Integrate Manufacturing related Materials and Quality Control Standards into Master Level Engineering Education

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1. Introduction

Engineering standards, such as ASTM, ASME, and ISO standards, and standardization concepts are becoming more and more important in engineering education as ABET starts introducing different engineering standards into its engineering program evaluation criteria [1]. While most engineering undergraduate programs start to integrate engineering standards into different courses [2], such as materials science, senior design projects, to meet the new ABET requirements, graduate students, especially international students in the graduate engineering programs, have less exposure and practical experiences with engineering standards [3].

In the Industrial Engineering Master of Science (M.S.) program at Texas A&M University-Kingsville (TAMUK), a Hispanic Serving Institution, graduate students get practical experiences with engineering standards and standardization in their M.S. research project or thesis course, which is normally the last course in their degree plan in the Industrial Engineering M.S. program. We conducted a survey with students who had not started their research project and received 50 responses. Less than 25% of the students ever heard that there are standards for materials selections and testing, while only 15% of the students heard about ASTM or ISO standards with only 5% of the students know how to use or ever used the engineering standards. Base on the feedback from students, it is needed to integrate standards and standardization training through a series of courses in the Industrial Engineering M.S. program to strengthen students' understanding and knowledge. In this paper, the authors introduce new course modules and lessons learned during the process of integrating manufacturing related materials and quality control standards into the Industrial Engineering M.S. program. Hands-on activities based course modules were developed and implemented into three graduate level courses, including modifying two existing courses and developing one new course. Since the three courses are not required courses in the Industrial Engineering M.S. program, a new graduate level certificate program was also developed [4] consisting the three courses to attract more graduate students to take the three courses. We conducted student surveys to collect their feedback on the effectiveness of the course modules, and their changes on the knowledge related to engineering standards and standardization in manufacturing related materials and quality control fields.

2. Design of Course Modules

We modified two existing courses, IEEN 5333-Six Sigma and ISO Standards and IEEN 5332-Manufacturing Systems Design, by introducing new course modules with hands-on projects. We also developed one new course, IEEN 5303-Standards of Product Design and Manufacturing.

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 [5], [6], [7]. It is critical for engineering students to understand and implement ISO 9000 and other standards [8]. The new course modules designed and used in IEEN 5333 cover the detail technique and processes of the internal and external audits. After completing the course modules, students are expected to be able to (a)

understand and discuss the aims of the audits, including how to verify a system is working as it is supposed to, how to find out where it can improve, and how 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.

Manufacturing related materials standards provide a framework for the manufacturers and customers to reach to consensus regarding desired properties. Moreover, these engineering standards provide analysis methods to measure the properties and leading to standard manufacturing procedures that ensure the quality. Accordingly, there is an urgent need to develop course materials that provide students with related knowledge [9], [10]. So the new course modules of manufacturing related materials standards were designed and used in IEEN 5332 course to polish students' skills on the development of engineering standards if there was no standard to deal with a specific project. These new course modules cover the topics on procedures of standard development, influence of materials selection on manufacturing process and system design. We also include a practical course project within the course module to allow students to develop the standards of material selection, preparation and testing to gain valuable hands-on experience. At the completion of this module, students are expected to be able to (a) develop standard procedures if there is 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. The detailed IEEN 5332 course module design is shown in Table 1.

Table 1: Course module design used in IEEN 5332

Topics covered	**Class time needed**
Introduction to Engineering Standards	2/3 week
Major Standards Developing Organizations of Manufacturing Systems	One week
International Classification for Standards (ICS) Code	One week
Case Study (ISO 6780) and Student Projects (student chooses product with approval from instructor)	Two weeks

Table 2: Course schedule of the new Standards of Product Design and Manufacturing course

Topics covered	**Class time needed**
Importance of Engineering Standards and Standardization	One week
Engineering Standardization and Mass Production	Two weeks
Engineering Standards Development and Modification	Two weeks
Major Types of Engineering Standards	Two weeks
Mandatory and Voluntary Standards	Two weeks
Engineering Standard Database and Searching Standards	One week
Engineering Standards Structure with case study: ISO 10303-240:2005	Two weeks
Characteristics of a good Engineering Standard	Two weeks

The new course, IEEN 5303-Standards of Product Design and Manufacturing, provides an overview of materials and processes standards in manufacturing, and covers the materials selection, system design, and use of equipment in manufacturing, from small scale operations to

massive automated plants. The course provides students with a comprehensive understanding of standards use in manufacturing, polishes students' skills to develop standard procedures, and prepares students for evaluation of new standards for modern production [11]. Upon the completion of this course, students are expected to be able to (a) apply the materials standards for metal, ceramic, polymer and composite, (b) select and/or develop standards for a product, and (c) develop solutions of standards for modern production. The detailed IEEN 5303 course schedule is shown in Table 2.

3. Survey Results and Discussion

Before we started offering the modified courses, we conducted another survey to collect students' potential interests in taking these courses. According to the 60 responses received, 50% of students were very interested in taking at least one of the modified courses, while 30% of students were interested in taking all three courses. There were 15% students who were not sure, and there were only 5% of students who were not interested.

After completing the redesign of the courses, each of the above three courses have been offered twice in the Industrial Engineering M.S. program, and we started conducting a student survey at the beginning of Spring 2020 semester to collect students' feedback on these course modules. The online survey was emailed to students who took all three courses. Although there are about 60 students taken at least one of the three courses, there are only 25 students who completed all three courses as of January 2020. We received 17 valid responses. In the survey, the students were asked to indicate the best descriptor of the extent to their participation in each of the three courses increasing their confidence/knowledge to perform different tasks. There are six options available to choose, including Not Sure, No Increase, A Little Increase, Some Increase, Good Increase, and Great Increase. The survey results are summarized in the Tables 3-5 below.

Table 3: Survey results related to revised IEEN 5333-Six Sigma and ISO Standards course

Confidence/knowledge to perform each task	**Results***
1) Understand ISO 9000 standards	0/0/0/6/38/54
2) Understand other standards	0/0/6/0/38/54
3) Implement ISO 9000 standards for audits	0/0/15/0/54/31
4) Implement other standards for audits	8/0/8/15/31/38
5) Participate in a team to prepare for internal or external audits	0/0/8/23/23/46
6) Lead a team to prepare for internal or external audits	8/0/8/38/31/15
7) Identify the opportunities of continuous improvement to meet ISO standards	0/0/0/15/46/39
8) Seek for a position that requires knowledge in ISO standards	0/0/0/23/39/38
9) Seek for a position that requires knowledge in other standards	0/0/0/15/46/39
10) Work in a project that requires to use ISO standards	0/0/0/15/39/46
11) Work in a project that requires to use other standards	0/0/0/15/46/39

(*Results presented in percentage as "Not sure/No Increase/A little increase/Some increase/good increase/great increase")

Based on the results in Table 3, most responded students indicate good or great increase in performing all the tasks after taking IEEN 5333 class. However, several students did not have

any increase in performing "Lead a team to prepare for internal or external audits." And it is the only task with less than 50% of the students having good or great increase in performing the task. IEEN 5333 course was offered in the summer semester (five weeks) as an online course, so its course project is an individual project without team effort. According to the survey results in Table 4 and Table 5, the students' responses are more positive after taking IEEN 5332 and IEEN 5303 compared to IEEN 5333. One possible reason is that IEEN 5332 and IEEN 5303 were offered in regular semester (Spring or Fall semester) with team projects, and both courses were offered as in-class course at least once before we conducted the survey.

Table 4: Survey results related to revised IEEN 5332-Manufacturing System Design course

Confidence/knowledge to perform each task	**Results***
1) Identify ASTM and/or ISO standard for materials Selection	0/0/0/8/38/54
2) Identify ASTM and/or ISO standard for material Preparation	0/0/0/8/38/54
3) Identify ASTM and/or ISO standard for material Testing	0/0/0/15/39/46
4) Develop standard procedures if there is no available standards for a product	8/0/0/0/54/38
5) Evaluate standard procedure and provide suggestions on manufacturing system design	0/0/0/15/31/54
6) Select materials for manufacturing processes based on a specific standard	0/0/0/15/31/54
7) Participate in a team to prepare for manufacturing system design	0/0/0/15/39/46
8) Lead a team to prepare for manufacturing system design	0/0/8/8/46/38
9) Seek for a position that requires knowledge in ASTM standards	0/0/0/15/46/39
10) Seek for a position that requires knowledge in other standards	0/0/0/8/54/38
11) Work in a project that requires to use ASTM standards	0/0/0/0/67/33
12) Work in a project that requires to use other standards	0/0/0/0/62/38

(*Results presented in percentage as "Not sure/No Increase/A little increase/Some increase/good increase/great increase")

Table 5: Survey results related to new Standards of Product Design and Manufacturing course

Confidence/knowledge to perform each task	**Results***
1) Identify standards for materials Selection	0/0/0/0/82/18
2) Identify standards for manufacturing Process Selection	0/0/0/0/64/36
3) Identify standards for manufacturing System Design	0/0/0/9/45/46
4) Identify standards for manufacturing Equipment Selection	0/0/0/0/64/36
5) Evaluate standard procedure and provide suggestions on manufacturing system design	0/0/0/18/45/37
6) Develop standard procedures if there is no available standards for a product	0/0/0/9/73/18
7) Apply materials standards for metal, ceramic, polymer, and composite	0/0/0/18/55/27
8) Lead a team to prepare for manufacturing process design	0/0/0/9/64/27
9) Participate in a team to prepare for manufacturing process design	0/0/0/9/45/46
10) Seek for a position that requires knowledge in standards	0/0/0/9/55/36
11) Work in a project that requires to use standards	0/0/0/18/36/46

(*Results presented in percentage as "Not sure/No Increase/A little increase/Some increase/good increase/great increase")

Overall, the survey results show that most students like these course modules, and they think these modules help them to improve their knowledge in engineering standards and standardization. Through the modified course modules, the authors expects to significantly increase students' awareness of engineering standard and standardization in the Industrial Engineering M.S. program. The Industrial Engineering M.S. program at TAMUK offers both 100% online master degree and traditional in-class master program. The ultimate goal is to make all modified course modules available for online teaching, and to share them with other engineering programs at TAMUK and nearby universities and colleges. However, differences are observed in the survey results between IEEN 5333 (online course) and the other two courses as indicated above. It is important to conduct a more detailed survey by separating students who took the courses online with students who took the courses inclass. Furthermore, the authors will also look into the differences on students' learning outcomes by using individual projects and team projects.

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