An Experiential Education Framework to Train Next-Generation Energy-Conscious Engineers through UNT Industrial Assessment Center

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Abstract

The mission of the newly established UNT Industrial Assessment Center (UNTIAC) is to assist small and medium-sized enterprises (SMEs) in manufacturing sector in North Texas region (a) increase energy efficiency, maximize productivity, and minimize waste; (b) train engineering students with professional skills in these areas; and (c) provide outreach and education opportunities to nonparticipating SMEs. This paper describes the overall UNTIAC training process for participating graduate and undergraduate engineering students from recruitment to graduation through examination and certification. The experiential education approach includes orientation and safety training, participation in assessments, collection and analysis of data, conception of impactful recommendations, and specific technical report writing. Additional training in emerging aspects of the program such as smart manufacturing, decarbonization, and cybersecurity are also described.

Introduction

The University of North Texas Industrial Assessment Center (UNTIAC) was established recently as part of a national program sponsored by the Office of Manufacturing and Energy Supply Chains (MESC) of the Department of Energy (DOE). IACs are currently located at 37 universities across the country. The mission of the UNTIAC is to assist small and medium-sized enterprises (SMEs) in manufacturing sector in North Texas region (a) increase energy efficiency, maximize productivity, and minimize waste; (b) train engineering students with professional skills in these areas; and (c) provide outreach and education opportunities to nonparticipating SMEs.

According to the National Association of Manufacturers[1], Texas' manufacturing sector produced 11.91% of the total output in the state corresponding to $226.95B in 2021. Texas is the #1 exporting state for manufactured goods in the U.S. for more than 20 years, exporting $254.5B worth of manufactured goods in 2021[2]. The number of manufacturing firms in Texas is 17,720 employing nearly 900,000 people[1]. Texas' manufacturing sectors include energy-intensive sectors such as petroleum refining, chemicals, and primary metals production. Such data clearly indicate that the UNTIAC could be instrumental in addressing a critical need in North Texas to reach out and serve the SMEs and prepare the next generation of engineering professionals in this field.

This paper focuses on one of the major goals of the center and describes its overall experiential education framework to train next-generation energy-conscious engineers. Experiential education is defined as a teaching philosophy that informs many methodologies in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, clarify values, and develop people's capacity to contribute to their communities.[3] Experiential education is particularly important in engineering education, and has been effectively utilized for years.[4-9] Inherently, IACs provide prime examples of experiential education in preparing engineering professionals.

The UNTIAC will have a major contribution towards promoting DOE's aspirational goal of establishing an accredited B.S. degree in energy engineering or equivalent field. In fact, UNT has already an established, ABET-accredited B.S. degree in Mechanical and Energy Engineering. Moreover, UNT Department of Mechanical Engineering (ME) offers M.S. and Ph.D. degrees in Mechanical and Energy Engineering, M.S. degree in Engineering Management with Energy Management concentration, and a graduate Certificate in Energy. Therefore, the UNTIAC's host department has a unique advantage among the peer institutions across the nation in terms of experience, resources, industry connections, and alumni base in energy engineering field.

Since the UNTIAC was established in fall 2022 and recruitment and training of students have started recently at the beginning of 2023, this paper mainly describes the center's vision for experiential education that will be implemented gradually in 2023. The UNTIAC's organizational model involves two ME faculty members who serve as director and assistant director, and a group of 12 graduate and undergraduate students who are employed as graduate research assistants and hourly undergraduate research assistants.

UNTIAC Training Process

Student Recruitment and Participation

The UNTIAC team comprises a total of 12 student members. Two graduate students are recruited from the College of Engineering (CENG) for a period of two or more years in order to maintain stability and assign them as team leads who can be role models for undergraduate students and facilitate knowledge transfer among the team members. Ten undergraduate students are recruited from the CENG, as well as College of Business and College of Science, including the following programs: Mechanical and Energy Engineering, Mechanical Engineering Technology, Electrical Engineering, Computer Science and Engineering, Construction Engineering Technology, Engineering Management, Management, and Environmental Science. Center website[10] in this regard is an important means to promote the IAC activities and provide clear instructions on how students can apply. The center normally recruits undergraduate students at the beginning of each academic year/fall semester, provides orientation training, and engages them in assessments and other IAC activities for a full year. Such operation brings logistical advantages such as streamlined training and staffing of concurrently operating assessment teams.

The IAC students are closely monitored and advised to ensure that they are pursuing the relevant coursework in their respective fields. As explained, the IAC students are strategically recruited to create a proper team composition with a broad expertise to successfully address all the needs of various SMEs, and make recommendations that will result in high impact, and cost-effective savings based on a site-specific industrial assessment. Prospect students' degree plans are carefully evaluated before their recruitment and monitored during their employment to make sure that they have the appropriate preparation in their majors. In other words, they are individually guided to take the relevant courses to support and compliment their IAC training and experience. As an example, for students in mechanical major, the required coursework includes circuit analysis and thermodynamics, along with other preferred courses such as fluid mechanics, heat transfer, machining principles and processes, CAD/CAM system operations, and quality assurance. This approach enables the center to educate a diverse and complimentary group of students for professional careers in the manufacturing sector who are highly skilled in implementing tools and methods to improve energy efficiency, manufacturing competitiveness, and waste management.

An assessment team, composed of the director or the assistant director, one graduate student, and three to six undergraduate students, conducts each assessment, collects data, performs the required analyses, strategizes recommendations, and generates the formal report. The student team composition reflects a combination of majors based on the profile of the company as determined by their response to a questionnaire administered by the IAC and other relevant information gathered before a scheduled visit.

Training

The overall UNTIAC training process from recruitment to graduation is described with a flowchart in Figure 1. Student competency in the program is evaluated through systematic examinations. When students join the IAC, they take an initial survey on the general industrial assessment concepts. This initial survey indicates the students' level of knowledge in the various aspects of the industrial assessment process and help the IAC management to understand the strengths and weaknesses of the newly recruited team members, allowing proper scope and emphasis in the orientation program.

Beginner level students in the IAC team first undertake a comprehensive orientation program. This program trains students on major assessment procedures through a series of workshops, focusing on the areas of; (i) health and safety guidelines for industrial assessment, (ii) energy, water, and waste management, (iii) manufacturing productivity and competitiveness, (iv) smart manufacturing, resiliency planning, decarbonization and electrification, and (v) cybersecurity technologies. The workshops are held in the CENG facilities for up to half-day sessions each, in order to lay the fundamental knowledge in each area and also to provide hands-on training on key assessment tools.

The UNT CENG has particular facilities that are instrumental for this part of the training, including Engineering Manufacturing Facility, Thermal-Fluids Sciences Laboratory, Central Process Utility, and Zero Energy Lab. Of these:

- Engineering Manufacturing Facility enables students to become familiar with various conventional and emerging manufacturing processes (milling, turning, welding, CNC machining, as well as industry-grade additive manufacturing).
- Thermal-Fluid Sciences Laboratory features various instructional equipment including temperature, pressure, flow measurement devices, IR thermal camera, HVAC and refrigeration cycles, heat exchangers, miniature Rankine Cycle power plant, wind tunnel, pneumatic/hydraulic systems, data acquisition devices and software.

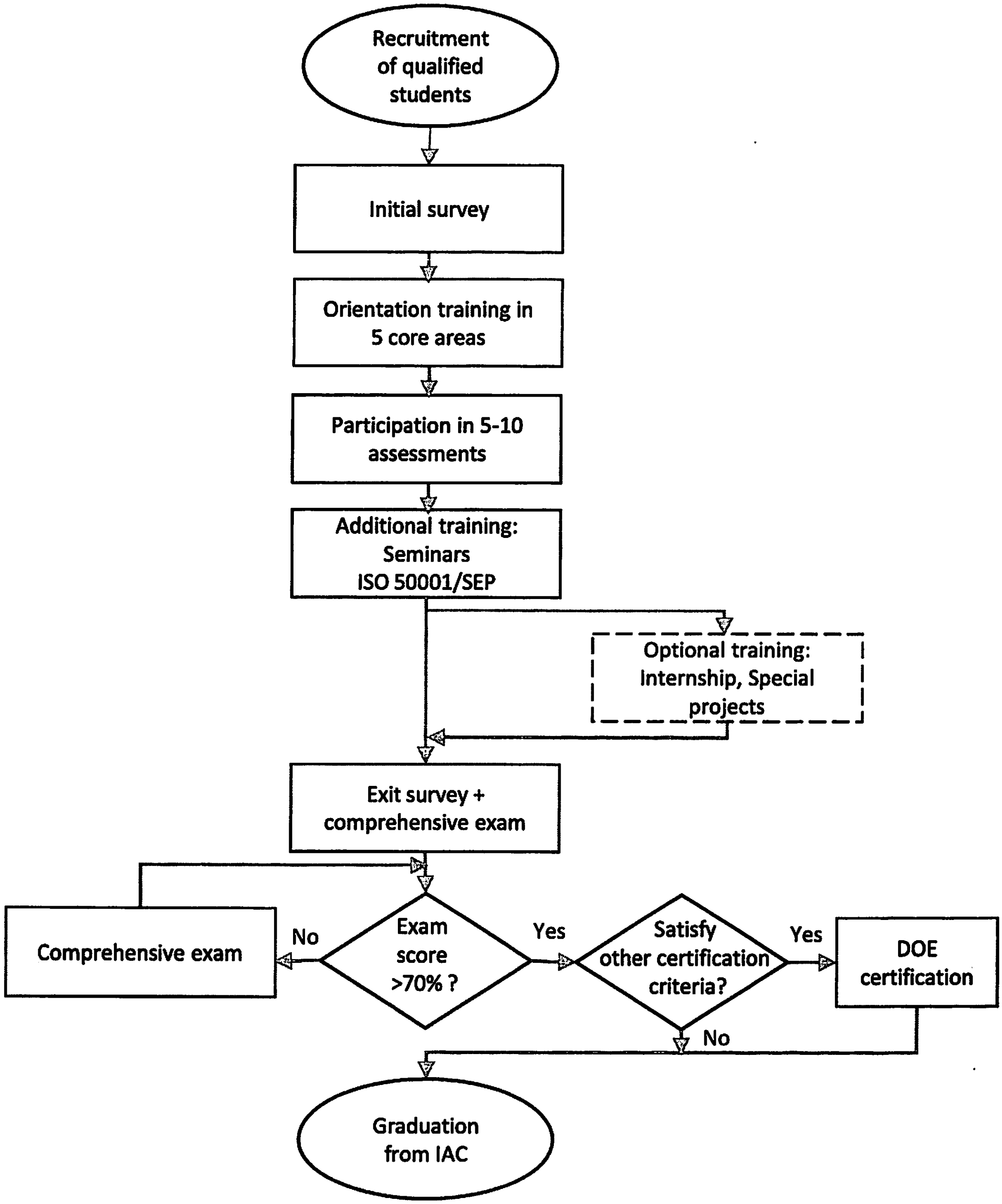

Figure 1. A flowchart describing the UNTIAC experiential education framework.

- The Central Utility Plant (CUP) (Figure 2a) is conveniently located within the CENG and features industrial scale systems that produce steam for heating, humidification, and sterilization; chilled water for comfort and equipment cooling; and compressed air for various pressure-driven processes. The CUP also includes emergency power generation systems that can serve the UNT CENG campus independently.

- The Zero Energy Lab (Figure 2b) is the only one of its kind in Texas featuring renewable energy sources such as solar and wind as well as smart energy management system, and is used to test emerging, sustainable technologies and materials to achieve a net-zero consumption of energy in buildings.

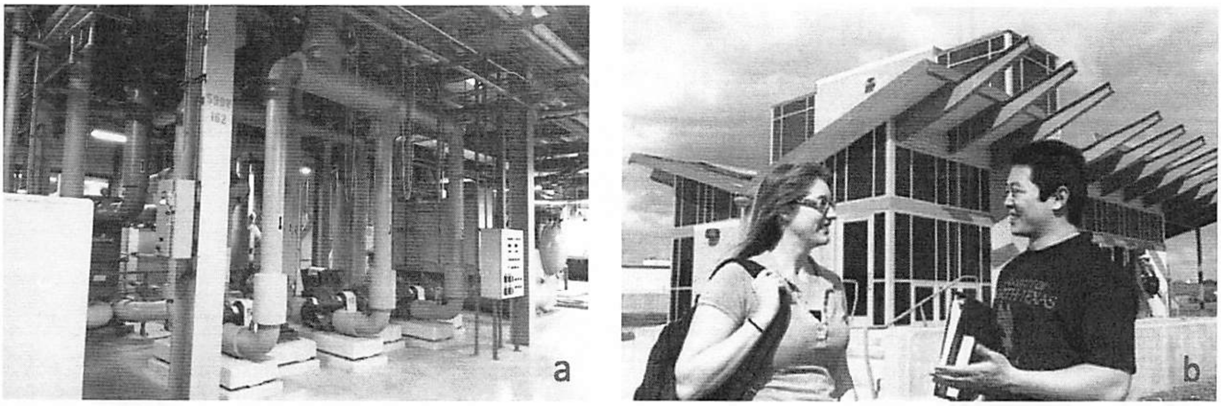

Figure 2. UNT CENG facilities: Central Utility Plant (a), and Zero-Energy Lab (b).

Therefore, once the beginner level students complete their orientation program, they have a strong grasp of the basics of industrial assessment approach. They learn the major assessment procedures, practice the use of assessment tools on actual systems, and become well-prepared to participate in site visits for conducting industrial assessment at SMEs.

Undergraduate students are expected to participate in 5-10 industrial assessments. IACs follow a five-step protocol[11] to conduct industrial assessments, outlined as:
Step 1: Pre-Assessment Information Gathering.
Eligible SMEs fill out an online Pre-assessment Form. This form includes

- Size of plant and plant layout
- Industry type (SIC/ NAICS code) and process description
- Production levels, units and dollars, operating hours
- List of major energy consuming equipment
- A one-year history of utility bills

Step 2: Obtaining Proper Points of Contact.
These personnel typically involve

- Plant manager
- Energy manager
- Environmental personnel
- Maintenance personnel

Step 3: Pre-Assessment Analysis.
Based on the preliminary information provided, IAC

- Analyzes the manufacturing process
- Charts and graphs utility bills
- Analyzes utility bills for trends and errors; establish unit cost of energy
- Starts plant profile using QuickPEP
- Identifies key energy systems

- Reviews design and other technical documentations
- Identifies energy saving potential recommendations using IAC database
- Develops strategy for assessment day

Step 4: Day of the Assessment.
IAC team conducts assessment with an agenda involving

- Arrival (typically 9 am)
- Introduction (~15 mins.)
- Description of manufacturing process and operations (~15 mins)
- Plant tour (~1-2 hrs.)
- Meeting room debriefing (~15 mins)
- Reviewing notes and brainstorming (lunch, ~1 hr.)
- Refining list of opportunities to be investigated (~10 mins.)
- Data gathering (~1 hr.)
- Exit interview (~ 15 mins.)

Step 5: Post Assessment Activities.
Following the site visit, IAC

- Conducts engineering and financial analysis
- Creates and delivers an IAC Report within two months after the site visit with the following content
    - Executive Summary including summary of recommendations
    - Plant Description
    - Process Description
    - Resource Charts and Tables
    - Major Energy Consuming Equipment
    - Best Practices
    - Description of Individual Energy Saving Recommendations
- Drafts Case Studies/Success Stories
- Follows-up to Report
- Posts information on social media for positive publicity

In parallel to gaining hands-on, real-world experience through the industrial assessments, students are exposed to additional training opportunities beyond the comprehensive orientation program. The IAC organizes two seminars every year and invite experts from industry or academia. Seminars create a platform to facilitate exchange of knowledge, experience, and networking opportunities, as well as to publicize the IAC activities to prospect students and SMEs.

The IAC program also provides students training opportunities in the areas of standardized energy management systems (ISO 500001/SEP), that can motivate and prepare the interested students for career paths such as Energy Management Systems Auditor certification.

As an optional component of the training, the IAC seeks to leverage its relationship with industry partners in North Texas to arrange internship or co-op positions for the participating students. Such opportunities further enhance the students' training and experience in various industrial settings. For this purpose, SMEs in energy-intense manufacturing areas are particularly useful, providing mutual benefits.

Moreover, the IAC provides unique research experiences for participating students to further enhance their training and achieve broader impacts. Graduate students work on assessment-inspired research topics for their thesis or dissertation while advised by the IAC directors. Every year, DOE IAC program accepts and reviews proposals for Special Projects from member IACs nationwide and awards several research grants. The UNTIAC pursues this research funding to support its relevant research efforts, and then publish and disseminate the results in the form of scientific papers and technical briefs. Undergraduate students are encouraged to take part in the research, and they are mentored by the IAC graduate students. Ideally, the Special Projects would address energy-intensive manufacturing technologies, and leverage research areas of the IAC directors, such as innovative Stirling engine-based energy conversion for waste heat recovery and distributed power generation, or additive manufacturing for increased competitiveness by minimizing total cost, realizing greener products and processes, and reducing carbon footprint.

When students complete their IAC employment, they are given the exit survey (same content as the initial survey), as well as a comprehensive exam comprising in-depth topical questions to assess their level of competency. Students at this stage are expected to have a high level of understanding in industrial assessment area, demonstrated by 70% or higher score in the exam, which is based on the established resources such as Essentials of Industrial Assessments.[12] The final surveys and exams are also important measures for their qualification towards the DOE IAC Certificates that come with additional requirements of mastering a number of core skills and participating in at least 6 assessments.

Students' experiential education process is closely observed by their team leads and the IAC directors during their involvement in center activities. Students graduate with the skills and abilities to conduct energy, productivity, and waste assessments; use instrumentation and diagnostic equipment; work safely in an industrial environment; and communicate successfully through written reports and presentations to clients. Long heritage of the DOE IAC program has shown that these skills -that can only be gained through real-world experience- make graduates highly attractive to employers.[13]

Integration with University Curriculum

The ME at UNT offers a B.S./M.S./Ph.D. degree in Mechanical and Energy Engineering. The degree is a blended approach to prepare engineers who have strong mechanical foundation and a broad energy perspective. Due to its inherent multidisciplinary environment and programs as described earlier and a strong focus on applied/hands-on approach, the Department of ME continually evolve its programs by adapting state of the art technologies. Hence, best practices, lessons learned, case studies and technical resources developed through the IAC will be added to the content of an already multidisciplinary curriculum in our existing B.S. degree programs, presenting a great fit to nurture the next generation of qualified engineering professionals who are also excellent candidates for DOE certification.

Initially, the orientation training adopts and utilizes the currently available training materials mainly from DOE's IAC related technical resources.[14] However, over a 4-year period, the UNTIAC will gradually develop its own training portfolio in the form of workshops on the same 5 core areas, including (i) health and safety guidelines for industrial assessment, (ii) energy, water, and waste management, (iii) manufacturing productivity and competitiveness, (iv) smart manufacturing, resiliency planning, decarbonization and electrification, and (v) cybersecurity technologies. For the development of these workshops, center directors will seek to leverage the relevant content from the offered courses and effectively utilize the existing expertise and prominent research programs at UNT; namely, (i)Advanced Environmental Research Institute, known for its strong and growing research on water quality, water resource management, and ecosystems and conservation , and (ii) The Center for Information and Computer Security, recognized as a leader in cybersecurity education and research. Once the IAC creates the workshops in the five core areas, they could potentially be expanded and integrated to develop an organized Industrial Assessment course as an upper-level engineering undergraduate course.

Moreover, as a culmination of lessons learned through the site assessments, special projects, and SME practical needs, the IAC aims to develop one technical resource every year to address the "how-to" guides that most SMEs need. Examples of such guides would cover a broad range, such as "how to ensure smart communication reliability", "how to measure vibrations on a CNC machine", and "how to implement predictive maintenance using infrared thermography". The objective of these efforts is the development and dissemination of practical technical resources that benefit the largest number of SMEs and hence have the most significant impact.

Summary and Conclusions

This paper introduces the recently established UNTIAC as part of the national DOE IAC program and focuses on describing its experiential education framework to train next-generation energy-conscious engineers. The training process is designed for participating graduate and undergraduate engineering students, follows steps from recruitment to graduation through examination and certification, and includes main activities of orientation and safety training, participation in assessments, collection and analysis of data, conception of impactful recommendations, and specific technical report writing.

Besides practical technical skills and abilities to conduct energy, productivity, and waste assessments, the IAC students experience teamwork, close collaborations, and gradually increasing responsibilities, and develop important communication and presentation skills that greatly enhance their professional career.

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