Final Technical Report (FTR)

Cover Page

a. *Federal Agency*	Department of Energy	
b. *Award Number*	DE-EE0009703	
c. *Project Title*	Development and Validation of Smart Building Technology Modules for Academic and Professional Education	
d. *Recipient Organization*	Slipstream Group, Inc.	
e. *Project Period*	*Start:* October 1, 2021	*End:* December 31, 2024
f. *Principal Investigator (PI)*	Xiaohui "Joe" Zhou Director of Research and Innovation jzhou@slipstreaminc.org 608.210.7155	
g. *Business Contact (BC)*	Katrina Keller Finance Officer kkeller@slipstreaminc.org 608.729.6826	
h. *Certifying Official (if different from the PI or BC)*	Xiaohui "Joe" Zhou Director of Research and Innovation jzhou@slipstreaminc.org 608.210.7155	

______________________________ ______________

Signature of Certifying Official *Date*

By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate. I am aware that any false, fictitious, or fraudulent information, misrepresentations, half-truths, or the omission of any material fact, may subject me to criminal, civil or administrative penalties for fraud, false statements, false claims or otherwise. (U.S. Code Title 18, Section 1001, Section 287 and Title 31, Sections 3729-3730). I further understand and agree that the information contained in this report are material to Federal agency's funding decisions and I have any ongoing responsibility to promptly update the report within the time frames stated in the terms and conditions of the above referenced Award, to ensure that my responses remain accurate and complete.

Acknowledgment: "This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office (BTO) under the Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT) – 2020, FOA# DE-FOA-0002196, Award Number DE-EE0009703."

Executive Summary

Smart building technologies can improve building energy efficiency and resilience, reduce carbon emissions, and provide load flexibility to the grid. However, in both college curricula and building professionals' continuing education, there is a lack of systematic instruction on smart building technologies.

Slipstream, partnering with Texas A&M University (TAMU), the Society of Building Science Educators (SBSE), and the National Institute of Building Sciences (NIBS), developed a semester-long smart building curriculum for college students and 16 training videos for building professionals and the general public. The education and training cover the drivers and benefits of smart building technologies, key building energy systems, the latest sensor technologies and IoT devices, and focus on topics related to smart building controls (i.e., energy management information systems, smart building control platforms, cybersecurity, grid-interactive-efficient buildings [GEBs], smart building control methods, and occupant-centric control).

The smart building curriculum for college students was taught at TAMU in the Spring semester of 2024 as part of the validation process. Student feedback was collected and summarized in a validation report by TAMU. The curriculum material was also reviewed by SBSE faculty who are interested in teaching smart building technology-related courses. Suggestions on revisions and better adoption of the materials by other faculty across the architectural, engineering, and construction (AEC) domains were compiled in a distinct validation report by SBSE. The SBSE validation report was used to create structured subsets of the curriculum material for adoption at different levels in different sub-disciplines. These subsets are categorized and offered on the SBSE website (https://www.sbse.org/courses/Smart-Building-Technologies).

The 16 training videos for building professionals and the general public were previewed by 17 industry experts, and feedback and suggested changes were incorporated into the final version of these videos. The videos are organized into a smart building technology training course and published on the Whole Building Design Guide website (https://www.wbdg.org/ce/doe/bto/sbtt), which is hosted by the National Institute of Building Sciences (NIBS).

Project team members created marketing materials to promote the awareness of these free, publicly available education and training resources. Outreach and marketing activities included creating short promotional videos, building project webpages, making project announcements on social media, conducting an email campaign, and directly reaching out to faculties and building professionals.

This report describes the project approach, provides outlines of the training materials, along with links to resources, and identifies lessons learned in creating the content. We also suggest ways to scale the instruction of smart building concepts to empower the workforce to accelerate the adoption of smart building technologies in the real world.

Table of Contents

Background

Designing, constructing, operating, and maintaining high-performance, energy-efficient, and grid-interactive buildings require a team effort and collaboration among smart building technology providers, building owners, architects, engineers, building energy modelers, builders, utilities, facilities managers, building operators, and other stakeholders. However, workforce development and training for advanced, smart building technologies are lacking at both the college and professional levels. Traditional college education programs in these engineering disciplines focus on teaching theories and fundamentals in specific areas like thermodynamics and fluids, load calculations, and mechanical, electrical, and plumbing system design. There are only a few certification programs that are focused on building controls (IIT 2024, Johnson 2024, NWTC 2024.) The classical course structure in engineering programs usually lacks an integrated approach to smart building design and system optimization, building sensors and controls, distributed energy resources (DERs), integration of multiple energy systems, load flexibility, control networks, communications, and cybersecurity. Building professionals rely on different resources for continuing education - such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Whole Building Design Guide website, the Department of Energy (DOE) Federal Energy Management Program (FEMP), etc., to keep up with the latest technology advancement in this area. Unfortunately, there is no standard training course integrating multiple components of smart building technologies and providing a systematic course or training in this very important topic area. The related training for building professionals on building operations and building controls is available from Building Efficiency for a Sustainable Tomorrow (BEST 2024), Environmental Security Technology Certification Program Advanced Building Controls Technology Transfer Project (ESTCP 2023), Northwest Energy Efficiency Council (NEEC 2024), Smart Building Center (SBC 2024), and UW Madison Interdisciplinary Professional Programs (UW Madison 2024.)

Slipstream, a mission-driven non-profit organization, led a team including Texas A&M University (TAMU), the Society of Building Science Educators (SBSE), the National Institute of Building Sciences (NIBS), as well as external consultants, to develop and validate a set of smart building technology curriculum modules for academic and professional education. For college education, we developed six smart building technology training modules that can be taught as a senior-level course in four-year colleges and universities. For professional continuing education, 16 technical training videos were developed and recorded.

Project Objectives

The objective of this project is to develop and validate a set of module-based, course materials ready to be adopted by college professors in scalable smart building technologies. Modules suitable for building professionals' continuing education and online training sessions will also be produced. The training content will bridge a gap for college students and building professionals in systematically learning smart building technologies. A trained workforce that understands smart buildings will be able to advance the national goals of clean energy.

This project's primary outcome is a set of validated module-based course materials ready to be adopted by college professors who teach smart building technologies. The technical training sessions for building professionals continuing education will be available to the general public through NIBS's WBDG offerings.

This project was divided into three budget periods with a total of five tasks:

Budget Period 1: Task 1 Overall Project Management and Planning and Task 2 Curriculum Module Development.

Budget Period 2: Complete Task 2 Curriculum Module Development and start Task 3 Curriculum Module Conversion to Technical Videos.

Budget Period 3: Complete the Task 3 Curriculum Module Conversion to Technical Videos. Task 4 Curriculum Module and Technical Video Validations, and Task 5 Information Dissemination.

The milestones and Go/No-Go decision points and metrics are listed in the table below.

Table 1. Project Milestones and Go/No-Go Decision Points

Milestone #	Milestone
1	Finalize the Project Management Plan (PMP) and the project advisor list
2	Finalize the curriculum topics, titles, and format.
3	A complete draft set of course materials for modules #1, #2, and #3 developed
4	A complete draft set of course materials for modules #1, #2, and #3 developed
5	**Go/No Go metric:** a complete draft set of course materials for modules #1, #2, and #3 developed
6	A complete draft set of course materials for module #4 developed
7	A complete draft set of course materials for module #5 developed
8	Technical session presentations and video recordings for Sessions #1-8 are complete
9	A complete draft set of course materials for module #6 developed

10	Technical session presentations and video recordings for Sessions #9-12 are complete
11	**Go/No Go metric:** a complete draft set of course materials for modules #4, #5, #6, and #7 developed
12	**Go/No Go metric:** Technical session presentations and video recordings for Sessions #1-16 are complete. Professional training courses are available on the WBDG website.
13	Curriculum module validation complete
14	Technical session validation complete
15	Marketing materials for the curriculum and course compete.
16	Produce distribution modules in the SBSE resources portal.
17	Outreach and marketing complete

Project Tasks, Processes, and Results

Task 1 Project Management and Planning

For this task, the project team developed, maintained, and updated a Project Management Plan (PMP) for this project throughout the three budget periods. The final version of the PMP can be found in Appendix A.

Task 2 Curriculum Development

Objectives

The overall objectives for the smart building technologies curriculum were to design a semester-long, senior-level course that would achieve specific, measurable learning outcomes through a modularized format. To guide the course development, the academic team identified overarching outcomes to include equipping students with the fundamentals and engineering tools of smart building technologies and preparing students to apply and integrate the knowledge in the design and operation of smart buildings such as grid-interactive efficient buildings. The curriculum design and course structure were assembled with the advisory council, faculty, and practitioner inputs from the building sciences industry. The team incorporated feedback and comments from the advisory council members, and funding agency on the structure, content, delivery, and format of the modules.

Target Audience

The academic course was fashioned around a 15-week traditional semester to offer three credit hours of content. Students enrolling in the course would be required to have achieved junior or senior standing and to have a basic knowledge, by the way of prerequisite courses, in foundational building engineering, including topics such as energy, thermodynamics, heat transfer, building heating and cooling load calculations, heat balance, radiant time series calculation methods, psychometric analysis, indoor air quality, and the effect of solar radiation on heating and cooling of buildings.

The students would also be expected to have introductory preparation in qualitative and quantitative engineering concepts of mechanical systems for buildings before taking the smart building course. This includes knowledge in control of indoor air pollutants and fire suppression systems, thermal behavior of buildings and building envelopes, human comfort requirements, HVAC systems/equipment, design of space air-conditioning, mechanical systems for indoor air quality, and fire suppression.

Learning Outcomes

The course development team developed a list of expected competencies and skills the learners should gain by the end of the course. These included the students having a conceptual understanding of a wide range of smart building technologies, components, and systems; sufficient background to make preliminary technological decisions to implement smart building technologies; the ability to formulate and apply assumptions to real-world smart buildings for conceptual design and analysis; and the ability to discuss the potential smart building technology has for contributing to energy use and challenges of its implementation in the real-world applications.

Curriculum Design

The curricular design and instructional methodologies for delivery of the course content were envisioned to follow the ICAP Framework, a well-researched and documented engineering education strategy to ensure a variety of strategies are used to meet the different types of learners and their learning styles, for effective and deep learning. The development team constructed an outline and template for the PPT presentations (passive learning), interactive lectures with questions and case studies included (active learning), and the design of homework consisting of mini projects (constructive and interactive student interactions with materials). The curriculum was designed for institutions with course management software systems that would help organize the materials into modules for each class period. A draft course syllabus was created with items including pre-requisite coursework requirements, course objectives and outcomes, an outline of the topics to be covered the sub-topics, and the approximate duration for the traditional semester course. The developers reviewed multiple textbooks; however, none were selected for the first-course offering. Instead, multiple online resources and supplementary materials were collected and provided throughout the course, including the projects (case-studies) that would be used for the completion of the homework.

Curriculum Outline

A curriculum outline was created based on known gaps in smart building knowledge typically seen in undergraduate programs. Then, the course structure was developed and was generally organized by module, then title, and by topic. The project team assembled an external project advisory council to review and comment on the draft curriculum outline proposed by the project team. The project advisory council consisted of faculty members who teach smart building-related courses at other universities and colleges, smart building technology researchers, and practitioners in the building industry. Several online meetings were held with the project advisory council members to collect their general guidance, comments, and feedback to the team on the module structure, content, deliverables, and format. Project advisors' written comments and feedback were also provided to the project team. The revised and updated outline incorporating project advisory council members' inputs are shown in Table 2:

Table 2. Curriculum Modules Outlines for College Education

Module #	Module Title and Topics	Teaching Duration
0	**Introduction of the Course** Review of Syllabus & Objectives and Outcomes What is a smart building and what can it do? One or two examples at a high level	30 minutes
1	**Review of Prior Knowledge** Building heat transfer Psychometrics, thermal comfort Indoor air quality (IAQ), ventilation and other IEQ factors Heating and cooling equipment Fenestration and lighting systems Heating and cooling loads Building energy calculation Utility bill Water system and water conservation Occupant behaviors/User interface	2 weeks
2	**Smart Building Technologies Drivers and Trends** 2.1. Codes and Standards ASHRAE 90.1 Overview of other ASHRAE codes and standards: • Commercial buildings: ASHRAE 90.1, 189.1, 62.1, AEDG • Residential buildings: ASHRAE 90.2, 62.2, IECC • ASHRAE Standard 55 Other codes and Standards (e.g., IgCC) 2.2. Trends, programs, and rating systems: LEED; WELL Building Standard; EPA Energy Star, electrification, decarbonization, etc. 2.3 Introduction of smart building technologies and relevant tools A list of commonly used modeling tools/programs • Whole building simulation programs: eQUEST, EnergyPlus, Ladybug, etc. Review of basics of building energy modeling capability • Building envelopes • HVAC equipment and Systems (steady-state vs. dynamic modeling) Introduction of smart building technologies at a high level using an example	4 weeks

	• Introduction to DOE office reference building • Medium-sized office building in EnergyPlus model • Medium-sized office building in Modelica (Modeling controls)	
3	**Fundamentals of Smart Building Technologies** 3.1 Introduction of sensor and IoT devices Occupancy sensors (presence vs. occupant counting) IAQ and CO_2 sensors Smart thermostats Additional sensors (e.g., new flow sensors) and devices 3.2 Introduction of smart building envelope Smart windows (e.g., electrochromic windows, thermochromic windows) Smart materials (e.g., Phase Change Materials, etc.) Automated shading Natural/mixed ventilation Building thermal mass, and materials with tunable thermal properties 3.3 Applications for performance monitoring and building controls Overview of basic building automation and control systems • Building automation system (BAS) • Sensors, actuators, etc. Building performance monitoring (definition and purpose) Automated Fault Detection and Diagnosis (FDD) Automated system optimization (ASO) including optimal controls (e.g., occupant-centric controls, model predictive control) Energy Information System (EIS) as resources/tools, and include other resources/tools from industry (e.g., JCI and Clockworks, etc.) 3.4 Introduction of building to grid integration Grid-interactive efficient buildings (GEB) • Traditional Demand Response (DR) for load shifting, etc. • Emerging GEB technologies (e.g., load modulation) Modern grid with distributed energy resources (DER) Building electrification	4 weeks
4	**Advances in Building Energy Management and Controls** Building Direct Digital Control (DDC) Building energy management system Building Automation Controls Network (BACnet), Modbus, etc. Cybersecurity Data structure and interoperability, data schema (Brick, ASHRAE 223P, etc.) Introducing the concept of optimizations in buildings Integration of different systems (HVAC, lighting, battery, security, etc.) and cloud applications etc.	2 weeks

5	**Applications of Engineering Tools and Standards – Building Operation** 5.1 Overview of existing building commissioning tools and methods 5.2. Overview of ongoing commissioning (TAMU Continuous Commissioning® tools)/ Automated system optimization (ASO) including optimal control tools 5.3. Overview of building operational Codes, Standards and Guidelines ASHRAE Guideline 36: High-Performance Sequences of Operation for HVAC Systems ASHRAE/IES Standard 202: Commissioning Process for Buildings and Systems ASHRAE Guideline 0 series ASHRAE Guideline 1.1 series	2 weeks
6	**Smart Building Technologies Case Studies for Design and Operation** Single-building case studies Connected buildings on a campus Smart and connected communities	2 weeks

The curriculum content developed consisted of presentation slides, in-class quizzes, and project assignments. The projects involve: 1) conducting a literature review on current smart building technologies, and 2) evaluating different smart building technologies using Sketchbox. Two mini-projects and the final project are staged, such that building envelopes created in the first mini-project are used in the following projects.

In addition to lectures, actual demonstrations of smart thermostats, portable indoor air quality sensors, variable air volume (VAV) controllers, small-scale coils/heat exchangers, phase change material, etc., would be conducted in the classroom. Thereby, the students gain both visional and practical engagements with smart building technologies. At the end of the semester, students would be asked to take pictures of smart devices/technologies in buildings around the campus or their homes and share them with the instructor and the class.

Assessment Techniques

For faculty teaching the course to have an effective assessment strategy in place, the developers designed formative and summative assessment tools consisting of in- and out-of-class quizzes, projects, exams, and final projects. The assessments were designed to ensure their alignment with the learning outcomes. The student work would have to be collected to measure the effectiveness of the course.

Modularization of the Curriculum

One of the objectives for the curriculum development for college education was to ensure the materials developed were “modularized” and could be widely adopted by architectural, other engineering, or construction programs outside TAMU. Faculty from other colleges and universities typically might not adopt the entire course but rather pick and choose specific modules or sub-contents they would like to teach and customize. Due to the extensive work that went into the development of the full course, creating (adapting) such subsets was daunting. One of the team partners, the Society of Building Science Educators (SBSE)—an association of university educators and practitioners in architecture, engineering, construction, and other related disciplines who support excellence in the teaching of environmental science and building technologies—suggested using a presentation slide template (Figure 1) to improve the training materials' adaptability. At the bottom of each slide, there will be an indication that the slide content is at knowledge level I, II, or III, and an identification of this content being suitable for either Architecture, Engineering, or Construction disciplines. SBSE provided subject matter experts for the different disciplines and conducted an inter-rater reliability assessment to develop a validated classification of the larger content broken down into discipline-specific representations of these knowledge levels.

Three Knowledge Levels / Categories

Level	Option A	Option B
Level 1: Intro Level Knowledge • Should be known by anyone in the (various) fields • Topics and elements related to terminology and basic principles	●○○	Ⓘ
Level 2: Intermediate Level • Should be known by decision-makers • Topics and elements of breadth	●●○	(II)
Level 3: Detail or Expert Level • Should be known by experts designing systems • Topics and elements of depth	●●●	(III)

●○○ 8 Ⓘ

Figure 1. Presentation Slide Template for College Education

Task 3 Curriculum Conversion to Technical Videos

Process

Slipstream led the development of 16 videos designed to meet continuing education requirements for building professionals on smart building technologies. Each video is between 30 minutes to one hour in length. Our original approach was to reuse most of the content developed for college education and then add more suitable content for building professionals and the general public. However, after reviewing the curriculum content developed by TAMU and discussing our originally proposed training video topics with the DOE technical manager, we made some revisions to the video topics and the order of the videos. As a result, most of the video content was developed from scratch and only a small portion was converted from the curriculum materials for college education.

Based on the revised video topics table (Table 3) and the project team staff's expertise, a developer/speaker was assigned for each video. External industry experts were invited to draft and present two of the topics: Video #11 Smart building control platform cybersecurity and Video #13 Occupant-centric control.

During the content development stage, the team first drafted the presentation slides and conducted a round of internal reviews. For two videos (Video #11 and Video #13), industry experts were invited to review content or provide comments and feedback. All content was then reviewed by a DOE technical manager overseeing the project who provided many detailed, constructive suggestions for changes. The feedback from the DOE technical manager covered the overall course structure and topics selected, questions on the technical content from the target audiences' perspectives, and logical arrangement of the presentation topics and subtopics. The project team incorporated most of this feedback into an updated version of the training content.

After the presentation slides were developed, presenters were asked to create a script or talking points for each slide, before creating voiceover recordings directly on the Microsoft PowerPoint presentation slides using the embedded "Record" function (Figure 2.)

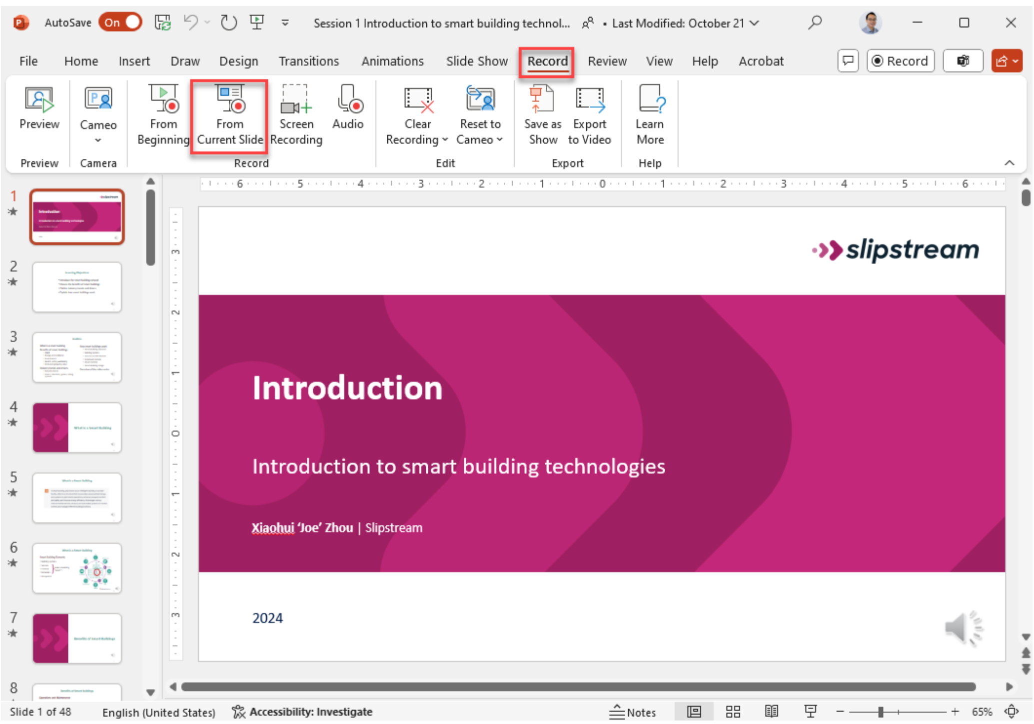

Figure 2. Microsoft PowerPoint "Record" Function

There are several advantages to using the Microsoft PowerPoint "Record" function. It allows presenters to record the voiceovers on a single platform, eliminating the need for third-party applications. Multiple presenters can record different slides in the same video, and they don't have to do the recordings at the same time. The interface is user-friendly and easy to use. Presenters can control slide timings, which can enhance the quality of the presentation. Microsoft PowerPoint provides built-in annotation tools, such as a pen and laser pointer, to highlight important points during the recording. Presenters have the flexibility to re-record individual slides if needed, without having to redo the entire presentation. This makes revising the content later much easier. Recordings can be exported directly to video formats, making it easy to be edited by video editing professionals using other video editing tools.

After voiceovers were added to the draft presentation slides, they were exported to videos in MPEG-4 video (MP4) format. MPEG-4 is a digital multimedia format that is widely used for encoding and storing audio and video data. We used these video versions (without video editing) in Task 4.2 Validation for the Technical Videos, which involved collecting industry experts' comments and feedback on the training content of the videos (more details of Task 4.2 are provided in a later section of the report).

Each presenter then made revisions to their videos based on the feedback. Once these revisions were completed, we created final versions of the 16 videos that were then edited by professional video editors for improved video and audio quality.

Finally, Slipstream worked with NIBS to design a training course structure that was suitable for the WBDG website. Information about the speakers, each video's summary, learning objectives, as well as 10 questions and answers, were collected and sent to NIBS for posting with the videos and other related information on the WBDG website.

Outcome

The 16 training videos for building professionals and the general public are grouped into five categories: 1) Introduction (Video #1); 2) Building systems (Video #2-#6); 3) Sensors and IoT devices (Video #7-#8); 4) Smart building controls (Video #9-#13); and 5) Smart building applications (Video #13-#16). The specific topics for each of the 16 videos are listed in Table 3.

Table 3. Topics in Smart Building Technology Training Videos for Building Professionals

Video #	Topic
1	Introduction to smart building technologies
2	Building HVAC - basic systems
3	Building HVAC - complex systems, Building Automation System
4	Networked lighting controls and HVAC integration
5	Solar PV, BESS, and EV charging
6	Smart window, automated shades, thermal energy storage, phase change material, and plug loads
7	Sensors
8	IoT devices and example building applications
9	Advanced building monitoring and controls
10	Smart building control platform
11	Smart building control platform cybersecurity
12	Smart building control methods
13	Occupant-centric control

14	Grid-interactive efficient buildings and Connected Communities
15	Review of whole-building simulation programs
16	Smart building application examples

The course is available to the public on the WBDG website. The Whole Building Design Guide is an ongoing 20-year project under NIBS's direction with an advisory workgroup of federal agencies to foster communication and knowledge-sharing among federal, industry, and academic partners. This website is a central information source for many federal agency staff, including energy managers, facility management, and operations and maintenance (O&M) staff. It also serves other building professionals for their continuing education needs. NIBS provides an online learning management platform and is a team partner for this project.

Each video session includes a post-test consisting of ten multiple-choice questions or true/false questions. Anyone who takes the course and passes the test receives either a half or one Professional Development Hour (PDH). Figure 3 to Figure 6 are screenshots of WBDG websites related to continuing education and training and smart building technology training.

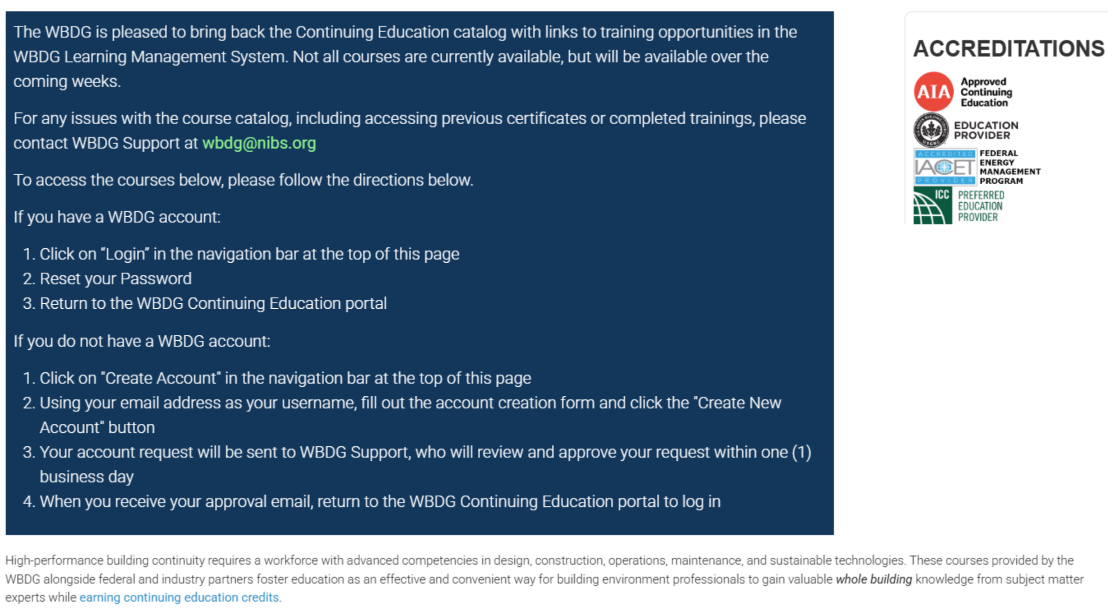

Figure 3. WBDG Continuing Education and Training Accreditations

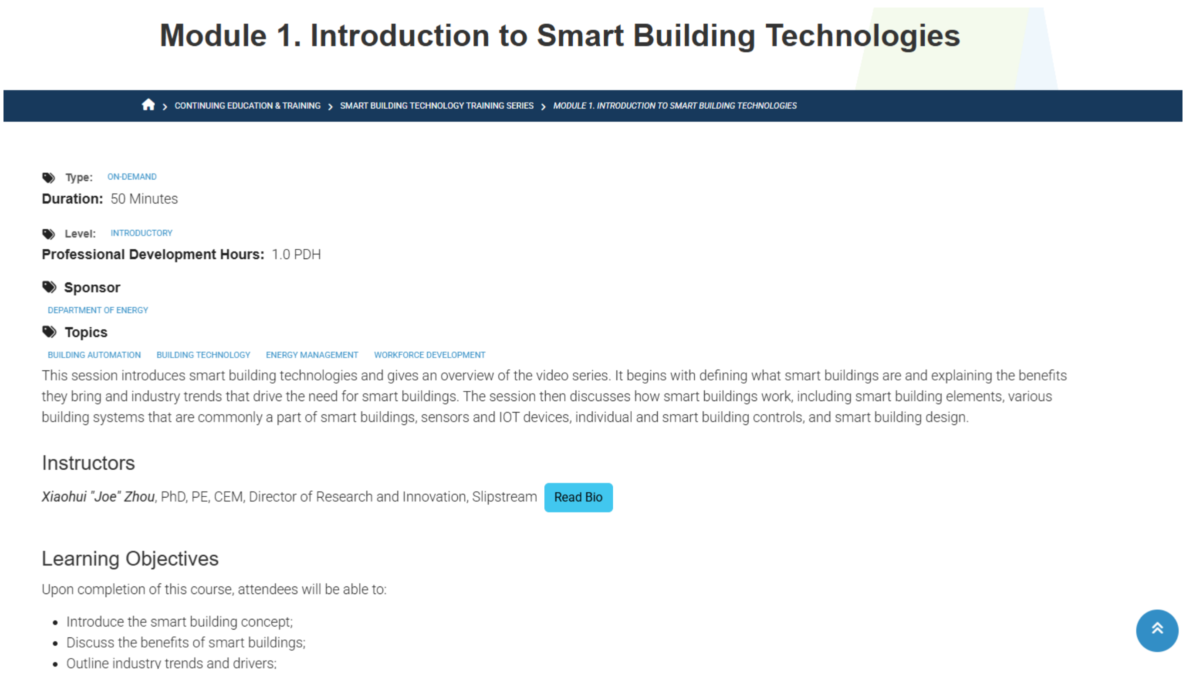

Figure 4. Smart Building Technology Training – Front Page

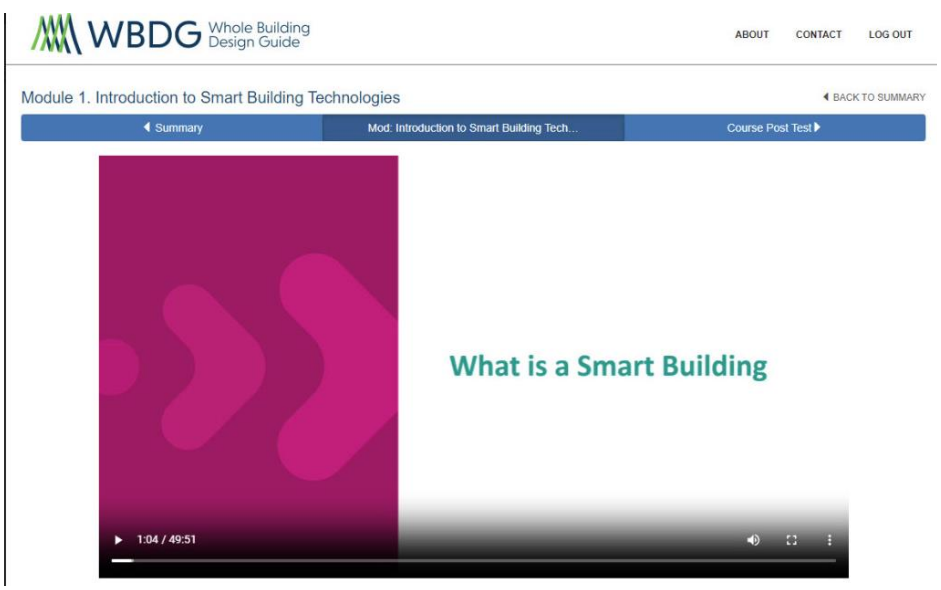

Figure 5. Smart Building Technology Training - Video

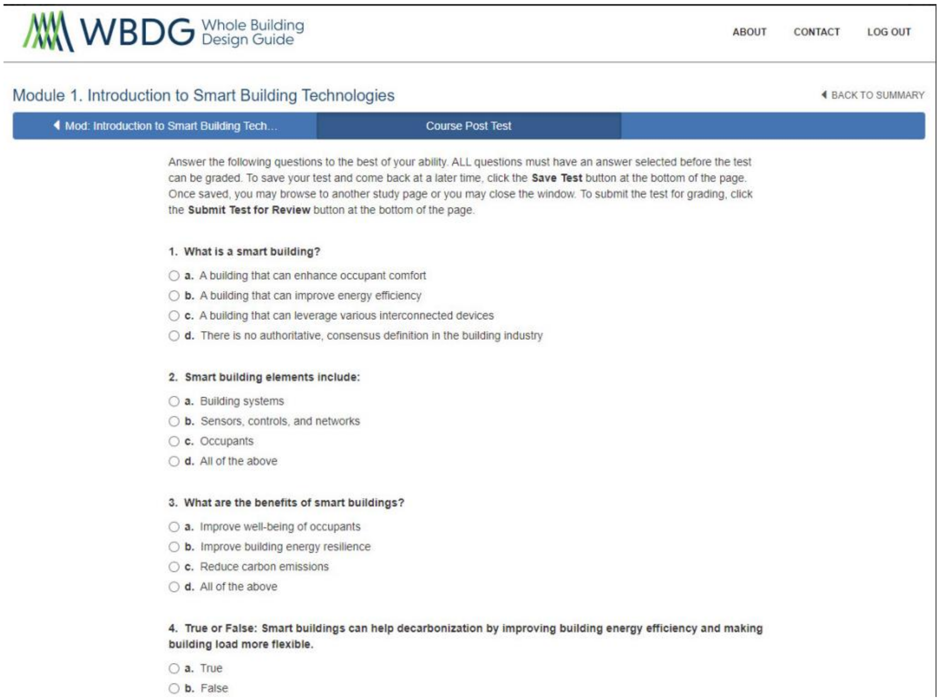

Figure 6. Smart Building Technology Training - Quiz

Task 4.1 Validation for the Curriculum

One of the validation activities for the curriculum content developed for college students was teaching a smart building technology course at TAMU in the Spring of 2024. TAMU validated the materials to ensure that students achieved the intended knowledge and skills outlined in the course learning outcomes that anchored the curriculum design.

Another validation activity was the comprehensive review of the curriculum content by SBSE members and other interested faculties. The project team member from SBSE solicited a call to their members from different fields for peer evaluation and potential adoption of course modules. The selected reviewers then participated in an initial orientation session where the expectations and outcomes for the review process were presented to the assessment team. Reviewers then individually developed and reported their adoption classification for the respective courses in their discipline. The returned score sheets were then anonymized and assembled into master sheets for further analysis. The resulting scores were averaged and mapped against slide numbers that could then be used for a visual representation of applicability and criticality. An overlay of these representations across the A/E/C disciplines was also generated and evaluated for further discussion.

TAMU Validation

The purpose of the academic course validation at TAMU was to assess the effectiveness and relevance of the Smart Building Technologies course within the architectural engineering program at TAMU. A comprehensive overview of the course’s development, alignment with institutional goals, and compliance with accreditation standards was evaluated, along with the instructional methods and materials used. The findings and recommendations from the validation process ensure the course is aligned with industry needs and provides students with a relevant and high-quality learning experience in the rapidly growing field of smart building technologies.

Verification Criteria

The course on smart building technologies was taught at TAMU in the Spring of 2024 to validate the training content developed. Course materials were evaluated to ensure students achieved the intended learning outcomes. The verification process centered on the effectiveness of the course materials in meeting the specific competencies and knowledge required. The curriculum was designed with clear learning outcomes, and the verification process evaluated whether students met these outcomes, including what they should know and be able to do because of participating in the course.

Academic Standards

The course adhered to the institution’s standards, including TAMU's mission, College of Engineering goals, and the program’s educational objectives (PEOs). These were mapped to ensure that the course aligned with broader academic and institutional goals, emphasizing technical competency, professional skills, and development. Additionally, the course was reviewed to ensure alignment with the accreditation standards of the Accreditation Board for

Engineering and Technology (ABET), particularly Criterion 3 on Student Outcomes (SO's). The outcomes include key competencies like problem-solving, design application, effective communication, ethical responsibility, teamwork, experimental skills, and lifelong learning. The verification process included mapping the course learning outcomes to relevant ABET student outcomes, to ensure the content prepares students for professional practice and aligns with the expected competencies in the field.

Industry Relevance

Through industry engagement, the course was developed with input from key stakeholders, including the program's Industry Advisory Council (IAC), ASCE-AEI's Academic Council, and ASHRAE members to incorporate industry standards and practices. Real-world applications were suggested by building industry experts, and case studies were integrated into the course to ensure that the theory taught in class is aligned with field work and application installation of smart building technologies.

Stakeholder Involvement

Throughout the development and validation period, academic faculty were actively involved in reviewing the course design. Evidence of student learning was collected, including pre- and post-course knowledge assessments, and was used to verify if the learning outcomes were met. Faculty collaborated with industry professionals to ensure the curriculum aligned with the latest industry trends and standards in smart building technologies. Finally, students provided feedback via surveys, highlighting their understanding of integrated building systems and their appreciation for the course structure. Feedback suggested that students wanted more opportunities to engage with smart buildings and technologies, an idea that aligns with the ICAP (Interactive Constructive Active Passive) Framework, which advocates for increasing interactive and constructive learning opportunities.

Documentation Reviewed

The course syllabus was reviewed and included as part of the documentation, with key components that align with the learning outcomes and structure. The syllabus included a detailed course schedule, topics, and subtopics for a 15-week semester. Examples of assessment materials, such as homework, quizzes, and the final project, were reviewed for alignment with the course objectives. These assessments were designed to measure both formative and summative learning outcomes. Although no textbook was available for the first course offering, various online resources, case studies, and supplemental materials were provided. These resources helped support student learning and contributed to the course's overall effectiveness. This comprehensive course verification process ensures that the course is academically rigorous, industry-relevant, and continuously improving based on stakeholder input.

Course Alignment with Institutional Goals

The course was created to align with TAMU's mission of fostering knowledge discovery, creativity, and application, common to most institutions of higher learning. It emphasizes preparing students for leadership roles in building design, construction and operation of sustainable, efficient and high-performing buildings. With a global awareness of smart building solutions, students are prepared to contribute responsibly to society. The focus of the course and its content meets the Program Educational Objectives (PEOs) and the course directly supports the PEOs of the architectural engineering program by preparing students for active engagement in architectural engineering practice or graduate studies, ensuring technical competence and eligibility for professional licensure, and by promoting continuous education and professional development.

Validation of Compliance with Accreditation Standards

The course adheres to the ABET Engineering Accreditation Commission (EAC) criteria, particularly Criterion 3 on Student Outcomes (SOs). The course outcomes align with ABET's standards, preparing graduates to enter professional practice in engineering, and support ABET's seven SOs—problem-solving, engineering design, communication, ethics, teamwork, experimentation, and lifelong learning. It integrates content and assessments that map to these competencies. In addition, the course complies with ABET's engineering curriculum requirements, addressing key aspects like building systems, construction management, real-world applications, and sustainability. It meets the synthesis and application levels in architectural engineering, reinforcing fundamental topics like mathematics, engineering design, and modern tools.

Quality of Learning Materials

The course materials on the Canvas platform are accessible to all learners, including those needing extra time for engagement. The materials are relevant for the study of building systems and align with course objectives, program outcomes, and current industry standards. Plans are in place to enhance the accessibility of materials in future offerings, including content difficulty levels and discipline-specific indicators through input from SBSE. Future offers will solicit feedback from students with disabilities to gather additional data points to ensure the course materials meet the broadest audience and are fully accessible.

Evaluation of Instructional Methods

Students had positive feedback when asked about the organization of the six content modules, to facilitate learning. Faculty in programs at other universities were asked if they found the modules adaptable for integrating smart building topics into their own courses. The limited feedback suggests the course's modular design will allow for ease of adoption and flexibility for updates for existing courses and in response to evolving smart building technologies and methodologies. Feedback suggests a live, active, collaborative classroom experience would enhance delivery and learning, given the complexity and novelty of the material. Shorter, more frequent quizzes to improve engagement and assess incremental learning, hands-on exercises, such as real-world building analysis, and interactive tools like Menti for class voting were recommended as well as reducing repetition in PowerPoint presentations.

Feedback from Stakeholders

Feedback from the stakeholders noted the high-level, theoretical approach was appropriate for a senior-level class. Students felt the course was beneficial for their future careers, particularly for industry-related decision-making and capstone design projects. Suggested areas for improvement included reducing repetition in the material to maintain engagement while retaining the benefits of circular learning, adding more interactive exercises and exposure to software tools like Sketchbox in future versions, and the feedback highlighted both strengths and areas of the course where instructors could evolve future offerings for greater engagement and relevance.

Recommended Enhancements to Course Content

A focus group and class climate survey provided valuable data, which will guide future updates. With a 21% response rate from architectural engineering students and a 16% response rate from other engineering students in the course, the verification and validation process allowed for meaningful analysis. The course materials were refined through multiple rounds of internal and external reviews, ensuring relevance and alignment with educational objectives. This iterative process, along with the collaborations with multidisciplinary faculty, provided valuable input across disciplines that enhanced the course structure, ensuring it met educational goals and reflected diverse perspectives in the first, pilot course delivery.

Suggestions for Teaching Methods

Although most of the feedback on current methods employed in the course delivery was positive, and the students appreciated the course materials, assessments, and faculty contributions, there were some meaningful suggestions for future improvements. Further enhancements to follow the ICAP Framework can include the development of active-collaborative teaching and learning practices. For example, more in-class exercises for students to engage with, and to have direct contact with course materials could provide opportunities for students to engage in increased in-class discussions. These strategies can lead to more interactions between faculty and students while allowing students to provide their thoughts, reflections, and ideas to deepen learning. Students did state that the course has value and is relevant to the very industry in which they aspire to practice.

Future Improvements in Assessment Strategies

Given more time, a longitudinal assessment study, using frameworks like the Teaching Dimensions Observation Protocol (TDOP), can be employed to assess the course's impact across multiple offerings. Additionally, a focus group from the program's Advisory Council, faculty, and industry experts can have an ongoing periodic review of the course materials to provide valuable input, to help ensure the curriculum continues to meet academic and industry standards.

Additional Resources Needed

Show-and-Tell Component: Students expressed interest in a demonstration-based component. An ASHRAE grant-in-aid could fund equipment for tabletop displays and other demonstrations of smart building technologies for opportunities to conduct mini-experiments in class or at a building site. Given the rising importance of security in smart building technologies, students recommend including cybersecurity in future offerings. This might pose an excellent chance for multidisciplinary collaborations with faculty who teach in areas of security, intelligence, and electronics.

Course Offering Frequency

The student feedback suggests the course should be offered annually, either with the current areas of emphasis or with additional ones, such as a segment on cyber security. Efforts are underway to co-list the course, making it available to students across different disciplines. For the course to be taught for the first time, a special topics course number was used. The students and faculty suggested and are currently working on developing and getting approval to have a unique course number. This will ensure recognition in academic catalogs and proper allocation of funding for the continued offering of the course for future semesters. These recommendations reflect a forward-thinking approach to course development, ensuring sustainability, student engagement, and alignment with industry standards.

Summary of Key Findings

The purpose of the validation report is to ensure the course successfully met its intended student outcome requirements. Feedback through three distinct "feedback clouds" (start, middle, and end of the course) confirmed that students gained a strong understanding of smart building technologies. Students provided valuable feedback, with positive responses on the course's content and delivery. Real-time adjustments by the instructor enhanced the learning experience.

The course met its objectives within the engineering disciplines it serves—particularly civil, architectural, and mechanical engineering and is well aligned with the university's mission and that of the accrediting body and program. In conclusion, the course successfully achieved its goal of preparing students for industry-relevant careers, particularly in smart building technologies.

Academic Course Viability

Key areas of the course's particular strengths and areas for future development include the instructor's observed passion and enthusiasm for the subject matter. These qualities have significantly contributed to student engagement and overall course experience.

The primary instructor is a subject matter expert (SME) and serves as the Principal Investigator (PI) of the course design. She was able to ensure alignment with academic and industry goals. The course will continue to be offered again in Spring 2025, addressing curricular needs in the architectural and mechanical engineering programs. The course content includes contemporary subjects and remains aligned with evolving industry needs, ensuring its continued relevance.

In conclusion, the course has proven to be effective, engaging, and aligned with academic and industry standards. It is well-positioned to continue preparing students for careers in the dynamic field of smart building technologies.

SBSE Validation

SBSE developed a report that collectively presents the results from an adaptability and validation review of course content developed by TAMU for their Architectural Engineering program. This review led to a classification of criticality and/or depth of the respective content for each of the developed modules in each of the domains, which was conducted through an inter-rater reliability process by faculty members of SBSE.

The report found that many of the developed modules have broad applicability across the different disciplines, although they will need rework for different pedagogical approaches that are prevalent in different disciplines.

Module 1 – Fundamentals of Building Mechanical and Energy Systems

This module, which serves as developing the foundation of the course, received overwhelming applicability scores across all disciplines as shown in Figure 7. The content was considered mostly critical (95% in ENG, 76% in ARCH, and 68% in CNST) or at least highly relevant and thus to be included in respected courses to be taught in A/E/C programs. It is noteworthy that none of the content was considered non-relevant for any of the domains.

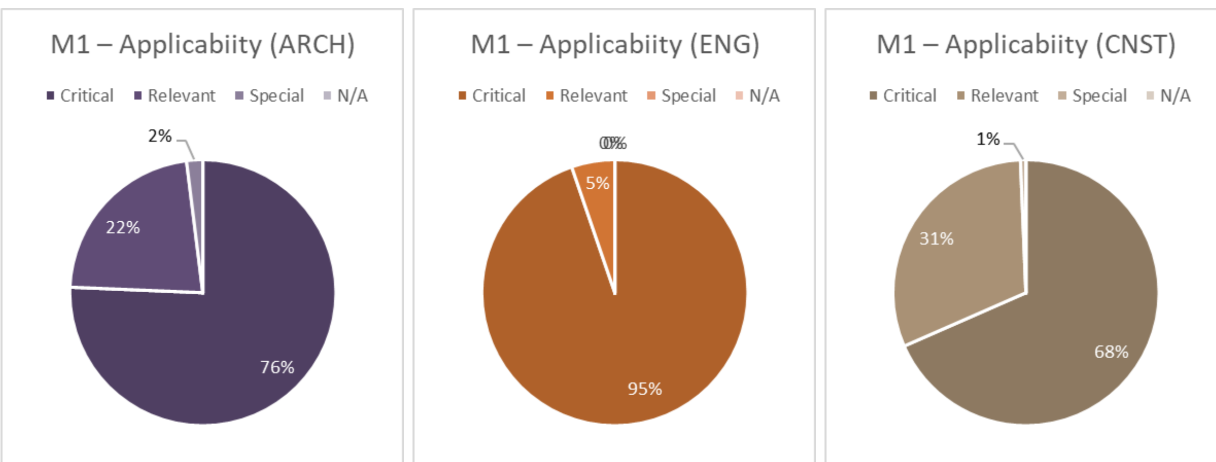

Figure 7. Example Result of the Distribution of Applicability Scorer for Module 1

Module 2 – Smart Building Codes and Standards

In this module, an overview is provided across all relevant regulatory texts. While the first half of this module was deemed mostly critical for all disciplines, the latter half was deemed as just somewhat relevant or applicable for advanced courses only in the architecture and construction domains. Still, none of the content was considered non-relevant for any of the domains.

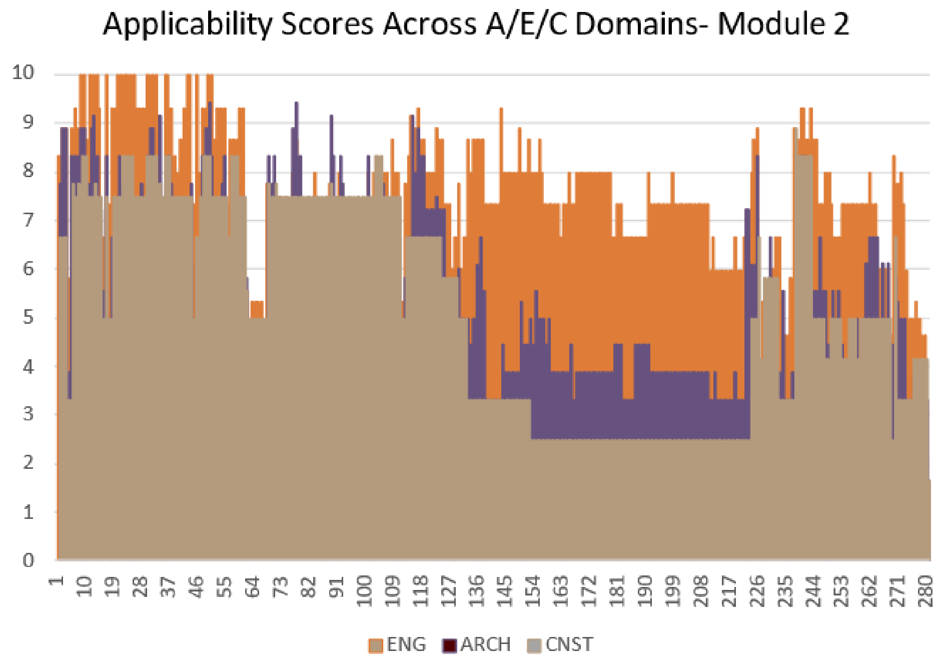

Figure 8. Example of a Visual Representation of Applicability Scores for Module 2

Module 3 – Fundamentals of Smart Building Technologies

This module covered detailed technical aspects of smart buildings and, therefore, was the first to see a portion of the content as not applicable broadly anymore for other disciplines. Only around 20-25% of the slides were considered to be critical for the architecture and construction disciplines, and about half of the content was considered still relevant for typical curricula on the topic of Smart Buildings. For the broader engineering fields, this score was still above the 80% mark, with the remainder being considered advanced knowledge and with none of the content as non-relevant.

Module 4 – Building Direct Digital Control (DDC)

Module 4 gets in-depth into engineering solutions for controls and building automation systems and was therefore mostly considered as only relevant for engineering programs. Thematically, architecture programs could use the content in a very advanced course, but overall, not more than 18% of this module seemed relevant to the respective domain reviewers. In construction, the adaptability scores were even lower, where reviewers considered 61% as not applicable and the rest possibly only in an advanced course oriented for facility management.

Module 5 – Applications of Engineering Tools and Standards

In this module, an overview is provided of the Building Commissioning processes and practices. Even for engineering curricula, only 4% were considered as critical core knowledge to be covered by other engineering faculty. However, the overall content still seemed quite relevant to them, and only 12% was considered as advanced-level content reserved for specialty courses.

Interestingly enough, the architecture discipline reviewers considered 2% of this content as critical and another 14% as highly relevant content. Still, close to half of the content (48%) was considered non-relevant at all.

The reviewer for the construction discipline came to a similar conclusion, though considering none of the content as critical, and only 4% as quite relevant to be included and introduced to construction students. Furthermore, 46% of the content was considered only applicable to be considered for inclusion in advanced courses, while the rest (50%) was deemed as non-relevant for construction students.

Module 6 – Smart Single-Building Case Studies

In this last module, several case studies are presented, which resonated well with the reviewers. While not all of them were deemed applicable for each domain, the majority of them were actually listed at least as relevant. Interestingly, the first six case studies (slides #1-25) were considered critical content by architecture and construction faculty, which was an even higher score than seen with engineering reviewers, who classified those as relevant but not critical. Case Study 7 (#49-60) had the lowest scores and was only considered relevant for engineering students. Case Study 8 (#61-74) was scored as critical for engineering students and highly relevant for construction students. Architecture faculty would consider this case study only in advanced settings. The remaining sections were considered equally as mostly relevant across all disciplines.

Conclusions

While the fundamentals module (M1) was universally considered critical, later modules naturally dropped in their applicability rating. Codes and Standards were perceived as still critical in Module 2 for all disciplines, but the coverage can be significantly cut for introductory courses in the architecture and construction domains. The highly technical equipment described in Module 3 can be reduced into smaller sets for all disciplines if introduced as parts of another course. This holds equally true for engineering, architecture, and construction programs, though to a much lesser extent for the latter. Module 4, covering building control strategies had the least cross-disciplinary application for adoption, where most of the architecture and construction faculty would not implement most of the content in any form in their curricula. Similarly, Module 5, which goes into building commissioning, is mostly deemed engineering content even though the introductory chapters were considered highly applicable for architecture and construction students. Lastly, Module 6, representing various case studies, received significant praise for applicability across disciplines but will require significant work in redesigning to make the content palatable for students in architecture or construction programs.

Overall, this inter-rater reliability analysis allowed the SBSE team to break up the original content into smaller packages and prepare subsets of content for the various disciplines that are now offered as scaled versions for faculty across different disciplines. The goal of this dissemination is to increase further adoption and domain-specific refinement of content, and the hope is that this content will be shared back with the broader education community through the SBSE network.

Task 4.2 Validation for the Technical Videos

Process

As described in Task 3 Curriculum Conversion to Technical Videos, Slipstream led the development of the 16 videos with assistance from industry experts. The final step in the development process involved validating the content for technical correctness and effectiveness.

The project team recruited smart building industry experts in the technical topic areas to preview the video series (online videos, presentation slides, quizzes, and answers) and provide comments and feedback for further improvement. The intent was to make sure our training content was without major technical errors or major omissions. Since the preview version of these videos had not gone through our detailed editing process, we were not looking for minor non-technical issues such as typos or formatting issues, mispronunciation, or repeated sentences. Each expert was asked to review no more than two different videos.

A full list of industry experts who agreed to preview our videos is provided in Table 4.

Table 4. List of Industry Experts for the Video Preview

Name	**Organization**
Eliot Crowe	LBNL
JoeDon Breda	TRC
Jesse Dean	Edo
John House	Independent Consultant
Lina Kohandoust	National Grid
Clay Nesler	The Nesler Group
Melanie Danuser	Smart Buildings Center
Ron Bernstein	RBCG Consulting
Jan Drgona	PNNL
Rebecca Sheppard	Smart Buildings Center
Melissa Sokolowsky	Smart Buildings Center
Dan Cautley	Independent Consultant
Julia Day	Washington State University, Integrated Design + Construction Laboratory
Rafat Elsharef	Milwaukee Area Technical College
Steve Selkowitz	Independent Consultant
Adam MacKenzie	Veil
Ben MacKenzie	Veil

A representative from Nexus Labs, Newcomb & Boyd, Fraunhofer, ComEd, and a few others either didn't respond to our requests for review or responded that they were unable to help with the review.

The final step in the validation process involved a Slipstream engineer reviewing several of the videos to ensure there were no major issues before posting them to the WBDG website.

Findings

Comments and feedback from the industry experts who previewed the videos were generally very positive. Some of the general comments are shown below:

- Video #1: "Overall, this was a solid introductory course that flowed well and covered key concepts. The test was a good knowledge check as well."

- Video #3: "Voice and language are easy to understand. I like that a lot of graphics and little text were used. The subject matter naturally includes a lot of acronyms. There is no way around that. For a student new to the content, it may be helpful to add a glossary slide at the end."

- Video #4: "The topic was effectively presented with a good mix of 1. introductory material to familiarize the audience with LED technology, and 2. an appropriate level of detail for NLC and HVAC integration, to convey the varying levels of complexity that can be undertaken when looking at smart lighting technologies." "I want to preface by saying that the content is very thorough and useful. I've highlighted some picky details to consider addressing, some from a content standpoint and some from a viewer experience standpoint."

- Video #5: "The course was well balanced and provided excellent content to familiarize the viewer with important GEB considerations."
-
- Video #6: "Overall, this is a good overview of a broad and complex set of topics that should be of increasing importance to all buildings in the future and thus to architects/engineers/designers/owners as well as suppliers, builders, building operators, etc."

- Video #10: "I think it is very well done and covers the topics in enough detail to provide value when combined with the other prior videos."

- Video #11: "A Well-done work, I would recommend creating hands-on labs related to smart building cyber security to support the discussion in these slides."

- Video #12: "Great job on this session, I didn't have many notes or recommended changes as I thought the content was really good."

- Video #13: "Great job! The subject is relevant and interesting. The flow of the lesson is well thought through. The learner is gradually introduced to the subject matter, and the lesson is easy to follow along. The different case studies deliver important data and are show-casing different relatable, real-world scenarios."

- Video #14: "My overall comment is that there isn't enough focus on actual control applications (sequences) throughout the course. There is only one simple example of a DR event with a rooftop unit. The optimal control of DERs and HVAC systems under various scenarios is complex and not treated in this course. There is too much emphasis on connected community case studies and high-level detail of targeted DERs, instead of control architectures and applications."

- Video #15: "Key concepts covered thoroughly. The course flowed fine from topic to topic. I also know my role is significantly focused on energy efficiency, but as I noted above might be good to talk a bit more about equipment right sizing benefits and efficiency ethic. I understand that is not the focus of this session though, so feel free to disregard that feedback if it doesn't fit into the overall purpose of the course."

- Video #16: "Nice job on this last video." "The review of the previous videos seems long and could be significantly reduced." "I would certainly recommend this video to those interested in advanced smart building control applications."

These reviewers also provide detailed comments, feedback, and suggested changes to the presentation slides, which are summarized in the following categories:

- <u>Audio quality issues:</u> Even though we mentioned to the reviewers that these videos were unedited, some of them still pointed out issues such as recording background noise, etc.

- <u>A desired new feature in the videos:</u> One reviewer suggested an improvement in navigating the video "It would be helpful to have a back arrow to previous slide or possibly a 15 sec Rewind or Fast Forward option built into the video."

- <u>Subtitles/captions:</u> One reviewer mentioned the subtitles need lots of editing because the voice recognition wasn't very reliable. Another reviewer pointed out that when captions are on, the audience cannot see the graphics or read the words on many of the slides.

- <u>Misspellings and grammatical errors:</u> Some reviewers pointed out the misspellings and grammatical errors in presentation slides, and suggested corrections.

- <u>Quiz questions and answers:</u> Some reviewers also reviewed the 10 quiz questions and answers at the end of the videos and indicated that some questions and answers may be confusing to the target audience. They provided suggested changes.

- Company names mentioned: A couple of reviews mentioned that presentation slides contained some manufacturers' names or their products' photos. Some questioned how we chose to include certain manufacturers. They were not sure about the commercialism policy for this training video series.

- Technical content: Most of the reviewers' comments, feedback, and suggested changes were technical in nature, and in the areas of 1) definitions, terms, and acronyms used; 2) references and labels on claims or graphics cited; 3) missed technical discussion related to the topics of the videos; 4) inconsistencies between texts and graphics; 5) technical correctness in some of the slides; 6) more effective presentation through alternative ways of arranging text and graphics on certain slides.

Overall, the findings from industry experts were very helpful for our project team in improving the final version of the videos' audio, visual, and technical qualities.

Results

The findings from the industry experts were shared with the presenters of the videos. The presenters were asked to review these comments, feedback, and suggested changes, and incorporate as much as they thought appropriate into the final version of the videos/ slides. Specific actions included:

- Audio quality issues. All the updated videos went through a video review and editing process by Slipstream's video strategist and a professional video editing subcontractor. The audio quality issues were fixed during the process.

- A desired new feature in the videos: This desired new feature is not part of the features available on the National Institute of Building Sciences (NIBS) learning management system that hosts these videos.

- Subtitles/captions: After consulting with DOE, subtitles were not a requirement in these videos, so we decided not to use subtitles/captions in the final version of the videos to avoid technical incorrectness in the subtitles/captions. However, most video players have auto-generated closed captioning that can be turned on when viewing the videos.

- Misspellings and grammatical errors: Presenters fixed these errors in the final version of the videos.

- Quiz questions and answers: Most of the quiz questions and answers were fixed in the final version of the videos. Presenters thought some of the quiz questions were appropriate and didn't need revisions.

- Company names mentioned: DOE does not have a commercialism-free policy on the training content for this project. Since our target audience is building professionals, smart building software developers, and the general public, we felt that in limited cases, mentioning the manufacturer names or showing their product information helped to provide useful information to our target audience. In those situations, we emphasized in the video the purpose was to provide technical information useful to the viewers, and not to promote these manufacturers or manufacturers' products. At the end of each video, we also included the disclaimer that views expressed in the videos are the speakers and don't represent views from DOE.

- Technical content: Presenters did their best to incorporate the technical comments and suggested changes to the final version of the videos. We estimated that over 70% of the suggested changes were accepted, and content revised. In some cases, slides were also re-recorded.

After all the videos were finalized, a Slipstream engineer was asked to spot-check (watch four of the 16 videos) to identify any major issues with video and audio quality and technical content. Only a couple of very few minor issues were found and our video editing team fixed them quickly. Comments were addressed and final videos were posted to the WBDG website.

Task 5 Information Dissemination

Once all the training materials were finalized, our team conducted outreach and marketing to disseminate these materials to our target audiences: professors teaching advanced building and energy technologies and building and energy professionals. SBSE works with professors of hundreds of university courses and can reach thousands of educators with technical resources and innovative curriculum elements. All adopted course modules and elements will be published with instructor notes and initial course feedback through the SBSE resources portal. Slipstream's education and marketing team and NIBS helped disseminate the information through an email campaign, websites, and social media to our clients who are building professionals. Papers were also shared at several conferences to introduce our project to a wide audience and exchange lessons learned with peers. Example activities include:

- Slipstream's PI published a conference paper and presented a poster at the ACEEE Summer Study on Energy Efficiency in Buildings on August 6 in Asilomar, CA.
- A conference paper was submitted to the Energy in Buildings 2024 Conference on November 22-23 in Greece.
- A Slipstream website was created, which includes the flyer and promo video for this project. (https://slipstreaminc.org/education/smart-building-technology).
- Slipstream also created social media and blog posts, along with an eblast. The eblast was included in Slipstream's January 2025 newsletter, which goes to 2,000 subscribers.
- Slipstream's PI sent an email to our external partners for this project to help spread the word.
- The team also plans to get the word out at various conferences even after the grant period is over. A few examples are presenting at the ASHRAE 2025 Winter Conference in Orlando, FL, and AEI conferences in 2025.
- Slipstream sent numerous emails to our external connections, including:
    - Smart Buildings Center (now Building Potential) https://smartbuildingscenter.org/, https://buildingpotential.org/ will share our project content with regional partners for dissemination and provide any feedback on future video topics. Will post our sessions directly on their Remote Learning Library, in their blog and in BOC's newsletter.
    - CREATE will distribute to hundreds of community/technical colleges around the country that are in their network (will go out in February). https://createenergy.org/
    - Eblast was sent to the Wisconsin Association for Environmental Education (WAEE) to distribute the project information.
    - University of Wisconsin-Milwaukee and Assistant Director- U.S. DOE Industrial Training and Assessment Center said, "The training topics are very interesting and would be very helpful for our Building Training and Assessment Centers (BTAC) training."
    - The State University of New York (SUNY) will help get the word out (with energy managers at SUNY and in remarks at the NYAPPA conference in February.)
    - USGBC WI will include in upcoming eblasts to members
    - BEST Center will include it in the spring newsletter

Screenshots of some of these outreach and marketing efforts are shown below. The links to the websites, blogs, and social media are included in the "Product" section.

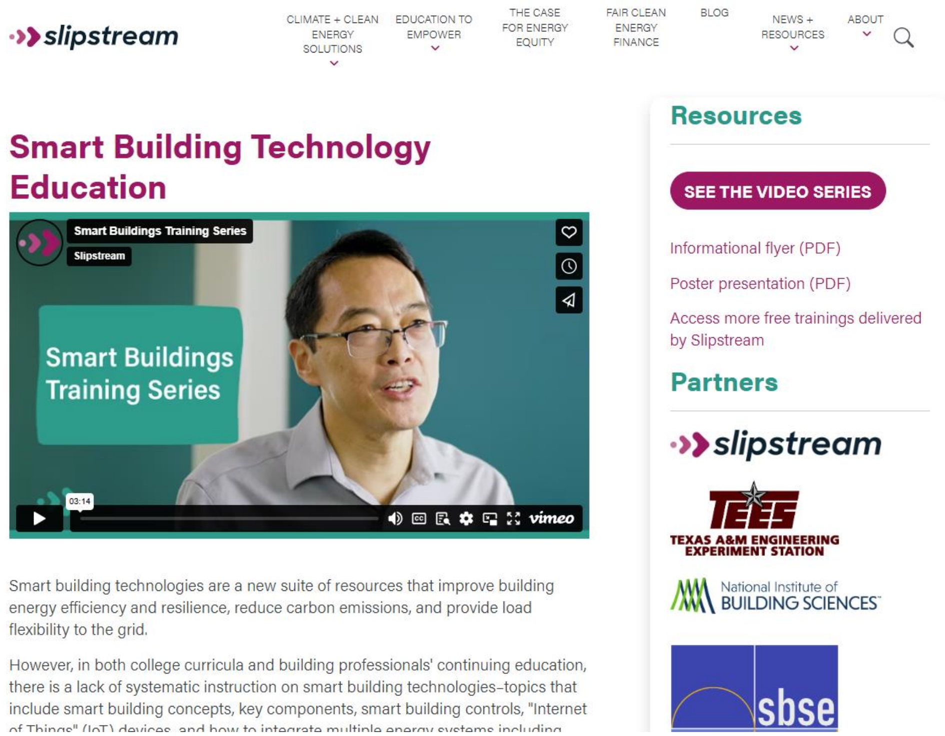

Figure 9. Slipstream Website Screenshot

SMART BUILDING TECHNOLOGY MODULES
for Academic and Professional Education

SUMMARY OF THE PROJECT

DEVELOP AND VALIDATE a set of module-based course materials ready to be adopted by college professors in smart building technologies.

GO HERE: https://www.sbse.org/courses/Smart-Building-Technologies

DEVELOP 16 online training videos suitable for building professionals' continuing education.

GO HERE: https://www.wbdg.org/ce/doe/bto/sbtt

DISSEMINATE project information and resource to target audiences.

- College professors
- Building professionals
- Smart building software developers
- General public

GO HERE: https://slipstreaminc.org/education/smart-building-technology

PROJECT PARTNERS

slipstream

TEES TEXAS A&M ENGINEERING EXPERIMENT STATION

sbse

National Institute of BUILDING SCIENCES

COURSE MODULES FOR COLLEGE EDUCATION

MODULE #	MODULE TITLE
0	Introduction of the Course
1	Fundamentals of Building Mechanical and Energy Systems, and Building Systems Integration
2	Smart Building Technologies Drivers and Trends
3	Fundamentals of Smart Building Technologies
4	Advances in Building Energy Management and Controls
5	Applications of Engineering Tools and Standards—Building Operation
6	Smart Building Technologies Case Studies for Design and Operation

ONLINE TRAINING VIDEOS FOR BUILDING PROFESSIONALS

TOPIC CATEGORY	SESSION #	TOPIC
Introduction	1	Introduction to Smart Building Technologies
Building Systems	2	Building HVAC—Basic Systems
	3	Building HVAC—Complex Systems
	4	Networked Lighting Controls and HVAC Integration
	5	Solar PV, BESS, and EV Charging
	6	Smart Window, Automated Shades, Phase Change Materials, and Plug Loads
Sensors and IOT Devices	7	Sensors
	8	IOT Devices and Example Building Applications
Smart Building Controls	9	Advanced Building Monitoring and Controls
	10	Smart Building Control Platform
	11	Smart Building Control Platform Cybersecurity
	12	Smart Building Control Methods
	13	Occupant-centric Control
Smart Building Applications	14	Grid-interactive Efficient Buildings and Connected Communities
	15	Review of Whole-building Simulation Programs
	16	Smart Building Application Examples

This work is funded by the U.S. Department of Energy under Award # DE-EE0009703. The project is led by Slipstream.

Figure 10. Slipstream Promotional Flyer Screenshot

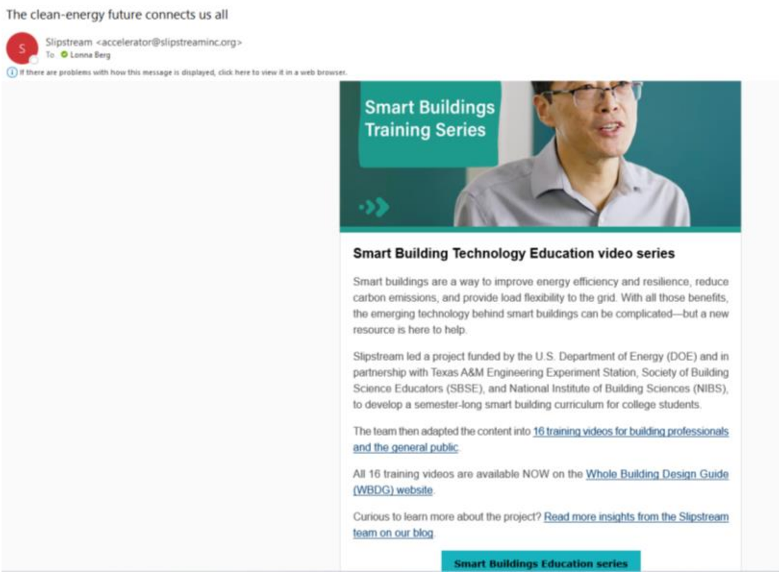

Figure 11. Slipstream Newsletter Screenshot

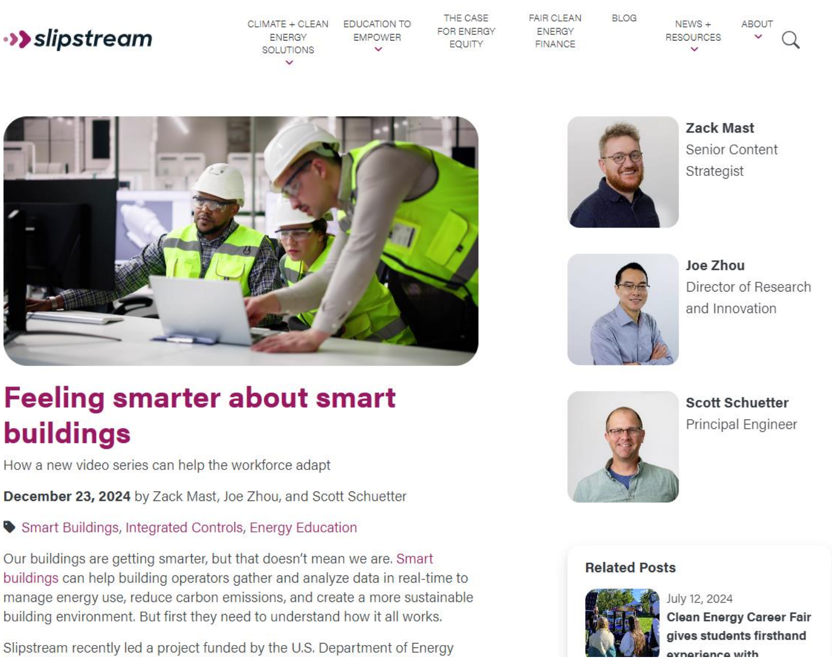

Figure 12. Slipstream Blog Screenshot

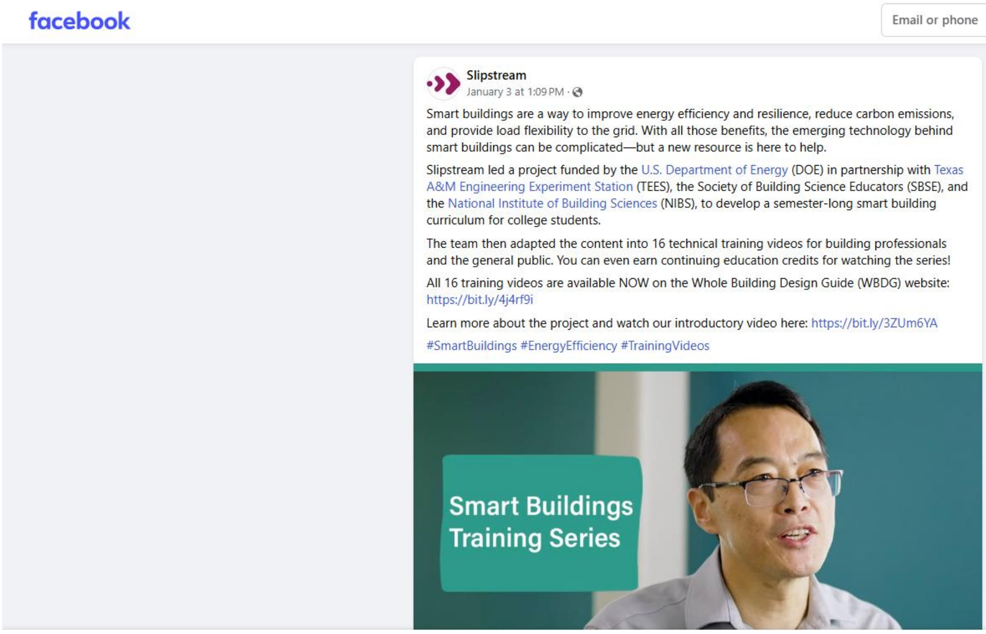

Figure 13. Slipstream Social Media Screenshot 1

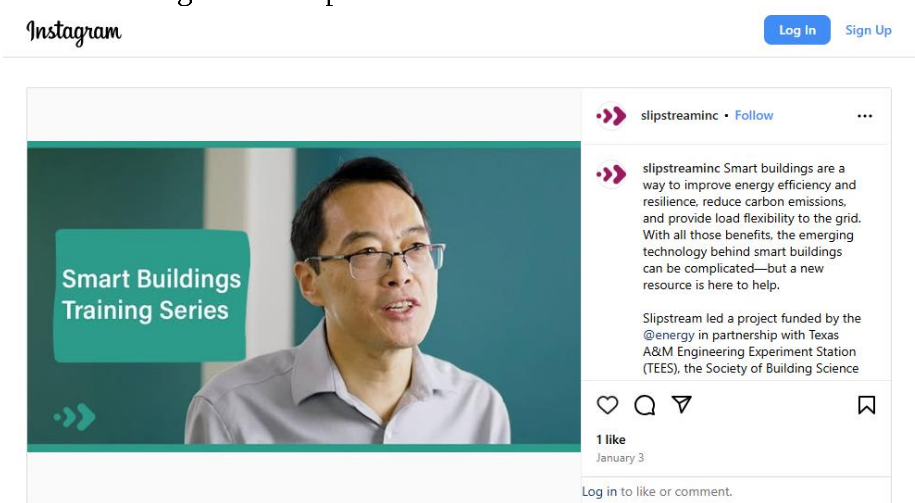

Figure 14. Slipstream Social Media Screenshot 2

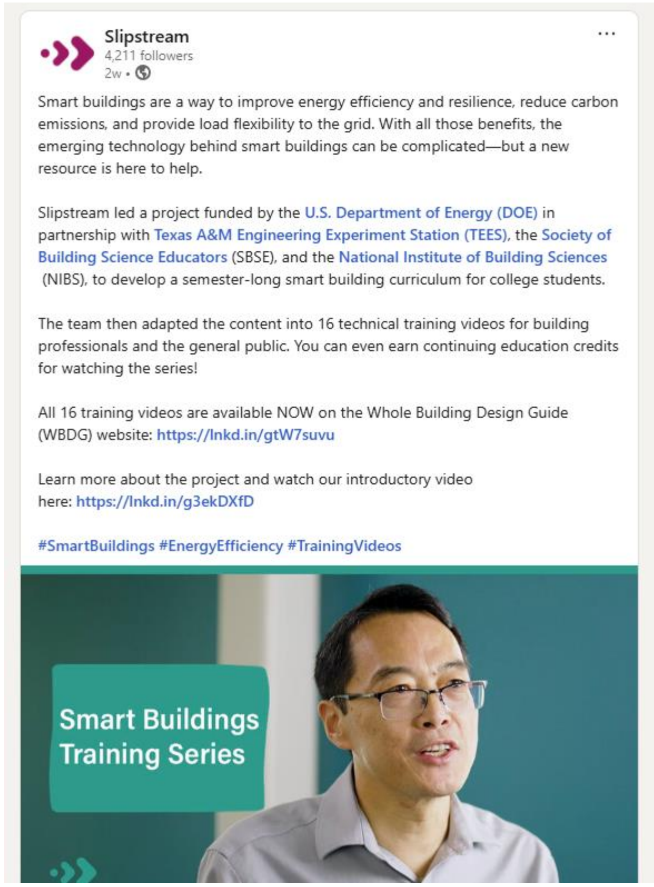

Figure 15. Slipstream Social Media Screenshot 3

Significant Accomplishments and Conclusions

The project team successfully created and validated training modules on smart building technology for academic and professional education. The products developed from this project are free resources that bridge a gap in the lack of systematic instruction on smart building technologies.

The best practices we followed in developing the training content were 1) involving project advisors early to review training outlines including topics covered; 2) going through multiple rounds of internal and external technical expert reviews, when possible, to minimize training content developer's personal bias or technical knowledge limitations; 3) developing modular content so academic program staff and building professionals can choose the content appropriate to their needs; and 4) collaborating with learning management system provider to structure the training course for effective online learning and testing.

Key lessons learned from this project are listed below.

- The content needed for academic programs is very different than that needed for building professional continuing education programs. Training content for academic education focuses on the theory of smart building technology and its fundamentals and capabilities while content for building professional continuing education focuses more on real-world smart building technology applications.

- It is important to offer training content in a modular format. A modular format allows both academic program staff and building professionals to choose specific smart building technology topics appropriate to their needs. An academic program does not necessarily have to adopt the whole course content nor does a building professional need to take the full course to get the Professional Development Hours they need. "Adoptability" could be improved by using a presentation template that indicates the levels of content difficulty or complexity and the disciplines to which the course is applicable.

- Request permission to use graphics and images used in the training content to comply with copyright laws.

- Inviting "project advisors" from academia and industry to review course outlines or training topics was invaluable in the planning stage.

- Multiple rounds of internal and external technical experts' "reviews" or "validations" kept our training content technically correct and unbiased.

This project focused on developing training content related to smart building technologies. Because the training covers a wide range of topics and technology areas, it was impossible to go into a lot of detail on many of the topics. In general, our training content provides introductory-level knowledge that covers the basics: theories, smart building technology components, building energy systems, and tools used, and gives simple examples. In the future, we expect more in-depth training will be developed on specific subtopics–especially for building professionals' continuing education. Because smart building technologies are evolving at a fast speed, building professionals will need to stay up-to-date on these changes.

Some improvements can be made for courses at the college level as well. The first course taught at TAMU did not provide much hands-on experience in a lab environment except for learning to use simple building energy simulation tools for smart building design. College students could benefit from field testing of equipment or more hands-on experience in future courses.

Finally, there are currently no industry-recognized certifications acknowledging professional competency in smart building technologies. The project team is in conversation with organizations such as Smart Buildings Center (https://smartbuildingscenter.org/), a project collaboration with Northwest Energy Efficiency Council, and the BEST Center (Building Efficiency for a Sustainable Tomorrow, https://bestctr.org/), which provides training for efficient building operations training, for potentially creating a future certification program for smart building technologies or adding content as part of the existing building operators certifications/training.

Products

- Websites:
  - https://www.wbdg.org/ce/doe/bto/sbtt
  - https://www.sbse.org/courses/Smart-Building-Technologies
  - https://slipstreaminc.org/education/smart-building-technology
- Blog:
  - https://slipstreaminc.org/blog/smart-buildings-education-series
- Social media:
  - https://www.facebook.com/share/p/1BR9h9Gp4E/
  - https://www.instagram.com/p/DEYKTTRp2kW/?utm_source=ig_web_copy_link&igsh=MzRlODBiNWFlZA==
  - https://www.linkedin.com/posts/slipstreaminc_smartbuildings-energyefficiency-trainingvideos-activity-7281044413001187328-B1nu?utm_source=share&utm_medium=member_desktop
- A promotional video: Smart Buildings Training Series on Vimeo
- A promotional flyer
- Conference papers:
  - 2024 ACEEE Summer Study
  - 2024 Energy in Buildings Conference
- A conference poster:
  - 2024 ACEEE Summer Study

Project Team and Roles

Slipstream, TAMU, SBSE, and NIBS worked together to develop and validate training modules on smart building technologies for academic and professional education. Slipstream is the Prime contractor for this project. TAMU, SBSE, and NIBS are subrecipients.

- Slipstream
  - Joe Zhou (PI), Lonna Berg (project manager)
  - Content developers/reviewers: Kevin Frost, Lee Shaver, Scott Schuetter, Robert Klein, Adrian Rivera, Ben Bartling
  - Admin (graphics, copyright, ADA, accounting, etc.): Rebecca Sadler, Heidi Holstad, Cherie Williams, Julie Bird, Sarah Lowery
  - Consultants (promo video, video editing): 2nd Delta, CineCism Media
  - Reviewers/ Validators (for 16 technical videos):
    - Eliot Crowe, LBNL
    - JoeDon Breda, TRC
    - Jesse Dean, Edo
    - John House, Independent Consultant
    - Lina Kohandoust, National Grid
    - Clay Nesler, The Nesler Group
    - Melanie Danuser, Smart Buildings Center
    - Ron Bernstein, RBCG Consulting
    - Jan Drgona, PNNL
    - Rebecca Sheppard, Smart Buildings Center
    - Melissa Sokolowsky, Smart Buildings Center
    - Dan Cautley, Independent Consultant
    - Julia Day, Washington State University, Integrated Design + Construction Laboratory
    - Rafat Elsharef, Milwaukee Area Technical College
    - Steve Selkowitz, Independent Consultant
    - Adam MacKenzie, Veil
    - Ben MacKenzie, Veil
- Texas A&M University
  - David Claridge (advisor)
  - Content developers: Filza Walters (content development, validation, outreach), Zheng O'Neill (content development, validation, outreach), Mingyue Guo (graduate assistant)
- SBSE
  - Georg Reichard and Ulrike Passe (academic advisory)
  - Georg Reichard (review design and adaptability analysis)
  - Reviewers/ Validators (curriculum content validation):
    - Philip Agee, Virginia Tech
    - Jonathan Bean, University of Arizona
    - Tom Collins, Ball State University
    - Julia Day, Washington State University

        - David Fannon, Northeastern University
        - Omar Al-Hassawi, Washington State University
        - Iason Konstantzos, University of Nebraska, Lincoln
        - Xiaoqi Liu, University of Nebraska, Lincoln
        - Ulrike Passe, Iowa State University
        - Hazem Rashed-Al, Kennesaw State University
        - Georg Reichard, Virginia Tech
        - Clarke Snell, New York Institute of Technology
- NIBS
    - Bob Payn and Brittany Kitchens (creating the WBDG site and posting content)

DOE personnel – Amy Falcon (project monitor), Amir Roth (technical manager)

References

- ASHRAE, 2018, Building Our New Energy Future, https://www.ashrae.org/file%20library/about/leadership/new_energy_future_web_061518.pdf
- BEST (Building Efficiency for a Sustainable Tomorrow). 2024. High-Performance Building Operations Professional Certification. High-Performance Building Operations Professionals (HPBOP) - BEST Center: Building Efficiency for a Sustainable Tomorrow (bestctr.org)
- ESTCP (Environmental Security Technology Certification Program). 2023. Advanced Controls Training. Advanced Building Controls | WBDG - Whole Building Design Guide
- IIT (Illinois Institute of Technology). 2024. Illinois Institute of Technology Certificate in Control Systems. https://bulletin.iit.edu/graduate/colleges/engineering/ece/control-systems-certificate/#programrequirementstext
- Johnson (Johnson Community College). 2024. Johnson Community College Controls Certificate. https://www.johnstoncc.edu/programs/construction/airconditioning-heating-refrigeration/certificate-controls.aspx
- NEEC (Northwest Energy Efficiency Council). 2024. Building Operator Certification Program. https://www.theboc.info/
- NWTC (Northeast Wisconsin Technical College). 2024. Northeast Wisconsin Technical College Control Systems Certificate. https://www.nwtc.edu/academics-and-training/control-systems
- SBC (Smart Buildings Center). 2024. Smart Buildings Center Education and Training. Education & Training - Smart Buildings Center
- UW Madison (University of Wisconsin Madison). 2024. Interdisciplinary Professional Programs on DDC Controls. https://interpro.wisc.edu/courses/ddc-controls/