A Curriculum Innovation Framework to Integrate Manufacturing-related Materials and Quality Control Standards into Different Level Engineering Education

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1. Introduction

The importance of standards and standardization is that they provide product manufacturers clear material, mechanical and dimensional requirements coupled with specific quality assurance and test methods to use to assure they are meeting specific standards [1]-[2]. Manufacturing related materials standards provide a consensus regarding desired properties between both manufacturers and customers. Moreover, these standards provide analysis methods to measure the properties and lead to standard manufacturing procedures that ensure the quality. The ISO 9000 family of quality management systems standards is designed to help organizations ensure that they meet the needs of customers and other stakeholders while meeting statutory and regulatory requirements related to a product or program [3]. For large manufacturer, the goal is to produce the same products with as little variation as possible among any of its factories. Standards and standardization make this possible and ensure products quality. However, this consensus and the skills of utilizing standards are not well established among students [4]-[5]. A survey [6] carried out in an US engineering school, found that: 1) Standards education is not a priority issue among schools of engineering in the United States; 2) Schools of Engineering in the United States do yet not accept the critical nature of standards in the new 21st century global economy. Standards and Standardization are becoming more and more important in the manufacturing industries. Many jobs in manufacturing industries require using knowledge related to different standards, including Industrial Production Manager, Manufacturing Engineers, Quality Control Analysts, and Industrial Engineers (especially Process Design Engineers and System Design Engineers). Based on data from onetonline.org,

- Industrial Production Manager: 10% increase in projected employment in Texas from 2014 to 2024.
- Manufacturing Engineers: 18% increase in projected employment in Texas from 2014 to 2024.
- Quality Control Analysts: 5%-8% increase in projected employment in U.S. from 2014 to 2024 (no Texas data available).
- Industrial Engineers: 13% increase in projected employment in Texas from 2014 to 2024.

To fulfill the need of real world systems, Texas A&M University-Kingsville (TAMUK) is planning and implementing a curriculum innovation to integrate manufacturing related materials and quality control standards into different level engineering education.

Texas A&M University-Kingsville is a Hispanic Serving Institution with an overall enrollment of 67% minority students. This two-year project will be the first effort at TAMUK to introduce manufacturing related standards into freshmen to graduate levels. A survey was conducted in the MEEN 3344-Materials Science course for three continuous semesters before starting the project. Among the 105 junior level students, less than 20% of the students ever heard that there are standards for materials selections and testing. Only 11.4% of the students know ASTM or ISO standards, and only 2.9% of the students know how to use or ever used the standards. Base on the feedback from students, this is due to a lack of courses that cover the contents of materials standards knowledge. Through the implementation of this project, the expected short-term impact is to significantly increase students' awareness of standard and standardization by creating sustainable and cost-effectiveness curriculum structure, while the expected long-term impact is to adequately prepare college graduates for the workplace (especially in manufacturing sector) with standards and standardization concepts, and with positive impacts on state and regional economy.

2. Program Design

The goal of this ongoing project is to create a systematic framework for different level engineering students to strengthen education and learning about manufacturing related materials and quality control standards and standardization. In order to successfully achieve this goal, there are three specific measurable objectives:

1) Develop innovative course modules to use in current undergraduate engineering curriculum to improve students' career readiness,
2) Develop graduate certificate program to advance students' professional preparedness, and
3) Create an online based cost-effectiveness structure to enhance education and learning impacts.

There are four major components in this project, including 1) manufacturing related materials standards course module development, 2) manufacturing related quality control standards course module development, 3) professional/graduate level certificate program development, and 4) industrial experience sharing through webinar. This two-year project started from Fall 2017, and will be implemented in three phases:

1) Phase I: curriculum materials (course modules, certificate program, etc.) creation and initial testing in selected pilot courses, including UNIV 1102 course,
2) Phase II: curriculum materials continuous improvement and internal sharing at TAMUK, and
3) Phase III: final project results and products sharing outside TAMUK.

The selected University Success Course (UNIV 1102) is a required course for all TAMUK freshmen students to ensure students' success. Each course module will be first created and tested with in-class version. The improved course modules will be in both in-class and online versions. The undergraduate course modules are closely tied to the following ABET student outcomes: (a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; and (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. Each type of course module will be categorized into three different levels, including freshmen (entry level), junior/senior (mid-level), and graduate students (advanced level). The course modules will cover both lecture and project. For manufacturing related material standards course module, the three levels include:

1) Entry level: This course module will cover the background and importance of standards, the numbering system for standards work, and standards used in manufacturing. It will be designed to (a) introduce background and evolution of ASTM and ISO standards, and (b) introduce various standards to be considered during the manufacturing process. Upon completing this

module, the students will be able to (a) understand the necessity of standards in materials selection and testing; and (b) gain basic knowledge about various types of materials standards that are appropriate for using in manufacturing.

2) Mid-level: It will be designed to provide students with hands-on experience on applying standards on materials selection for a specific product. This module will cover the major sections of ISO ICS 83, including raw materials for rubber and plastics, rubber, plastics, manufacturing processes in the rubber and plastics industries, rubber and plastics products, reinforced plastics and adhesives. A project will be designed within this module to allow students to practice using ISO ICS 83. Upon completing this module, students should be able to (a) discuss the contents of the 10 sections of ISO ICS 83 family; (b) identify the criteria for selecting a standard; and (c) choose appropriate standards for materials selection, preparation and testing.

3) Advanced level: It will be designed to polish students' skills on the development of standards if there is no standard that deals with a specific project. This module will cover the topics on procedures of standard development, influence of materials selection on manufacturing process and system design. A project will be designed within this module to allow students to develop the standards of material selection, preparation and testing. Upon completing this module, students should be able to (a) develop standard procedures if there's no available standards for a product; (b) identify one ASTM and/or ISO standard test procedure that correlate with the developed procedure; and (c) evaluate the developed standard procedure and give suggestions on manufacturing system design.

For manufacturing related quality control standards course module, the three levels include:

1) Entry level: It will introduce the origin and background of ISO 9000 standards, evolution and importance of ISO 9000 standards, the basic structure of ISO 9000, and the seven quality management principles that the ISO 9000 series are based on. At the completion of this learning module, students should be able to (a) describe what ISO 9000 series standards are and why it is important in both industries and service sectors; (b) describe the differences of the ISO 9000 1987, 1994, 2000, 2008, and 2015 versions and the key changes and the content structure of ISO 9000:2015; and (c) understand and discuss the seven quality management principles and how they are related to ISO 9000.

2) Mid-level: This module will cover the major sections of ISO 9001:2015 including context of the organization, leadership, planning, support, operation, performance evaluation, and improvement. It will also cover the steps to registration, and the basic internal and external audit process. At the completion of this learning module, students should be able to (a) discuss the contents of the 10 sections of ISO 9001:2015; (b) understand and implement the Plan-Do-Check-Act cycle and the risk based thinking in the planning; and (c) understand and implement the tasks of each step to registration.

3) Advanced level: It will cover the detail technique and processes of the internal and external audits. At the completion of this learning module, students should be able to (a) understand and discuss the aims of the audits which is to verify a system is working as it is supposed to, to find out where it can improve, and to correct or prevent problems identified; (b) lead or participate in

a team to prepare for the internal and external audits; and (c) identify the opportunities and strategies of continuous improvement.

The advanced level module was developed first, and the mid and entry levels modules will be created based on the advanced level module. The advanced level module of material standards will be taught in four separate sessions as listed below:

- An overview of standards: a) the definition of a standard, b) the characteristics of a standard, and c) different types of standards.
- The importance of standards: a) the benefits of using standards, b) the value of standards for a company, society and consumers, and c) standards supporting innovation.
- Standards structure: a) standards overall structure, and b) typical structure of an individual standard.
- Standards for manufacturing-equipment perspective:

  1) Introduction to manufacturing equipment, including classification of manufacturing equipment, assemblies utilized in the construction of manufacturing equipment, etc.

  2) Standards for manufacturing equipment, such as BS 6101-6:1990: machine tool ball screws, specification for ball nuts and principal dimensions of ball screws, and BS 2573-2:1980: rules for the design of cranes, specification for classification, stress calculations, and design of mechanisms.

  3) Standards related to operation of the equipment, such as ISO 1268-4:2005: fibre-reinforced plastics - methods of producing test plates - part 4: moulding of prepregs, and bs en 61310-3:1999: safety of machinery, indication, marking and actuation. requirements for the location and operation of actuators.

The advanced level module of quality control will be taught in seven separate sessions as following: 1) Introduction and history of ISO 9000:2015, 2) Overview of ten sections of ISO 9000:2015, 3) ISO 9000:2015 section 4 context of the organization, 4) ISO 9000:2015 section 5 leadership and section 6 planning, 5) ISO 9000:2015 section 7 support and section 8 operation, 6) ISO 9000:2015 section 9 performance evaluation and section 10 improvement, and 7) Implementing ISO 9000:2015 and audits.

A graduate certificate program consisting of three graduate courses has been approved at TAMUK, which was designed to teach graduate students and industrial professionals to apply standards and standardization as powerful analytic tools. Students will complete two required courses (existing courses with new learning modules), and one of the two elective courses. It allows full time students to complete it in one regular semester and industrial professionals to complete it as non-degree students without applying to any degree programs at TAMUK. The certificate program will be offered starting from Spring 2018, and it will be open to all major graduate students and professionals who meet with the certain requirements. The objective of this certificate program is to promote standards and standardization concepts and increase students' awareness of the importance of standards and standardization by introducing knowledge related to the creation, modification, interpretation of standards and standardization in manufacturing field. Upon completing this certificate, students and professionals are able to: 1) Develop critical thinking towards standards and standardization concepts, 2) Identify and interpret different standards in manufacturing, and 3) Provide technical oversight and coordination to ensure manufacturing process meet national and international standards.

The last component is webinars and e-conference. The webinars will be hold three times a year (Spring, Summer, and Fall), and be offered by invited industrial professionals. Each webinar will last 45 minutes to one hour, and be free to students, instructors, and industrial professionals. It will focus on how standards and standardization being applied in industries. An annual e-conference will also be organized by the project team every year to introduce the proposed course modules and certificate program. Instructions on how to use the course modules and how to apply the certificate program will be given through the e-conference. It will be designed as a one-day conference, and be free to students, instructors, and industrial professionals. Registration is required for both webinars and e-conferences. All the webinars and e-conferences will be offered through Blackboard Collaborate, and be recorded so that the information could be available to the public later.

3. Discussion and Conclusion

The project team will implement an appropriate comprehensive evaluation plan to shape the development of the proposed project from beginning to end. The plan consists of two components, including 1) Objectives based evaluation plan utilizes internal research objectives designed to track progress toward meeting all proposed research objectives; and 2) Outcomes based evaluation plan designed to verify project success.

Surveys and focus group will be used to collect students' feedbacks. The comprehensive evaluation plan will include specific quantitative and qualitative measures to

- evaluate techniques and methods and their appropriateness to the proposed research objective (formative),
- measure success in achieving objectives at the end of project (summative), and
- provide the disclosure of both expected and unanticipated project outcomes.

First, the objectives based evaluation plan will be utilized to evaluate the project on a monthly basis during the project years (formative) and serve as benchmark. Second, the project team will continuously collect latest results and compare them to the expected outcomes. The scalability and performance of the proposed methods and research results will also be evaluated by using them to other STEM major courses. Meanwhile, the project team will also compare the effects on students' learning outcomes between in-class format and online format. Online format will be then further improved by including more interactive components. The effects on students' learning outcomes between using as lecture materials and using as supplementary materials will also be compared through students' and instructors' surveys.

According to the recent student survey results at Mechanical and Industrial Engineering Department at TAMUK (52 responses as of 02/04/2018), 52.08% of students are very interested in the proposed certificate program, and 29.17% of students are interested in this proposed certificate program. There are 16.67% students who are not sure at this moment, and there are only 2.08% of students who are not interested. There are 41.67% of students who think getting this proposed certificate will help their job hunting a lot after graduation, and there are 41.67% students who think it will help their job hunting. There are 16.67% of students who are not sure at this moment.

Since all the course modules, certificate courses, and recorded webinars and e-conferences will be available in both in-class and online formats, the impacts of this two-year project would be sustained by sharing these materials within TAMUK and with other educators beyond the project period. It will also give the other educators the flexibility to decide how much of each topic they would like to include in their own courses. Material science and quality control are the core curriculum contents for Mechanical Engineering, Industrial Engineering, Manufacturing Engineering, and System Engineering, so the learning modules can be directly used by instructors in these major in their courses. For the other engineering majors, instructors can easily use part of the modules in their senior design projects to solve product and process related engineering problems.

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