

Final Technical Report (Project Period: 9/15/2021-3/14/2024)

Project Title: Curricular Integration of Design and Material Standards in Engineering (CID-MaSE)

Federal Award ID Number: 70NANB21H175

Organization: Texas A&M University-Kingsville, 700 University Blvd., Kingsville, TX 78363

PI: Mohammad Motaher Hossain, Ph.D.
Associate Professor, Department of Mechanical & Industrial Engineering
Texas A&M University-Kingsville
700 University Blvd. MSC 191, Kingsville, TX 78363
Ph: (361) 593-3341, E-mail: mohammad.hossain@tamuk.edu

Co-PI: Larry D. Peel, Ph.D., P.E.
Professor, Department of Mechanical & Industrial Engineering
Texas A&M University-Kingsville
700 University Blvd. MSC 191, Kingsville, TX 78363
Ph: (361) 593-2292, E-mail: larry.peel@tamuk.edu

Co-PI: Breanna M. Bailey, Ph.D., P.E.
Professor and Chair, Department of Civil & Architectural Engineering
Texas A&M University-Kingsville
700 University Blvd. MSC 194, Kingsville, TX 78363
Ph: (361) 593-2369, E-mail: breanna.bailey@tamuk.edu

PROJECT OBJECTIVES

The overarching goal of this project is to stimulate students' interest in standards and standardization methods in a way that will increase their use of standards throughout their professional career. It is expected that by adding various modules to the current curriculum and/or by modifying components of the curriculum at various stages of engineering education, an integrated education model, reinforced by a certificate program, can be developed. This reproducible education model can be implemented in other science, technology, and engineering programs. The specific objectives are:

- i) **Educate** engineering students about design- and materials-related standards, the standardization procedures and standards-related organizations.
- ii) Through **repeated classroom practice**, embed a deep appreciation and understanding of standards in students.
- iii) Through reinforcement in multiple courses and a certificate program, instill the importance of standards and standardization into students in a way that will **promote life-long use of standards** in their professional careers.

PROJECT ACCOMPLISHMENTS

A. Course Modification to Educate Students on Standards

To educate students on standards and standardization procedures, standard related course modules were implemented in several courses, as shown in Table 1. The new course module(s) was embedded in the course and taught as part of the course after development and implementation

of the course module(s) in a semester. Table 1 presents undergraduate courses according to the year in which they are anticipated to be taken by a student following published degree plans, rather than by the year indicated by course level. At Texas A&M University-Kingsville (TAMUK), as at many other institutions, the first number in a course title indicates its level (1000 = freshman, 2000 = sophomore, etc.) and the second number indicates the number of credit hours (1 = traditional laboratory meeting, 3 hours a week; 3 = traditional lecture meeting, 3 hours a week). To stay on track for graduation, Mechanical Engineering (MEEN), Civil Engineering (CEEN), and Architectural Engineering (AEEN) students typically take their first junior level (3000-level) courses in sophomore year. Also, linked lecture and laboratory courses are presented together in Table 1; although separate modules were developed for both the lecture and laboratory components of these courses. Lastly, structural engineering courses required for both CEEN and AEEN students are traditionally cross-linked and taught as a single course (due to limited number of faculty).

Table 1. List of Courses where Course Modules were Developed and Implemented

Level	Mechanical Engineering	Civil and Architectural Engineering
Freshman	GEEN 1201: Engineering as a Career (Fall 2022).	
Sophomore	MEEN 3344/3145: Materials Science and Laboratory (Spring 2022). CEEN 3311: Strength of Materials (Spring 2022).	CEEN 3311: Strength of Materials (Spring 2022).
Junior	MEEN 3349: Fundamentals of Manufacturing Processes (Spring 2022).	CEEN/AEEN 3303: Structural Analysis (Spring 2022). CEEN/AEEN 3304: Reinforced Concrete Design (Spring 2022). CEEN 3244/3145: Construction Materials and Laboratory (Spring 2022).
Senior	MEEN 4382: Polymer Science & Engineering (Spring 2022). MEEN 4385: Manufacturing of Composites (Spring 2022). MEEN Senior Design Project (Spring 2022).	CEEN/AEEN 4316: Structural Steel Design (Fall 2022). CEEN Senior Design Project (Spring 2023).
Graduate	MEEN 5331: Advanced Materials Science (Fall 2022). MEEN 5333: Polymer Science (Spring 2022).	CEEN 5361: Advanced Structural Steel Design (Spring 2023).

* Semester when the course module(s) first implemented is indicated within the parentheses

The course modules developed and implemented are described below:

- A.1. GEEN 1201 (Engineering as a Career): Lecture on use of codes and standards in Engineering (importance, use of standards, types of standards) and benefits of standards in design was added. A lab activity (Flexure test using the ASTM D790-15 standard to test composite samples and perform analysis) was also added. A total of 144 students have registered in this course since the first implementation of course module in Fall 2022 (Fall 2022: 63, Fall 2023: 81).
- A.2. MEEN 3145 (Material Science Laboratory): For each experiment, relevant issues questionnaire has been added where the students have to answer specific standard-related questions while submitting report on that particular experiment. Number of lab experiments based on ASTM standards for material testing was increased. Oral presentations on non-destructive testing (NDT), presented by the students as groups, are now required to focus on specific standards used for the NDT. Midterm and Final Exams were updated to include more questions on ASTM standards for material testing (increased from 20% to 50%). A total of 138 students have registered in this course since the first implementation of course modification in Spring 2022 (Spring 2022: 31, Fall 2022: 28, Spring 2023: 21, Fall 2023: 35, Spring 2024: 23).
- A.3. MEEN 3344 (Materials Science): A module was added to discuss the effect of temperature, environmental condition, testing rate, etc. on material properties, and how these aspects are addressed in the standards. Homework was added on the topic to assess students' understanding. Students were asked to provide specific information on standards if they are providing any testing information in their term paper and presentation, where each student research on a topic in materials science. A total of 191 students have registered in this course since the first implementation of course modification in Spring 2022 (Spring 2022: 39, Fall 2022: 38, Spring 2023: 35, Fall 2023: 43, Spring 2024: 36).
- A.4. MEEN 3349 (Fundamentals of Manufacturing Processes): A lecture on manufacturing standards and homework/exam problems on manufacturing standards were updated, and a supplemental recorded lecture was added to Blackboard. A total of 129 students have registered in this course since the first implementation of course modification in Spring 2022 (Spring 2022: 19, Fall 2022: 30, Spring 2023: 18, Fall 2023: 30, Spring 2024: 32).
- A.5. MEEN 4263/ MEEN 4264 (Senior Design Project): Lectures on importance of standards and standardization procedures in engineering design were provided to students. A total of 61 students registered in these courses in Spring 2022, when the lecture was given.
- A.6. MEEN 4382 (Polymer Science & Engineering) and MEEN 5333 (Polymer Science): Material testing and characterization procedures according to the standards, specific to polymeric materials, were added in the course. Homework was added on standards to assess students' understanding. A total of 10 students registered in these courses in Spring 2022, when the course modification was first implemented.
- A.7. MEEN 4385 (Manufacturing of Composites): A lab module on adhesives and natural fiber testing was updated to include ASTM standards on single lab shear tests and 3-point bending. Students were supplied with relevant ASTM standards, and key points were covered in exam questions. A total of 19 students have registered in this course since the first implementation of course modification in Spring 2022 (Spring 2022: 12, Spring 2023: 7).

- A.8. MEEN 5331 (Advanced Materials Science): Significance of standards in material testing and characterization and advanced material testing standards are included in a lecture. Students were asked to provide specific information on standards if they are providing any testing information in their term paper and presentation, where each student review research papers on a topic in materials science. A total of 8 students have registered in this course since the first implementation of course modification in Fall 2022 (Fall 2022: 5, Fall 2023: 3).
- A.9. CEEN 3244 (Construction Materials) and CEEN 3145 (Construction Materials Lab): In CEEN 3244, Term project was modified to require the students identify standard tests to be performed on construction materials in a real-world project. In CEEN 3145, students were provided with ASTM standard copies and were asked to study these standards rather than the summary of experiments as provided in the textbook. Students write a reflection essay to describe the importance of enhanced understanding of ASTM standards. A total of 183 students have registered in CEEN 3244 since the first implementation of course modules in Spring 2022 (Spring 2022: 73, Spring 2023: 62, Spring 2024: 48). A total of 189 students have registered in CEEN 3145 since the first implementation of course modules in Spring 2022 (Spring 2022: 80, Spring 2023: 85, Spring 2024: 24).
- A.10. CEEN/AEEN 3303 (Structural Analysis): The embedded content module discusses dead, live, and wind load calculations using ASCE 7. 33 students registered in these courses in Spring 2022, when the course modification was first implemented.
- A.11. CEEN/AEEN 3304 (Reinforced Concrete Design): The knowledge of students on the most widely used reinforced concrete design standard (American Concrete Institute ACI318-19 – *Building Code Requirements for Structural Concrete*) is enhanced through several course modifications: i) Several sets of homework problems involving reading the code and extracting specific information, listing definitions, summarizing topics of several chapters, etc. have been created. ii) One question was added to the midterm and final exam that relates to the ACI code content. A total of 223 students have registered in these courses since the first implementation of course modifications in Spring 2022 (Spring 2022: 94, Spring 2023: 67, Spring 2024: 62).
- A.12. CEEN 3311 (Strength of Materials): A course module related to material properties was modified to introduce ASTM standards (e.g., ASTM E8), where students learn how to identify relevant standard(s) depending on the material of interest. Students are required to prepare a project report, describing their analysis and determine parameters for engineering properties. A total of 186 students have registered in this course since the first implementation of course modification in Spring 2022 (Spring 2022: 59, Fall 2022: 29, Spring 2023: 67, Fall 2023: 13, Spring 2024: 18).
- A.13. CEEN/AEEN 4316 (Structural Steel Design): A unit discussing the structure of AISC and the processes used to revise the steel manual was added. A total of 142 students have registered in this course since the first implementation of course modification in Fall 2022 (Fall 2022: 84, Fall 2023: 58).
- A.14. CEEN 4289 (Design in Civil Engineering II): A new unit was introduced to discuss the ASCE 7 load standard. An assignment incorporated ASCE 7 dead and live loads to find the shear and moment demands on a floor slab. A total of 61 students have registered in

this course since the first implementation of course modification in Spring 2023 (Spring 2023: 38, Spring 2024: 23).

- A.15. *CEEN 5361 (Advanced Structural Steel Design)*: The course was modified to include a discussion of AISC as an organization and the role of codes within structural engineering. 7 students registered in this course in Spring 2023, when the course modification was first implemented.

B. Certificate Program on Standards for Material Testing and Characterization

The Certificate on Standards for Material Testing, Characterization, and Applications is a transcribed certificate offered at the undergraduate and graduate level. The undergraduate certificate became effective in Fall 2022 and appears in the 2022-2023 undergraduate catalog. The graduate certificate became effective in Spring 2023. The proposals for both the undergraduate and graduate certificates were routed simultaneously; the date of publication is a result of TAMUK internal processes. To earn the certificate, both undergraduate and graduate students are required to attend 6 standards-related seminars. The seminar series is described later.

Other requirements for undergraduate students include:

- Completing a total of 12 credits (4 lecture courses or a combination of lectures and labs) with a grade of “B” or better in each course. The certificate courses may be selected from a list of MEEN, CEEN, and AEEN courses.
- Completing a senior capstone project that has significant component focused on standards.

Graduate student requirements are similar with the following differences:

- Completing a total of 9 credits (3 courses) with a grade of “B” or better in each course. The certificate courses are selected from a list of MEEN and CEEN graduate courses; there is no AEEN graduate program at TAMUK.
- Completing a thesis that has a significant component focused on standards.

Six seminars on standards and standardization methods for material testing and characterization and their appropriate usage in standard engineering design were conducted in the Spring 2022 semester, as listed below. A total of 93 students attended these seminars.

March 9, 2022	Mr. Antonio Reyna	TxDOT
March 23, 2022	Mr. Travis Murdock	ASTM International
March 30, 2022	Dr. Larry D. Peel	TAMUK
April 6, 2022	Dr. Mohammad M. Hossain	TAMUK
April 13, 2022	Dr. Hoang Pham	Avery Dennison
April 20, 2022	Dr. Pavan Valavala	Dow Inc.

Four seminars on standards and standardization methods for material testing and characterization and their appropriate usage in standard engineering design were conducted in the Spring 2023 semester, as listed below. A total of 54 students attended these seminars.

February 8, 2023	Dr. Brian McFall	US Army Corps of Eng.
February 15, 2023	Dr. Ruth Chatelain-Jardon	TAMUK
February 22, 2023	Mr. Steven Bailey	Nine Energy Service
March 1, 2023	Mr. Erik Puskar and Dr. Titi Shodiya	NIST

Four seminars on standards and standardization methods for material testing and characterization and their appropriate usage in standard engineering design were conducted in the Spring 2024 semester, as listed below. A total of 60 students attended these seminars.

April 1, 2024	Dr. Jacob Bice	Walter P. Moore
April 8, 2024	Dr. Larry Peel	TAMUK
April 15, 2024	Mr. Richard Martinez	Retired, Chemours Chem.
April 22, 2024	Mr. Alfredo Trevino	Keller – North America

Some of the seminar presentations were recorded so that the students can have the option to review the recorded seminar videos and submit a report to get credit for attendance, to satisfy the certificate requirements. This would help a student receive the transcribed certificate if he/she misses seminar(s) due to any unavoidable circumstances. A pool of 12 recorded seminar presentations is available at this point. To date, 5 students have taken advantage of the recorded seminar option. To date, 4 students have received the transcribed certificate, all majored in Mechanical Engineering.

C. Summary of Survey Conducted in Various Semesters

Students enrolled in courses with an embedded content module were invited to complete an anonymous survey to measure the effectiveness of the content modules in developing students' awareness of and appreciation for standards and codes. The survey is designed to be completed twice: once at the beginning of the semester for a pre-course picture of understanding/engagement and again at the end of the semester to determine if there are significant changes. However, the survey was developed throughout the Spring 2022 semester, so only post-course survey results are available for Spring 2022. Pre- and post-course survey data of later semesters are discussed later.

In Spring 2022, 14 students completed the post-course survey. Note that 511 students were registered in classes with embedded course modules in Spring 2022, so it is immediately clear that survey completion is a challenge. Of the respondents, 13 (93%) were male, and 1 (7%) preferred not to share gender information. The respondents were demographically and ethnically diverse: 3 (21%) identified as white, 4 (29%) identified as Hispanic/Latinx, 2 (14%) identified as Asian, 3 (21%) identified as black or African American, and 2 (14%) declined to respond. Table 2 summarizes Spring 2022 student survey responses.

As demonstrated in Table 2, the majority of students (86% or above on all questions) indicated improved understanding of or appreciation for industry standards at the “intermediate” level or higher, while less than 60% of students rated themselves at “high” or above on these questions. The strongest response (high or above: 57%) occurred when students were asked to rate their understanding of standards for engineering design/materials. Similar responses (high or above: 50%) were recorded for overall appreciation of standards and ability to apply relevant standards.

In Fall 2022, 277 students were registered in classes where standards related course modules were implemented. 23 students completed the pre-course survey, and only 13 students completed the post-course survey. Table 3 summarizes the pre-course and post-course survey results for Fall 2022. Table 3 data show that course modules had a net positive increase on student respondents' confidence and interest in the application of standards and codes. The degree of increase varied from over 30% (ability to identify relevant standards) to just 1% (ability to apply relevant standards).

Table 2. Spring 2022 Student Post-Course Survey Responses

Survey Questions: On a scale of 1 to 5, indicate your...	Very High	High	Intermediate	Low	Very Low	Responses High or Above
Overall understanding of standards	0	4	8	1	1	29%
Overall appreciation of standards	1	6	6	0	1	50%
Understanding of standards for engineering design / materials	0	8	4	1	1	57%
Appreciation of standards for engineering design / materials	0	6	7	0	1	43%
Ability to identify relevant standards	0	5	7	1	1	36%
Ability to apply relevant standards	0	7	5	1	1	50%

Demographically, the Fall 2022 pre-course respondents were 87% male (20 students), 4% female (1 student), 26% white (6 students), and 65% Hispanic/Latinx (15 students). 2 students did not provide gender or ethnicity. Fall 2022 post-course respondents were 77% male (10 students), 23% female (3 students), 8% white (1 student), and 92% Hispanic/Latinx (12 students).

Table 3. Fall 2022 Student Survey Responses

Survey Questions: On a scale of 1 to 5, indicate your...	Responses High or Above		Change
	Pre-Course	Post-Course	
Overall understanding of standards	57%	77%	+20%
Overall appreciation of standards	69%	85%	+16%
Understanding of standards for engineering design / materials	57%	77%	+20%
Appreciation of standards for engineering design / materials	74%	85%	+11%
Ability to identify relevant standards	43%	77%	+34%
Ability to apply relevant standards	61%	62%	+1%

It is interesting to note that 87%-91% of pre-course survey responses and 84%-92% of post-course survey responses were at the “intermediate” or higher range for Fall 2022. This range is similar to the number of “intermediate” or higher responses reported in Spring 2022 (86-93%). These data suggest the importance of looking at the “high” and “very high” responses in tracking future survey results, since very little difference appears among intermediate, low, and very low responses.

In Spring 2023, 407 students were registered in classes where standards related course modules were implemented. However, only 30 students started the survey, and from those, only 6 students completed the pre-course survey, and only 9 students completed the post-course survey. Table 4

summarizes their pre-course and post-course survey results. Table 4 data shows that the course modules caused a net positive increase on student respondents' confidence and interest in the application of standards and codes. The degree of change varied considerably with the highest increase of 39% achieved in both understanding of standards for engineering design/materials, and ability to apply relevant standards.

Table 4. Spring 2023 Student Survey Responses

Survey Questions: On a scale of 1 to 5, indicate your ...	Responses High or Above		Change
	Pre-Course	Post-Course	
Overall understanding of standards	33%	22%	-11%
Overall appreciation of standards	50%	67%	+17%
Understanding of standards for engineering design/ materials	17%	56%	+39%
Appreciation of standards for engineering design/ materials	33%	67%	+34%
Ability to identify relevant standards	50%	56%	+6%
Ability to apply relevant standards	17%	56%	+39%

Demographically, the Spring 2023 respondents were 87% male (13 students), 7% female (1 student), and 1 person stated other for gender. By race, 27% indicated white (4 students), 40% indicated Hispanic/Latinx (6 students), 20% or 3 students preferred not to respond, and 7% or 1 student each indicated Asian and Black or African American.

It is interesting to note that 100% of the post-course responses for the first 4 questions in Table 4 were at an intermediate level or higher. It is also interesting to note that 67%-83% of pre-course survey responses and 89%-100% of post-course survey responses were at the “intermediate” or higher range for Spring 2023. This range is similar to the number of “intermediate” or higher responses reported in Spring 2022 and Fall 2022 (84-93%). These data suggest the importance of looking at the “high” and “very high” responses in tracking survey results, since very little difference appears among intermediate, low, and very low responses.

Since each survey respondent has a number assigned to their response, a weighted average for each response can be calculated, with 3 being the Intermediate response. The weighted average responses for the same survey as listed in Table 4, are shown in Table 5.

Table 5. Spring 2023 Student Survey Weighted Average Responses

Survey Questions: On a scale of 1 to 5, indicate your...	Weighted Average		Change
	Pre-Course	Post-Course	
Overall understanding of standards	3.17	3.22	+0.05
Overall appreciation of standards	3.50	4.00	+0.50
Understanding of standards for engineering design/ materials	3.00	3.78	+0.78
Appreciation of standards for engineering design/ materials	3.17	4.33	+1.16
Ability to identify relevant standards	3.17	3.44	+0.27
Ability to apply relevant standards	2.83	3.44	+0.61

Even though the data in the first row of Table 4 seems to indicate that the overall understanding of standards went down, the weighted average shows a slight increase. Perhaps the most significant increase was the students' confidence in their ability to apply relevant standards. That indicates that the courses and their increased emphasis on standards is making a difference.

Another question asked the students "Are you interested in pursuing higher level degrees where engineering design and material characterization using standards are needed?" 2 out of 4 or 50% pre-course students said yes, or maybe, and 4 out of 8 or 50% post-course respondents said yes, indicating (assuming our small sample size is accurate) that the courses haven't changed any student's opinion on graduate school.

In Fall 2023, 11 students completed the post-course survey, although 263 students were registered in classes where standards related course modules were implemented. Of the respondents, 9 (82%) were male, and 2 (18%) were female. 10 (91%) respondents identified as Hispanic/Latinx, and 1 (9%) identified as Asian. Table 6 summarizes the Fall 2023 student survey responses.

As shown in Table 6, the majority of students (91% or above on all questions) indicated improved understanding of or appreciation for industry standards at the "intermediate" level or higher, while less than 85% of students rated themselves at "high" or above on these questions. The strongest response (high or above: 82%) occurred when students were asked to rate their appreciation of standards for engineering design/materials. Similar responses (high or above: 73%) were recorded for overall appreciation of standards and understanding of standards for engineering design/materials.

Table 6. Fall 2023 Student Post-Course Survey Responses

Survey Questions: On a scale of 1 to 5, indicate your...	Very High	High	Intermediate	Low	Very Low	Responses High or Above
Overall understanding of standards	4	1	6	0	0	45%
Overall appreciation of standards	5	3	2	1	0	73%
Understanding of standards for engineering design / materials	4	4	3	0	0	73%
Appreciation of standards for engineering design / materials	5	4	2	0	0	82%
Ability to identify relevant standards	4	3	3	1	0	64%
Ability to apply relevant standards	4	1	5	1	0	45%

We wanted to see more student participation in the survey. However, because of Institutional Review Board (IRB) regulation, it was very difficult to persuade students to take the survey. As approved by the TAMUK IRB, survey requests were distributed to students enrolled in courses with embedded content modules at the beginning and end of each semester. Students were contacted by the department administrative associates, since neither the project leaders nor the

faculty members may distribute or discuss the surveys (to prevent any undue influence on students taking the course). In addition to the survey being completely anonymous and optional, this method of delivery places a very low priority on completion.

D. Dissemination and Publications

A project website (<https://www.tamuk.edu/engineering/departments/mien/projects/NIST-CID-MaSE.html>) has been created. All the standards-related modules, revised course syllabi, and related publications are posted on this site. Furthermore, syllabi for all courses (including standards-related modules) are available on the online university class schedule (www.tamuk.edu/bluegold) and can be retrieved during and after each semester. Information about and forms for completing the undergraduate and graduate certificates are also published online (<https://www.tamuk.edu/engineering/departments/mien/mechanical/NIST-CID-MaSE.html>). This information has been shared with Chairs and Administrators from different universities to disseminate the project outcomes.

A conference paper has been published and presented at the American Society of Engineering Education (ASEE) Conference in Baltimore, MD, June 25-28, 2023 (B. Bailey, M.M. Hossain, L.D. Peel, “Work-In-Progress: Curricular Integration of Design and Material Standards in Engineering”, *American Society of Engineering Education (ASEE) Conference, Baltimore Convention Center, MD, June 25-28, 2023*, <https://peer.asee.org/44200>). The project progress and findings have also been presented at the *NIST Standards Services Curricula Development Cooperative Agreement Program New Awardee Meeting* on December 3, 2021, and *NIST Standards Services Curricula Development Cooperative Agreement Program Awardee Meeting* on December 16, 2022.

CONCLUSIONS

The framework for the Certificate on Standards for Material Testing, Characterization, and Applications is complete, and a number of students received the transcribed certificate as well. Three seminar series have been completed in support of the certificate program, with 207 students attending the seminars. 12 seminar presentations have been recorded and are available to students unable to attend seminars in person. The students can easily get the information regarding the certificate programs when the seminar series is being promoted or by going through the program website.

Although the number of student survey responses is not great, the survey results indicate that the course modifications to add standard related course modules is raising engineering students’ awareness of the role of codes and standards in material and design.

More than 1,700 students learned about the standards and standardization methods with the course modifications to include standards related modules in various courses. Therefore, a huge number of students were educated on standards and, as such, are positively impacted by this project. The students also learned about standards repeatedly throughout their study here at TAMUK as the standard-related course modules were implemented at various stages of their study. This is expected to embed a deep appreciation and understanding of standards in students. Through inclusion of standard-related modules in multiple courses and the certificate program, importance of standards and standardization is instilled into students in a way that is expected to promote life-long use of standards in their professional careers.