first attempts to create draft course outlines based on the learning outcomes in measurement science that the industry team had outlined. Although we realized our task had suddenly expanded, we kept our focus on manufacturing and, within that, the two dominant disciplines characterized by mechanical systems and electronic systems. Given the limited time period for this initial phase our scope and scale made good sense. The design team developed three five-credit courses that will be described in more detail later in this article. These courses very broadly were Measurement Science Fundamentals (MESC101), Measurement Science—Electrical Emphasis (MESC 102), and Measurement Science—Mechanical Emphasis (MESC 103).

At this same time, a work schedule for the project was developed. This schedule was built from the grant proposal and the deliverables expected by NIST at the end of the project. With a final delivery of June 30, 2015, the time frame was tight and careful organization was called for. Contracts were drawn up for all consultants, a memorandum of understanding was developed for each of the five colleges, and a list of expectations for the roles of our industry partners was created. This was an important step since it mapped out roles and responsibilities very clearly in the context of the work plan. Communication protocols were established that put the CoE staff at the hub of all communications among the team. This worked well, by and large, and ensured that all team members could track progress and address difficulties and obstacles as they arose.

The project manager visited the participating companies and government agencies early in January of 2015 at the same time as the curriculum design team began their curriculum work. In the course of these visits it became obvious that the business case for measurement science KSAs for all employees was strong and common across all our industry partners. The Boeing Company, for example, had to replace a set of wings that had been installed on a new 787 aircraft simply because some tools used in the assembly had not been calibrated according to specifications. This error cost the company several million dollars and delayed delivery of the aircraft. The Puget Sound Naval Shipyard and the Lockheed-Martin Company work within tight federal regulations. When any parts or processes are out of compliance in any way with established regulations, the work must be redone and processes adjusted. Measurement science specifications are integral in regulations and guidelines and if employees do not have the requisite KSAs in measurement science, processes may be compromised, costing a company significant rework expenses.

**LEAN Technologies and Their Influence**

Fluke Manufacturing Company illustrates important aspects of measurement science. The company makes a wide range of calibration and test instruments that are used the world over in many industries. Their product range is broad and the calibration division in Everett where many of these test and calibration instruments are manufactured is itself measured and monitored according to LEAN manufacturing methods. The very principles and practices of LEAN manufacturing methods (which dominate all modern manufacturing environments) are built upon measurement.

The Division Director of the Calibration Division at Fluke can log into this system and get a real-time picture of every process underway at any time of the day or night. And paralleling the digital controls that enable such access are performance standards for everything. So in the modern manufacturing setting the industry standards are maintained by a digital network of controls that alert workers to out-of-compliance equipment and processes. In such work settings it is therefore not surprising that measurement science KSAs are seen to be fundamental; without them, a worker could possibly not be hired.

**The Results**

The three courses that were developed had the following student learning outcomes.

**MESC 101: Measurement Science: The Fundamentals of Measurement Science**

Upon successful completion of the course, participants will be able to:

1. Demonstrate safe practices and situational awareness typical of a manufacturing environment.
2. Recall or recognize terms, definitions, facts, ideas, materials, patterns, sequences, methods, and principles, as applied to metrology and measurement science.
3. Read and understand descriptions, communications, reports, tables, diagrams, directions, regulations, standards, etc. as applied to metrology and measurement science.
4. Use applied math to solve measurement related problems.
5. Correctly interpret technical illustrations and documents for specifications, measurements, tolerances, etc. (“Spackmanship”).
6. Appropriately select and use precision measuring and test equipment to inspect parts and devices to ensure that they conform to specifications.
7. Demonstrate soft skills required in an industrial environment.
8. Demonstrate the importance of attention to detail, personal integrity, interpersonal skills and effective communication.
9. Demonstrate familiarity with applicable standards including the concept of traceability as it applies to materials, calibration and finished products.
10. Appropriately use Excel for data collection, analysis, and presentation of information.
11. Translate a measurement problem to measurable quantities.
12. Estimate whether a quantity is measurable under certain conditions.

**MESC 102: Measurement Science - Electronics Emphasis**

Upon successful completion of the course, participants will be able to:

1. The learning outcomes from MESC 101.
2. Describe the uses and operating principles of the following: DMM, oscilloscope, power supply, frequency counter, function generator, spectrum analyzer, power meter and Fluke calibrators.
3. Appropriately select and properly use the above listed test equipment.
4. Demonstrate communications, reports, tables, diagrams, directions, regulations, standards, etc.
5. Use applied math and statistics to document measurement.
6. Inspect circuitry to confirm they conform to specifications.
7. Demonstrate soft skills required in an industrial environment.
8. Show familiarity with applicable standards, including the concept of traceability as it applies to electronics test equipment.
10. Identify and document out of tolerance results.

**MESC 103: Measurement Science - Mechanical Emphasis**

Upon successful completion of the course, participants will be able to:

1. The learning outcomes from MESC 101
2. Interpret technical drawings and apply inspection tools and techniques to verify the acceptability of machined parts.
3. Measure using surface plate layouts and the coordinate measuring machine (CMM).
4. Demonstrate familiarity with standards applicable to manufactured parts.
5. Demonstrate familiarity with the concepts of traceability as applied to calibration.
6. Properly use computer software used in quality management.
7. Identify nonconforming instruments, finished parts and assemblies, and initiate resolution.
8. Describe the uses and operating principles of:
   a. Ruler
   b. Caliper
   c. Micrometer
   d. Surface plate/height gauges
   e. Indicators
   f. Balance/scale
9. Demonstrate communications, reports, tables, diagrams, directions, regulations, standards, etc. as applied to mechanical measurement.
10. Use applied math and statistics to document measurement.
11. Demonstrate soft skills required in an industrial environment.
12. Apply appropriate standards, including the concept of traceability as it applies to mechanical measurement.
13. Compose reports using Excel and other industrial software for data collection, analysis and presentation of information.

**Note:** It is anticipated that most colleges will offer at least two of these courses depending on the manufacturing programs that the courses are linked to. MESC 101 is seen as the introductory and foundational course for all students of measurement science to be followed by either MESC 102, MESC 103, or both. The colleges that participated in the development of these three courses will be implementing them according to what best fits the needs of their students and their particular program mix.

**What We Learned**

Several important findings emerged:

- The process of new curriculum development that begins with a DACUM workshop and is based on a clear industry need does work well. Colleges respond, and industry collaborates and assists; where an inclusive and participatory communication system is employed, results are generally achieved.
- In the absence of standards that have been identified, codified, and built into job descriptions, it can be problematic to implement new training across a complex higher education network of autonomous colleges.
- In health care, nursing certifications are required for employment. Colleges that train nurses do so in the full knowledge that their nursing graduates must be prepared to take and pass these certified examinations. Failure to pass any such certifications automatically precludes employment. Such standards provide a common guide or template for nurse training and education at every college.
- If measurement science KSAs are essential in so many fields, a similar common guide or template may be required if all colleges are to include these KSAs in their programs.
- At the very least, a standard must be defined and it does require the support and backing of major industry employers if colleges are to invest in such training.
- Unless this occurs, full implementation of this work on the scale that our SMEs envisaged may be stalled.

**Next Steps**

Following the completion of the three courses, the workforce deans at each of the five colleges involved were visited with a view to clarifying how and when each college would begin to offer the courses. The implementation plans for each college were devised and shared with the CoE and the SMEs from industry at the final meeting (which was attended remotely by NIST representatives.)

The Center will be seeking continued funding from NIST and other sources in order to take this work to the next level. The colleges in the state of Washington operate autonomously within the general guidelines set down by the State Board of Community and Technical Colleges. The current strategy is to have the five partner colleges pioneer the implementation of the courses and demonstrate both their marketing potential to students and positive feedback from employers.

Within the college system in the state, the numbering of courses and programs is set within a statewide system of codes that is in transition. This coding matrix is multi-layered and complex and is linked to student tuition payments, faculty salaries, state funding, and other metrics such as student completion rates. Not unlike the tax code in this country, it has its roots in an earlier time, long before the Internet, WIFI technology, and online courses. Its designers have long since retired. The time is long past to revisit these structures and systems and bring them up to date with the digital age.

The outside influence of industry is critical to bring this about. Without it, the out-of-date systems and processes within the CTC system may remain unchanged and impede the response to industry’s needs.
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Unless new approaches to meeting the demands from industry are found colleges may be bypassed as companies seek more relevant and responsive educational partners elsewhere.

That said, the establishment of industry recognized standards for measurement science that are widely supported by employers will be the key pillar by which the KSAs of this project become widely recognized and supported.

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by Mickie S. Rops, CAE

An ASTM international standard, and an ANSI accreditation program citing that standard, provide a gauge of the quality of a certificate program—whether it addresses engineers, physicians, or chefs. **ASTM: E2659, Standard Practice for Certificate Programs**, defines certificate programs and delineates the characteristics of a high quality program. It is the standard against which the ANSI certificate accreditation program measures applicants.

**Why a Certificate Standard? Why Accreditation?**

The idea of a certificate program standard and an accreditation based upon the standard arose in early 2007 when governmental agencies and consumers expressed concern to the American National Standards Institute that there was no nationwide regulation, oversight, or monitoring consistently applied to entities that offer education-based certificates. Consumers were often unclear about the meaning of certificates, how to differentiate among certificate programs with varying levels of rigor, and how certificate programs differ from personnel certifications. Prior to publication of **ASTM E2659: Standard Practice for Certificate Programs**, there had been no American National Standard for certificate programs. There was an American National Standard for personnel certification programs—the adoption of ISO/IEC 17024, Conformity assessment—General requirements for bodies operating certification of persons. ASTM E2659 closes the loop by distinguishing between these two program types and outlining the quality criteria for certificate programs.

**ASTM E2659**, developed by ASTM’s Subcommittee E36.30 on Personnel Certificate Programs, is a part of Committee E36 on Accreditation and Certification, and represents collaboration across the certificate program spectrum, including colleges and universities, community colleges and trade schools, government agencies, nonprofits, and for profits.

**Certification versus Certificate Programs**

What is a certificate program? In a certificate program, an individual participates in a learning event or series of events designed to assist him or her in achieving specified learning outcomes within a defined scope. The individual receives a certificate only after verification of successful completion of all program requirements (including, but not limited to, an evaluation of learner attainment of intended learning outcomes).

What is certification? In certification an organization grants a credential to an individual after verifying that he or she has met established criteria for proficiency or competency, usually through an eligibility application and assessment. While certification eligibility criteria may specify a certain type or amount of education or training, the learning event(s) are not typically provided by the certifying body. Instead, the certifying body verifies through an application process education or training and experience obtained elsewhere and administers a standardized test of current proficiency or competency.

In a certificate program (unlike a certification system), a certificate issuer develops and administers both the learning event(s) and the assessment(s); there is an essential link between them. The learning event(s) are designed to help participants achieve learning outcomes and the assessment is designed to evaluate the learners’ attainment of those intended learning outcomes.

There are fundamental differences between the standards-based requirements of certification systems and certificate systems. To conform to the international standard ISO/IEC 17024, a certification program must:

- Have ongoing requirements (called recertification or renewal) and a system for revoking the certificate when requirements are not met; and
- Not have an integrated learning component offered and required by the certifying body.

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