Smart Building Technology Training Modules for Academic and Professional Education

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ABSTRACT

Smart building technologies are a new suite of resources that 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–topics that include smart building concepts, key components, smart building controls, "Internet of Things" (IoT) devices, and how to integrate multiple energy systems including distributed energy resources (DER). This major gap in smart building education prevents stakeholders from understanding and adopting smart building technologies in building design and operations.

Slipstream leads a DOE-funded project developing a semester-long smart building curriculum for college students and adapting the contents into 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.

This paper describes the project approach, provides outlines of the training materials, 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.

Introduction

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 (WBDG) website, 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. Only related training for building professionals on building operations and building controls are available (BEST 2024, ESTCP 2023, NEEC 2024, SBC 2024, UW Madison 2024.)

Slipstream, a mission-driven non-profit organization, is leading 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 modules for academic and professional education. For college education, we have 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 are being developed and recorded.

Approaches, Outlines, and Validations for Academic Education

For academic education primarily targeting students in civil, architectural, and mechanical engineering majors, TAMU's College of Engineering is the primary curriculum developer. TAMU offers an industry-driven and learner-centered undergraduate Bachelor of Science degree in Architectural Engineering (BS AREN). TAMU is committed to incorporating the course into the BS AREN program once it is developed. It will also make it available to students in mechanical engineering and other relevant engineering majors.

The first step for the curriculum development team was assembling a project advisory council, which consists of faculty members at other universities and colleges who teach related smart building courses, smart building technology researchers, and practitioners in the building industry. The advisory council provided general guidance, comments, and feedback to the team on the module structure, content, deliverables, and format. Our team incorporated their comments and feedback and created a curriculum outline based on the existing knowledge gaps in smart building technologies at the college level. The outline is listed in Table 1.

Table 1. Curriculum Modules Outlines for College Education

Module #	Module Title and Topics	Teaching Duration
	Introduction of the Course (First day of the class) - What is a smart building and what it can do? - One or two examples at the high level	30 minutes
1	**Fundamentals of Building Mechanical and Energy Systems, and Building System Integration** - Building heat transfer - Psychometrics, thermal comfort - Indoor air quality (IAQ), ventilation and other IEQ factors - Heating and cooling equipment	2 weeks

Module #	Module Title and Topics	Teaching Duration
	- Fenestration and lighting systems - Heating and cooling loads - Building energy calculation - Utility bill - Water system and water conservation - Occupant behaviors/User interface	
2	**Smart Building Technologies Drivers and Trends** 2.1. Codes and Standards - ASHRAE 90.1 - Overview of other ASHRAE codes and standards: o Commercial buildings: ASHRAE 90.1, 189.1, 62.1, AEDG o Residential buildings: ASHRAE 90.2, 62.2, IECC o ASHRAE Standard 55 o 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 o Whole building simulation programs: eQUEST, EnergyPlus, Ladybug, etc. - Review of basics of building energy modeling capability o Building envelopes o HVAC equipment and Systems (steady-state vs. dynamic modeling) - Overview of basic building automation and control systems o Building automation system (BAS) o Sensors, actuators, etc. o Introduction of smart building technologies examples	4 weeks
3	**Fundamentals of Smart Building Technologies** 3.1 Introduction of sensor and IoT devices - Occupancy sensors (presence vs. occupant counting) - IAQ and CO2 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	4 weeks

Module #	Module Title and Topics	Teaching Duration
	- Natural/mixed ventilation - Building thermal mass, and materials with tunable thermal properties 3.3 Applications of performance monitoring and building controls - Building performance monitoring - Automated Fault Detection and Diagnosis (FDD) - Automated system optimization (ASO) including optimal controls. - Add Energy Information System (EIS) as resources/tools and include other resources/tools from the industry. 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 modulating) - Modern grid with distributed energy resources (DER) - Building electrification	
4	**Advanced 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.) - Introduce the concept of optimizations in buildings	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/ 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	2 weeks

Module #	Module Title and Topics	Teaching Duration
	- Connected buildings on campus. - Smart and connected communities	

One of the project objectives for the curriculum development for college education is to ensure the materials developed are "modularized" and can be widely adopted by architectural or other engineering programs outside TAMU. Faculty from other colleges and universities do not have to adopt the entire course but rather can pick and choose the modules they would like to teach and customize. One of the team partners, the 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.

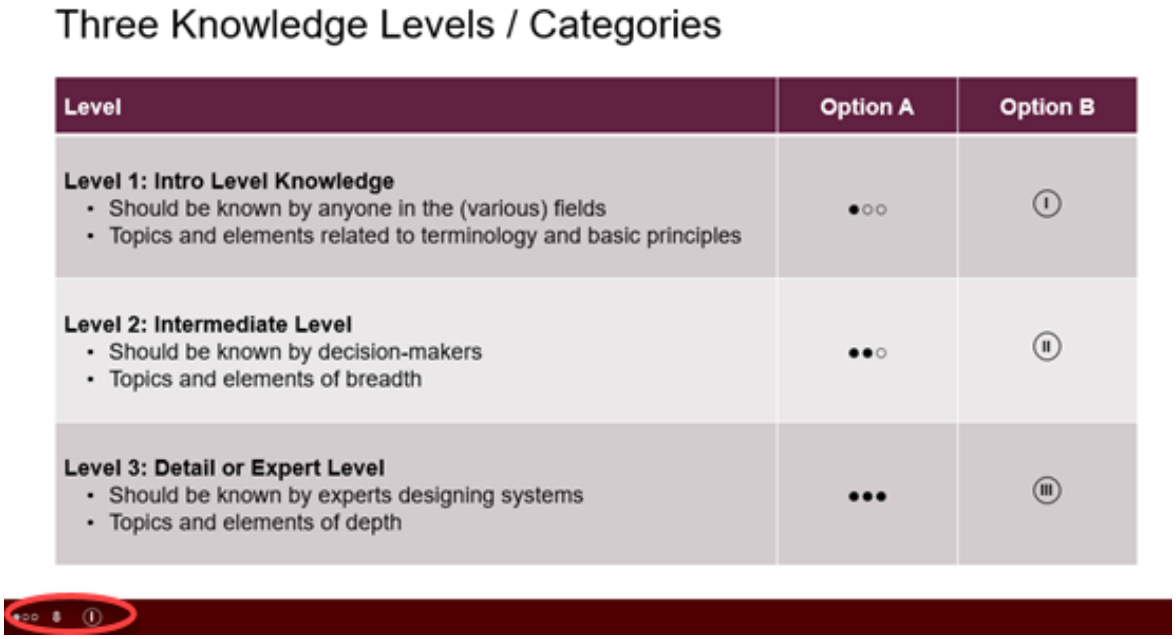

Figure 1. Presentation slide template for college education

One of the curriculum validation activities for the training content developed for college students was teaching a smart building technology course at Texas A&M University in the Spring of 2024. TAMU is validating the materials to ensure that students achieve the intended knowledge and skills outlined in the course learning outcomes anchoring curriculum design. Curriculum development follows a cycle of steps, beginning with the creation of course learning outcomes – measurable statements of what the learner will know, be able to do, or value resulting from participating in the course. Over 16 weeks of the validation period, evidence of student learning was collected based on pre and post-knowledge assessments. Currently, the team is reviewing the results to verify if the predetermined learning outcomes have been

achieved. Feedback from the students as well as the faculties at other universities will be used for future revisions of the teaching materials.

Another validation activity will be a comprehensive review of the training content by SBSE members and other interested faculties in Summer 2024. SBSE advisory council members, who are involved in the initial review of course materials, will solicit a call to their members from different fields for peer evaluation and potential adoption of course modules. The selected reviewers will participate in an initial orientation session where the review process's expectations and outcomes are presented to the SBSE team. Reviewers will then individually develop and report their adoption strategy for the respective courses they teach. SBSE plans to organize a panel session or workshop where review outcomes will be presented and discussed by the reviewers.

Approaches, Outlines, and Validations for Professional Continuing Education

For building professionals' continuing education on smart building technologies, our approach is to reuse some of the content developed for college education and add content that is relevant to building professionals and the general public based on Slipstream engineers' and researchers' practical knowledge on smart building system design, controls, integration, building energy modeling, and load flexibility (ASHRAE 2018.) Slipstream is leading the development of 16 training videos, each between 30 minutes to one hour in length. The videos are grouped into five categories: 1) Introduction; 2) Building systems; 3) Sensors and IoT devices; 4) Smart building controls; and 5) Smart building applications. The specific topics for each of the 16 videos are listed in Table 2.

Table 2. Topics in Smart Building Technology Training for Building Professionals

Session #	Topic Category	Topic
1	Introduction	Introduction to smart building technologies
2	Building Energy Systems	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, PCM, plug loads
7	Sensors and IoT Devices	Sensors
8		IoT devices
9	Smart Building Controls	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	Smart Building Applications	Grid-interactive Efficient Buildings and Connected Communities
15		Review of whole-building simulation programs

Session #	Topic Category	Topic
16		Smart building application examples

The project team will make video recordings of these presentations and create a professional continuing education course on smart building technologies on the Whole Building Design Guide (WBDG) website (https://www.wbdg.org/). The course will be available to the public for free access starting in the Fall of 2024. WBDG is an ongoing 20-year project under NIBS's direction and 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, as well as other building professionals for their continuing education. NIBS provides an online learning management platform and is a team partner for this project. To validate the effectiveness of the online training content for building professionals, the team will recruit smart building industry experts to preview the video series (online videos and presentation slides) and provide comments and feedback for future improvements. Either a half or one Professional Development Hour (PDH) certification will be provided for each video session for someone who takes the course and passes a course post-test consisting of ten multiple-choice or true/false questions related to the course content. Figure 2 to Figure 5 are screenshots of WBDG websites related to continuing education & training and this smart building technology training content for building professionals and the general public.

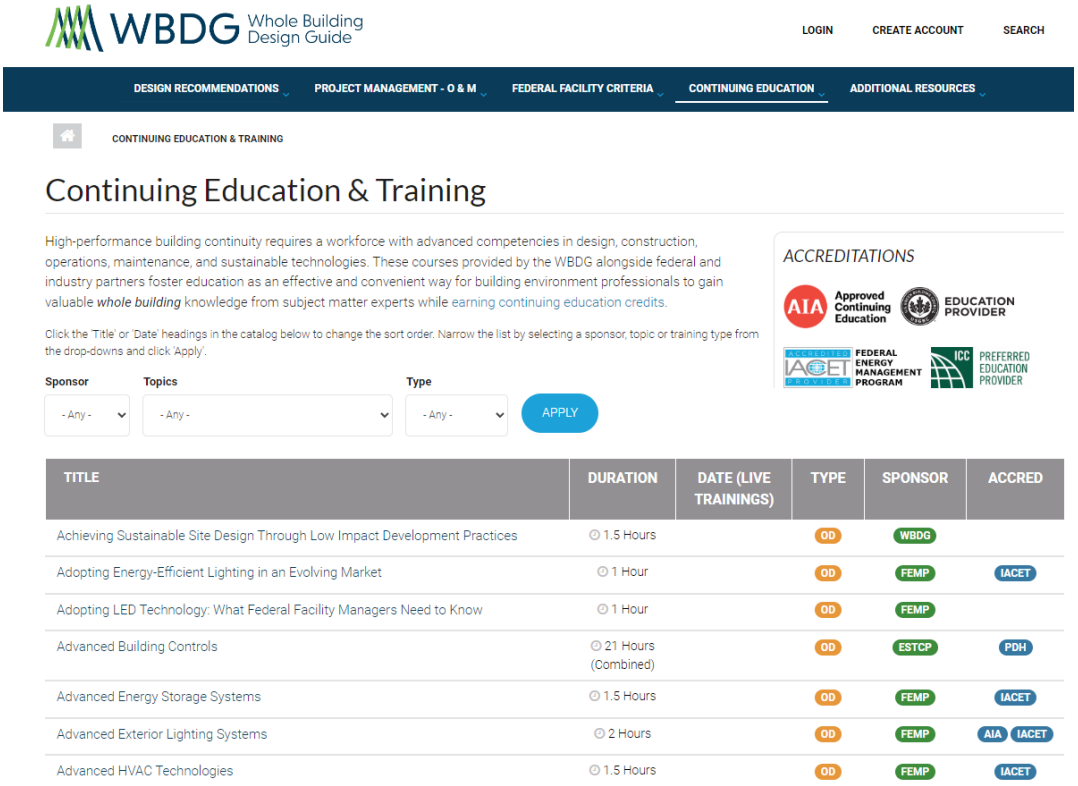

Figure 2. A screenshot of the WDBG website continuing education and training courses

Figure 3. A screenshot of the first smart building technology training video cover page

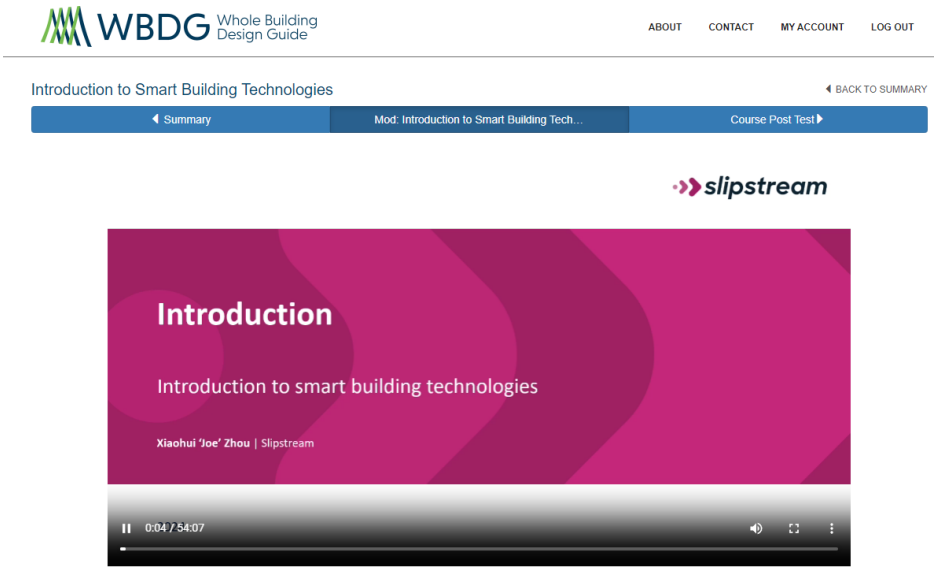

Figure 4. A screenshot of the first smart building technology training video

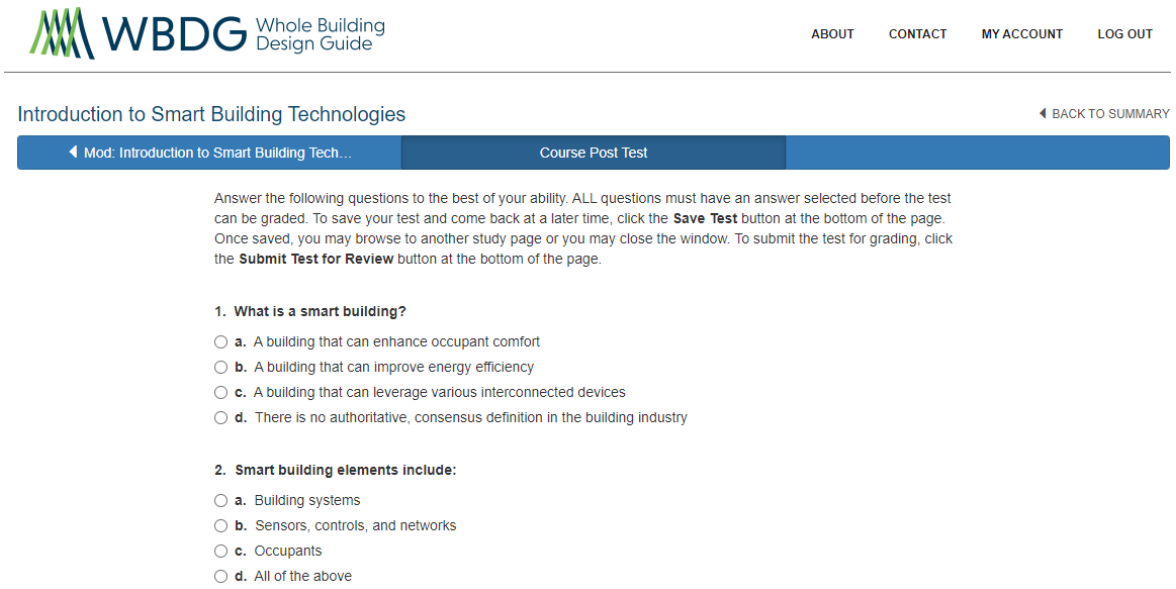

Figure 5. A screenshot of the first smart building technology training video post-test questions

Internal Reviews, Current Status, and Future Information Dissemination

In developing the training content, the team first drafted the modules and conducted an internal review process. For some sessions targeting building professionals, industry experts were invited to develop or contribute to the content or provide comments and feedback on the topics covered, technical content correctness, presentation format, and suggested changes. All contents were then reviewed by a DOE technical manager who oversees the project and provided many detailed, constructive suggestions for changes. The feedback gained from the DOE technical manager includes 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, comments, and suggested changes into an updated version of the training content before the validation tasks.

This content is undergoing a similar validation process to that of the undergraduate course content. As of May 2024, one Texas A&M professor and team member has completed teaching the new course "Smart Building Technologies" as part of the validation process. Texas A&M is in the process of writing a summary of the validation process and result which will be included as a part of the project's final report to DOE. In the Summer of 2024, SBSE members and other invited faculties will conduct a review of the curriculum content as well. For building professional continuing education, Slipstream has recorded nine of the 16 videos and worked with NIBS to post them on the WDBG website for selected industry experts to preview and provide feedback. It is expected that the final version of the course content will be released to the general public by the end of Summer or early Fall of 2024.

Once all the training materials are finalized, our team members will conduct outreach and marketing to disseminate these materials to our targeted 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 education and marketing team and NIBS will also help disseminate the information through an email campaign, website, and social media to our clients who are building professionals. As part of the information dissemination tasks, this paper is an effort to introduce our project to a wide audience and exchange lessons learned with peers. At the end of the project, we will document the findings in a final project report.

Key lessons learned so far from this project developing training content for both academic and professional education are listed below. More information will be provided in the final report to DOE at the end of this project once the team completes all the validation tasks.

- For different target audiences, the training content and format could be very different. While for academic education, the training content is focused on the theory and smart building technology fundamentals and capabilities, the team added a lot of content from the building industry on real-world smart building technology applications in the training videos for building professionals.
- Modularized training content is good for faculties at other universities to pick and choose specific smart building technology topics to teach and not necessarily to adopt the whole course content. "Adoptability" should be improved by using a presentation template indicating the levels of content difficulty or complexity and applicable discipline.
- For training content for the general public and building professionals, the team needs specific permission to use certain graphics and images from the sources. For academic education and training, there may be less stringent requirements.
- In the planning stage, inviting "project advisors" from academia and the industry to review course outlines or training topics covered is very important.
- Multiple rounds of internal and external technical experts' "reviews" or "validations" help keep 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 is impossible to discuss everything in super detail in our project. 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 on many of these specific subtopics will be developed – especially for building professionals' continuing education. This is because smart building technologies continuously evolve at a fast speed. The first course taught at Texas A&M 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. Currently, there are no industry-recognized certifications acknowledging professional competency onsmart building technologies. The 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 the content as part of the existing building operators certifications/training.

Conclusion

Slipstream, Texas A&M University, SBSE, and NIBS are working together to develop and validate training modules on smart building technologies for academic and professional education. The course content will be finalized and released to the public for free access in late 2024. The training content will bridge a gap for college students and building professionals in systematically learning smart building technologies. The team believes the best practices in developing curriculum or training content are 1) involving project advisors early to review training outlines including topics covered; 2) going through multiple rounds of internal and external technical expert reviews, if possible, to minimize training content developer's personal bias or technical knowledge limitations; and 3) collaborating with learning management system provider to structure the training course for effective learning and testing.

There is no known standard, systematic training on smart building technologies in academic and professional education and this project fills the gap. There are a few building controls related to training, education, or certification programs in two-year technical colleges or the building industry. The reference section lists a few examples.

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