

THESIS

CSU INDUSTRIAL HYGIENE PROGRAM TRAINING NEEDS ANALYSIS

Submitted by

Jillian Moore

Department of Environmental and Radiological Health Sciences

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2022

Master's Committee:

Advisor: William Brazile

Stephen Reynolds

Jill Zarestky

Copyright by Jillian Michelle Moore 2022

All Rights Reserved

ABSTRACT

CSU INDUSTRIAL HYGIENE PROGRAM TRAINING NEEDS ANALYSIS

Graduates of industrial hygiene (IH) programs must be able to meet continuously evolving health and safety needs in a wide variety of occupational settings. Therefore, academic IH graduate programs must regularly evaluate their curricula and solicit input from industry professionals in order to make curricular changes that will better prepare their students for professional roles in industry.

The purpose of this study was to identify the training gaps that exist between industry needs, accreditation criteria, and the current curriculum for the CSU Industrial Hygiene graduate program.

In Phase 1 of this study, a set of curriculum maps were developed to evaluate training gaps between accreditation criteria, course learning objectives, and course assessment mechanisms for each core course in the IH curriculum. In Phase 2, the research team facilitated two group interviews with the Colorado State University (CSU) IH Advisory Board, collected alumni survey data, and performed a qualitative analysis to identify skills gaps/needs for CSU IH Program graduates.

In Phase 1, only one gap was identified between accreditation criteria and IH program course objectives in the nine core departmental courses of the CSU IH graduate curriculum. No gaps were found between IH Program course objectives to course assessment mechanisms. In Phase 2, the research team identified three themes (technical, applied, and soft skills) and

selected several skills within each theme that interview participants thought were necessary proficiencies for young IH professionals.

The curriculum mapping exercise generally validated the satisfactory accreditation status of the CSU IH Program graduate curriculum. The development of the curriculum mapping tool and evaluation method can aid in providing evidence for the re-accreditation process for the CSU IH Program, as well as other occupational health programs. The skills identified in the qualitative interview and survey data can be incorporated into the curriculum to improve the training of IH students. Additionally, by using qualitative analysis, the researchers uncovered soft skills previously unidentified in IH needs assessments, providing valuable information for all IH graduate programs.

TABLE OF CONTENTS

ABSTRACT	ii
LIST OF TABLES.....	vi
LIST OF FIGURES	vii
CHAPTER 1: INTRODUCTION.....	1
CHAPTER 2: LITERATURE REVIEW	3
Curriculum Crosswalks.....	3
IH Needs Assessments	5
CHAPTER 3: PURPOSE AND SCOPE.....	8
Purpose.....	8
Research Question	8
Scope.....	8
CHAPTER 4: METHODS AND MATERIALS	10
Phase 1: Curriculum Crosswalk.....	10
Phase 2: Interview Data Collection.....	13
Phase 2: Alumni Survey Data Collection.....	15
Phase 2: Interview & Alumni Survey Data Analysis.....	16
CHAPTER 5: RESULTS	18
Phase 1: Curriculum Crosswalk.....	18
Phase 2: Group Interviews and Alumni Surveys.....	20
Technical Skills.....	21
Applied Skills	23
Soft Skills	29
CHAPTER 6: DISCUSSION	34
Phase 1: Curriculum Crosswalk.....	34
Phase 2: Group Interviews & Alumni Surveys	38
Technical Skills.....	38
Applied Skills	40
Soft Skills	44
CHAPTER 7: CONCLUSION	50
REFERENCES	51
APPENDIX A: Curriculum Crosswalk Spreadsheet Examples.....	54
APPENDIX B: Curriculum Crosswalk Instructions for Faculty.....	57
Document 1: Faculty Instructions.....	57
Document 2: Resource 1 – Bloom’s Overview	61
Document 3: Resource 2 – Writing Effective Objectives	66

Document 4: Resource 3 – Bloom’s Action Verbs.....	70
Document 5: Resource 4 – Level of Achievement Framework	71
APPENDIX C: Accreditation Comparison.....	73
BCSP (2019 accreditation vs 2021 curriculum map)	73
ABET (2019 accreditation vs 2021 curriculum map).....	79
LIST OF ABBREVIATIONS	83

LIST OF TABLES

Table 4.1: Alumni Survey data details.....	15
Table 5.1: Themes from CSU IH Program Advisory Board Interview Data.....	20

LIST OF FIGURES

Figure 3.1: Visual representation of curriculum crosswalk	8
Figure 4.1: BIM Level of Achievement Framework	12
Figure 8.1: Course Objectives vs Course Assessment Mechanisms spreadsheet for ERHS 526 .	54
Figure 8.2: ABET Criteria vs Course Objectives spreadsheet for ERHS 526	55
Figure 8.3: BCSP Criteria vs Course Objectives spreadsheet for ERHS 526.....	56

CHAPTER 1: INTRODUCTION

The role of industrial hygiene (IH) professionals is to provide a “strategic approach to identifying, assessing, and managing health hazards that arise...” in the workplace (American Industrial Hygiene Association, 2019). These professionals often serve as environmental, health, and safety (EHS) generalists in a wide variety of industries, from manufacturing and construction to healthcare, military operations, and research; this requires the education of IH professionals to be broad enough to solve both known and emerging safety and health issues that can appear in any context.

To support this need of a broad safety and health education, ABET has established core competencies for academic programs to train future IH professionals. Additionally, ABET requires accredited academic IH programs to demonstrate continuous improvement of their curricula to ensure that they are adjusting to the perpetually evolving needs of IH professionals in industry (ABET, 2019).

One common method of continuous improvement is to perform a needs assessment to verify the skills currently addressed in an academic program and identify additional skills that need to be enhanced or added into the curriculum. There is a paucity of published literature that provides research on the needed and/or expected skills of IH program graduates and early career IH/EHS generalist professionals. In all of the existing publications, the ability to effectively communicate was identified as a crucial but often underdeveloped skill (American Industrial Hygiene Association, 2019; L. Brosseau, 1995; L. Brosseau & Fredrickson, 2009; L. M. Brosseau et al., 2005; Oestenstad et al., 1994). Other necessary skills identified in this literature included problem-solving skills, business skills, and technical skills in ventilation, hazard recognition and control, and risk assessment.

While there have been a few published studies where researchers assessed the skills needed to be a successful IH professional, only two have conducted interviews and performed a qualitative analysis to identify these skills (American Industrial Hygiene Association, 2019; L. Brosseau & Fredrickson, 2009). Given the lack of industry-based, IH skills assessment data, there is a need to perform current interview-based research with industry professionals that uses robust qualitative analysis methods to identify and clearly define soft skill needs, in addition to technical skill needs. Additionally, no published research has included data that were collected for existing curriculum content and accreditation criteria for a specific academic program; this is a necessary component of a needs analysis that aims to make improvements to a program.

The purpose of this study was to identify the training gaps that exist between industry needs, ABET and Board of Certified Safety Professionals (BCSP) academic program criteria, and the current curriculum for the Colorado State University (CSU) Industrial Hygiene Master's Program (henceforth referred to as the CSU IH Program). The researchers examined quantitative data from a curriculum map and qualitative data from small group interviews and alumni surveys in order to perform a comprehensive training needs assessment and recommend improvements to the curriculum. The methodology used in this research could be applied to other occupational health and/or ABET-accredited programs that want to ensure that their graduates are well-prepared to meet both the technical and the soft skill expectations of the professional world.

CHAPTER 2: LITERATURE REVIEW

The current research project involved the performing a curriculum crosswalk, facilitating small-group interviews, and reviewing alumni surveys to identify training skills needs in the CSU IH Program. These three sources of information were used to identify technical, applied, and soft-skills needs. To find existing literature in these areas of research, the authors performed searches in the following databases: Web of Science, PubMed, and Education Resources Information Center (ERIC). One search focused on curriculum mapping in science, technology, engineering, and math (STEM) programs, while the other focused on needs and/or gap analyses of IH, EHS, or occupational health training programs and/or young professionals. A small number of peer reviewed studies were found in each search; these are discussed in detail below.

Curriculum Crosswalks

While there has been no published literature on developing curriculum maps for IH academic training programs, there are a handful of curriculum improvement studies in related fields, such as veterinary medicine, pharmacy, and engineering.

Chaney, et al. (2017) used curriculum mapping as part of a comprehensive curriculum redesign process for the Veterinary Medicine program at Texas A&M University (TAMU). With the help of TAMU's Center for Teaching Excellence (CTE), the researchers developed a qualified and dedicated curriculum redesign team that used curriculum mapping software to catalog information about the instructional activities and assessments in each core course and map this information to previously defined competencies and outcomes. These data were evaluated across the whole program for curricular misalignment and re-design opportunities.

Researchers for a veterinary medicine program in the United Kingdom used curriculum mapping as a tool to review and improve the curriculum, as well as provide clarity and

transparency to accreditation bodies and students (Bell et al., 2009). Similar to Chaney et al., (2017), Bell et al. (2009) assembled a small faculty-based team to collect and map program outcomes to individual course learning objectives, using software developed in-house. One important takeaway from this study was that the process of building and validating the map required a large amount of staff time. The researchers also noted that there was a wide variety in the quality of written course outcomes and finally, that the ongoing upkeep of the map may prove to be difficult.

Zelenitsky et al. (2014) developed a curriculum map for the pharmacy program at the University of Manitoba in order to evaluate how well the intended curriculum (e.g., expected learning outcomes) aligned with both accreditation requirements and what is actually learned by students. Program instructors were asked to link course objectives to accreditation outcomes and identify the expected student learning and performance levels for each objective using provided frameworks. The data for all program courses were compiled in Microsoft Office software and evaluated as a whole. This process was found to be both efficient and effective for the researchers' needs.

A Canadian engineering school used curriculum mapping as one part of a framework developed to facilitate accreditation assessments (Easa, 2013). Commercially available curriculum mapping software was used to map accreditation attributes to courses in the undergraduate civil engineering curriculum. Assessment methods (e.g., labs, tests, projects) for each course were further evaluated using a numerical rating scale.

Finally, Curtis, et al. (2012) developed tools to support ABET accreditation and continuous improvement processes for an engineering program at the University of Nebraska. While the researchers did not define the tools as “curriculum maps”, the evaluation process

described was certainly a form of curriculum mapping. Microsoft Access was used to create a matrix for each course that matched ABET objectives to course assessment mechanisms. Additionally, Bloom's taxonomy was used as a framework to evaluate each assessment mechanism for the expected level of student learning with regard to each matched ABET objective.

In summary, across the handful of studies where researchers have developed curriculum mapping tools for engineering and health programs in higher education, a primary goal was to facilitate accreditation and improve curriculums. Interestingly, each study used different software and evaluation frameworks that were often developed as part of the project, indicating that no tools currently exist that can fully meet the needs of different programs, even within the same discipline. Only two studies evaluated expected levels of learning; however, they used different frameworks for this evaluation, further demonstrating the wide variability of frameworks and tools that can be used in curriculum evaluation (Curtis et al., 2012; Zelenitsky et al., 2014).

IH Needs Assessments

A small number of studies have been published that assessed the needs and/or performance of students and early career professionals in industrial hygiene, occupational hygiene (OH), and environmental, health, and safety (IH/OH/EHS) fields.

In a recently published white paper, the American Industrial Hygiene Association (AIHA) (2019) surveyed employers, professors, and recent graduates of EHS programs to determine how well academic programs were preparing students for their professional roles in EHS. The AIHA researchers identified several areas of desired improvement, including written and verbal communication, project management, and a handful of technical skills.

Brosseau, et al. has published three studies that examined the skills that industrial hygiene graduates need to be successful professionals. In 1995, Brosseau surveyed industrial hygiene and hazardous waste professionals about the need to include certain topics in IH curricula. The survey results indicated a need for students to have a strong background in relevant regulations, communication skills (as they pertain to training workers), and adequate technical skills (L. Brosseau, 1995). In 2005, Brosseau, et al. surveyed IH employers to assess their expectations of Master's level IH graduates. The researchers asked employers to rate a few dozen topics and skills, primarily technical, on their perceived importance when hiring recent graduates. Hazard recognition, evaluation, and control topics, along with communication and ethical behavior, were rated as the most essential skills (L. M. Brosseau et al., 2005). In 2009, Brosseau and Fredrickson performed a study assessing student outcomes of industrial hygiene graduate programs, with collected data from alumni surveys and group discussions with employers. In the two group discussions, participants were asked to discuss the needs of and expectations for certain skills when hiring EHS professionals. Communication, business skills, and problem-solving skills received substantial discussion; these topics were all deemed crucial to success in the workplace (L. Brosseau & Fredrickson, 2009). The discussion data also provided rich context around these skills. In the alumni surveys, graduates from a single academic program were asked to rank the importance of a comprehensive list of competencies; technical skills in the recognition and evaluation of hazards were consistently rated as highly important by this group (L. Brosseau & Fredrickson, 2009).

Oostenstad, et al. (1994) surveyed 34 occupational health and safety managers about their expectations for entry-level industrial hygienists. The survey results clearly indicated communication as the most important single skill. Participants also had the opportunity to

respond to two open-ended questions about the preparation of IH professionals and obstacles or weaknesses observed in the workplace. These comments provided rich context to support the forced-response survey questions. Ultimately, the researchers concluded that entry-level industrial hygienists need to be able to work independently, collaborate and communicate with employees at all levels, and possess solid science and technical skills.

In 2005, Vincent proposed a framework for graduate education in occupational hygiene. He discussed the changing roles and expectations of occupational hygiene professionals, noting the need for more training in management, communication, and the ability to be a “generalist”. Vincent (2005) also recommended that academic programs seek regular input and participation from professionals, in the form of an advisory committee.

Based on a comprehensive literature review, Wybo and Van Wassenhove (2016) developed recommendations for building an academic program that can successfully prepare graduate students to be EHS professionals. Communication and risk management appeared as critical skills to include in an EHS program. The researchers also emphasized the importance of interactive, real-world learning exercises, such as case studies, field work, and internships.

In summary, among a handful of studies that examined the needs or performance of IH/OH/EHS students and professionals, almost all highlighted the importance of communication skills. Most of these studies focused on forced-response survey questions and were weighted heavily toward technical skills. The researchers who collected qualitative data through open-ended questions and group interviews were able to provide additional context that can be used to support the design and re-design of courses in IH/OH/EHS curricula.

CHAPTER 3: PURPOSE AND SCOPE

Purpose

The purpose of conducting this research was to determine what gaps exist between industry needs, ABET and BCSP criteria, and the current curriculum for the CSU IH Program. The results from this gap analysis will influence changes to the CSU IH Program that will improve the knowledge and skills for future graduates.

Research Question

This research was used to answer the following question: What gaps exist between industry needs, ABET and BCSP criteria, and the current curriculum for the CSU IH Program?

Scope

This research was performed in two phases. In Phase 1, the researchers performed a curriculum crosswalk between ABET criteria, BCSP blueprint objectives, and the objectives and assessments for every core course in the current CSU IH Program curriculum to identify any existing training gaps. A visual representation of Phase 1 is shown in Figure 3.1 below.



Figure 3.1: Visual representation of curriculum crosswalk

In Phase 2, the researchers facilitated a series of virtual focus group interviews with the members of the CSU IH Program Hygiene Advisory Board and gathered the results from several recent alumni surveys to identify program needs from the perspective of alumni and EHS

professionals. The Phase 2 data were qualitatively analyzed to identify themes and recommend additional training for the industrial hygiene curriculum at CSU.

CHAPTER 4: METHODS AND MATERIALS

The purpose of this study was to identify knowledge gaps in the CSU IH Program, with the intent to use the results to improve the program and ensure program graduates are able to meet the evolving needs within the field of IH/EHS. To gain a complete picture of program deficiencies from multiple perspectives, the research team chose to explore this question both internally (through curriculum mapping) and externally (through qualitative interviews and survey data). The data collection and analysis methods for both phases are described in detail below.

Phase 1: Curriculum Crosswalk

Using the curriculum mapping information from Texas A&M's (TAMU) Center for Teaching Excellence (CTE) Program [Re]Design model as a foundation, the research team developed a set of three Microsoft Excel spreadsheets for each core course in the CSU IH Program curriculum to facilitate the curriculum mapping process (TAMU, n.d.). In the first spreadsheet, objectives from the syllabus for a given course were added to columns across the top and all course assessment mechanisms (i.e., homework, lab reports, exams, etc.) were listed in rows on the far left, creating a matrix where faculty could indicate where an assignment met certain objectives. In the second spreadsheet, the course objectives were pulled into the rows on the far left and ABET program criteria and student outcomes were added to the columns across the top. Similarly, the third spreadsheet pulled the course objectives into the rows on the far left and added BCSP criteria (from the ASP10 Examination Blueprint) to the columns across the top (BCSP, 2019). These curriculum maps provided space to evaluate whether a match existed between any given course objective and accreditation criterium. See Appendix A for examples of the spreadsheets showing course objectives vs assessment mechanisms, course objectives vs

ABET accreditation criteria, and course objectives vs BCSP examination blueprint criteria, respectively.

To gain an accurate picture of how the assignments, course objectives, and accreditation criteria aligned to create a cohesive curriculum, a second layer of analysis was added to assess the degree of understanding students are expected to demonstrate. The researchers used Bloom's Taxonomy and resources presented by the ABET Institute for the Development of Excellence in Assessment Leadership (IDEAL) program as a basis for the establishment of a three-tiered framework to evaluate the expected level (or extent) of student learning as Beginner, Intermediate, or Master (BIM) (Briedis et al., 2017; Shabatura, 2022). The Beginner Level (B) is tied to Bloom's Levels 1 and 2, Remember and Understand; at this level of understanding, students are expected to absorb new material as a foundation for future application. The Intermediate Level (I) corresponds with Bloom's Levels 3 and 4, Apply and Analyze; at this level of understanding, students should begin to apply their knowledge and explore connections at a deeper level. The Master Level (M) corresponds with Bloom's Levels 5 and 6, Evaluate and Create; at this highest level of understanding, students are expected to use their knowledge to ask critical questions and solve novel problems.

The CSU IH Program curriculum should theoretically be designed such that students can progress through multiple levels of learning to achieve each course objective and accreditation criterion. The BIM Level of Achievement Framework and its connection to Bloom's taxonomy are shown in Figure 4.1 below:

BIM Level of Achievement Framework

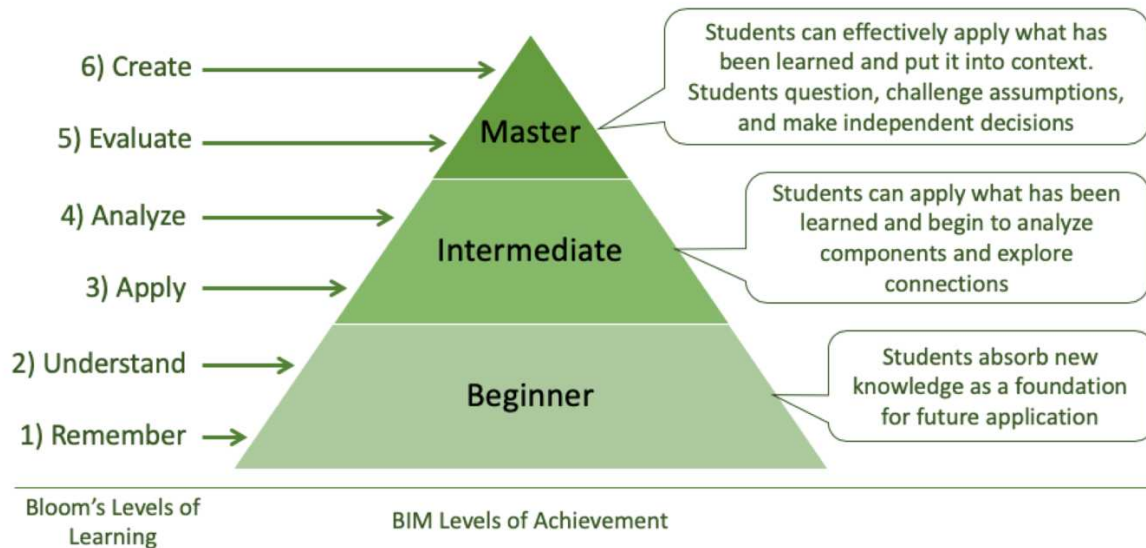


Figure 4.1: BIM Level of Achievement Framework

It was strongly desired for core CSU IH Program faculty to evaluate their courses independently, so researchers developed an information packet containing an explanation of the BIM Level of Achievement Framework and instructions on how to use the framework to evaluate their courses on the provided spreadsheets. (The documents in this packet can be found in Appendix B.) The researchers planned to review each completed spreadsheet and validate as needed with faculty.

Core IH Program faculty were instructed to first insert course objectives and assessment mechanisms into the appropriate spreadsheet and define an expected level of achievement for each objective. Next, faculty determined which course objectives were tied to each assessment mechanism and used the BIM Level of Achievement Framework to assign an expected level of achievement to each matched course assessment/objective pair. Finally, faculty were instructed to use the ABET and BCSP criteria spreadsheets to map the course objectives to the ABET and

BCSP criteria with an “x”. (The decision was made to not extend the BIM analysis to ABET and BCSP criteria for this project due to the additional complexity and anticipated time requirement.)

The research team reviewed each completed set of spreadsheets and facilitated validation meetings with faculty for each course to ensure full understanding and attempt to establish consistency across course evaluations.

Two courses in the industrial hygiene curriculum were taught by non-core faculty, and the decision was made to conduct facilitated meetings with the faculty members for both of these courses to perform the curriculum crosswalk with pre-populated spreadsheets as described above.

Once all of the data were collected and reviewed, the ABET and BCSP spreadsheets for each course were compiled into a single matrix to evaluate how all accreditation criteria were being met across the curriculum. This was also compared to recent ABET re-accreditation and BCSP qualified academic program (QAP) application paperwork. Finally, all gaps were recorded and compiled for further consideration and recommendations.

Phase 2: Interview Data Collection

To solicit input from industry professionals, group interviews were performed with members of the CSU IH Program Advisory Board. This population was selected because of convenience as well as participant familiarity with the CSU IH Program and its goals.

Participants were recruited via email for the semi-annual Advisory Board update meeting. A total of 12 board members participated in one of two group interviews; of these members, five worked in government or industry, four worked as consultants, and three were academic professors, two of which actively taught IH courses at CSU. In addition, two of these participants were also recent graduates (<5 years) of the CSU IH Program. Digital consent was obtained for voluntary

participation and recording of the interview session(s), per CSU Institutional Review Board (IRB) protocol 20-10381H.

Based on the evidence presented in the AIHA white paper (2019), the research team developed an interview protocol with the intent to encourage semi-structured discussion and capture a broad range of potential training needs and gaps. Participants were asked one main question: *What performance problems (technical and non-technical) have you seen in recent CSU IH Program graduates?*

To ensure that enough context and details were captured in the discussion, follow-up questions included (but were not limited to):

- What do these skills *look like* in your place of work?
- What should graduates be able to *do* or *execute* if they have these skills?
- What specifically needs work?

All three researchers/facilitators were trained on the discussion questions and goals of the interviews; they were also provided with an interview guide that contained the above questions and space for recording notes during the interviews.

The group interviews were performed via Zoom on two dates: 3/26/2021, during the semi-annual Advisory Board update meeting, and 4/26/2021, to provide an opportunity for board members who could not attend the original meeting. During the 3/26 meeting, nine board members and three researchers/facilitators were present for the discussion. After a brief background and explanation of the interview process were presented, participants were divided into three breakout rooms for small group discussions. Each breakout room consisted of three participants and one researcher/facilitator. Due to software limitations, the audio from only one breakout room conversation was recorded; however, extensive notes were taken in all breakout

rooms. After approximately one hour of discussion, participants reconvened into the large group for a recorded debriefing summary and discussion.

During the 4/26/2021 meeting, three board members and two researchers/facilitators were present for the discussion. One researcher facilitated a small group discussion with the participants, while the other took notes and assisted with facilitation. This interview was successfully recorded and lasted approximately one hour.

Phase 2: Alumni Survey Data Collection

Qualitative data were also collected from four alumni surveys that were completed by CSU IH Program alumni between 2015 and 2021 (Table 4.1). These surveys are typically e-mailed to program alumni every three years in order to solicit feedback on the strengths and weaknesses of the program and understand the current challenges alumni face in the workplace. Two of the surveys used in this research were sent to CSU IH Program alumni, and the other two to alumni of the Mountain and Plains Education and Research Center (MAP ERC) program, which is an interdisciplinary program that sponsors students from five different occupational health disciplines, including Industrial Hygiene.

Table 4.1: Alumni Survey data details

Year	Survey Population	# of IH Responses
2015	IH Alumni	12
2018	MAP ERC Alumni	25
2019	IH Alumni	10
2021	MAP ERC Alumni	21

The research team was provided with de-identified responses from each of the four alumni surveys, which was approved through the IRB protocol. For the MAP ERC survey data, the researchers considered only the responses from CSU IH Program alumni for analysis.

Phase 2: Interview & Alumni Survey Data Analysis

Transcripts were generated from two of the group interview breakout sessions and the 3/26 large group de-briefing discussion. (Two of the 3/26 breakout sessions were not recorded due to unanticipated technical issues and therefore could not be transcribed; however, detailed notes from these sessions were considered in the analysis.) These transcripts were manually reviewed, edited, and de-identified per the IRB protocol. The de-identified alumni survey responses described above were also included for analysis. Given the straightforward nature of the data (in relationship to the research question), the research team chose to perform a content and thematic analysis to identify and analyze patterns within the data, using methods described by Braun and Clarke (2006).

First, a content analysis was performed on all transcripts and survey responses to identify skill gaps and categorize them into two deductively identified themes: “soft” skills and technical skills. Supporting contextual evidence for each skill gap was placed within each theme. For the technical skills theme, a semantic approach was used to identify several specific technical skills. A latent approach was used to iteratively review the soft skills subset of data to inductively derive and refine specific essential workplace skills (Braun & Clarke, 2006). The two researchers performing this qualitative analysis coded the transcripts independently and then came together to review and compile the data. Both researchers had backgrounds in adult education; however, one was a graduate student in the IH department and had an in-depth understanding of technical issues, and one had an extensive background in qualitative analysis and soft skills. These differing perspectives led to an overlap of skills in both the technical and softs skills themes; after some discussion, the researchers developed a third theme, named applied skills, that accounted for skills that required both technical and soft skills elements. The

transcripts and survey data were coded again to account for this change. The final themes derived from the data were technical skills (e.g., ventilation, non-OSHA standards), applied skills (e.g., critical thinking, business communication), and soft skills (e.g., conflict management, leadership).

Summary

The detailed curriculum map data populated by CSU IH program faculty and the rich, qualitative perspectives provided by industry professionals (i.e., the advisory board) and IH alumni enabled an in-depth understanding of skill gaps that can be addressed within the CSU IH Program curriculum. A thorough presentation of the results and discussion can be found in the succeeding chapters.

CHAPTER 5: RESULTS

Through this project, the research team explored the gaps that exist between industry needs, accreditation criteria, and the current CSU IH Program curriculum. In Phase 1, researchers performed a curriculum crosswalk to compare the current curriculum to accreditation criteria. In Phase 2, the research team asked the CSU IH Program Advisory Board members about performance gaps in recent graduates and qualitatively analyzed these results, along with alumni survey data, to identify potential areas for curriculum improvement. The results from these two phases are presented below.

Phase 1: Curriculum Crosswalk

ABET Objectives vs Course Objectives

Overall, the completed IH Program course curriculum maps indicated thorough alignment between ABET program criteria, ABET student outcomes, and the IH Program course objectives; this was expected since the CSU IH Program was recently re-accredited in 2019. One gap uncovered by the crosswalk exercise was a lack of IH Program course objectives that support ABET program criterion 6.3.10: Attain recognized professional certification (Brazile, 2020). Recommendations for addressing this gap can be found in the Discussion Section.

In general, there were many IH Program course objectives within each course that met many ABET program criteria and student outcomes. However, when the curriculum maps were compared to the 2019 ABET reaccreditation materials, there were some discrepancies between the curriculum maps provided in the 2019 ABET materials and the curriculum maps in the current study that need to be evaluated. (The results of this comparison are included in Appendix C.)

BCSP Blueprint vs IH Program Course Objectives

No gaps were found when the CSU IH Program course objectives were mapped to the BCSP Associate Safety Professional (ASP) Examination Blueprint objectives; this was an expected result since the CSU Industrial Hygiene Master of Science Program was designated as a Qualified Academic Program (QAP) by the BCSP in 2017 (BCSP, 2019; T. Turnbeaugh, personal communication, April 18, 2017).

To meet BCSP requirements to be recognized as a QAP, a program's curriculum needs to cover at least 70% of the criteria in the ASP Examination Blueprint (K. Golding, personal communication, August 9, 2022). Based on the curriculum crosswalk for BCSP criteria, 80% (67/84) of the criteria were met. During the 2019 reaccreditation process, however, the CSU IH Program met 85% (71/84) of the BCSP criteria. This indicates potential gaps between the two evaluations that need to be reviewed.

The BCSP criteria are categorized into nine domains with a total of 84 individual competency criteria. The CSU IH Program covered 70-100% of the criteria for seven of these domains (Ergonomics, Emergency Response Management, Environmental Management, Law and Ethics, Applied Science and Mathematics, Industrial Hygiene and Occupational Health, and Safety Management Systems). Domains with less than 70% criteria coverage were: Fire Prevention and Protection, and Training, Education, and Communication. Similar to the ABET program criteria and student outcomes, several IH Program courses covered multiple BCSP criteria.

IH Program Course Objectives vs IH Program Course Assessment Mechanisms

Overall, minimal gaps were found within the nine core IH Program courses evaluated for alignment between CSU IH Program course objectives and course assessment mechanisms. Four of nine of the courses contained one or more objective-level BIM designation that was

“higher” than the level achieved in the assessment mechanisms; this typically occurred for Master-level designations. These course maps provide direct links to evidence (assignments) that supports the ABET accreditation and BCSP QAP evaluation spreadsheets.

Phase 2: Group Interviews and Alumni Surveys

Using a content and thematic analysis of the interview transcripts and alumni survey data, the research team identified many skills that the CSU IH Program Advisory Board members and IH Program alumni thought were necessary for new graduates to perform well in a variety of workplace contexts. Based on supporting transcript and alumni survey data, the codes were organized into three themes that encompassed the skills needed to be a successful IH/EHS professional: technical skills, applied skills, and soft skills. A complete list of the technical, applied, and soft skills identified in the data can be found in Table 5.1 and are further described below.

Table 5.1: Themes from CSU IH Program Advisory Board Interview Data

Technical Skills	Applied Skills	Soft Skills
Aerosols & Ventilation	Business skills <ul style="list-style-type: none"> • <i>Business Case</i> • <i>Project Management</i> • <i>Communication</i> 	Communication & Interpersonal skills <ul style="list-style-type: none"> • <i>Conflict Management & dealing with resistance</i> • <i>Collaboration & Negotiation</i> • <i>Building relationships & rapport</i>
Non-OSHA standards & regulations	Critical thinking / problem-solving <ul style="list-style-type: none"> • <i>Modeling & understanding limitations</i> • <i>Resource awareness</i> • <i>Data analysis & quality</i> 	Self-directed Learning & Management
Special topics	Real-World Application	Leadership
	Adult Education & Training	Diversity, Equity, Inclusion

Technical Skills

There were three technical skill categories identified in the group interviews and alumni surveys. Identified skills were considered technical if they were fundamental areas of knowledge specific to industrial hygiene and occupational safety (AIHA, 2018). Evidence for each skill category is summarized below.

Ventilation & Aerosols

Ventilation and aerosols were mentioned as necessary skills for IH program graduates in both the interviews and alumni surveys, as evidenced by the comments from two advisory board members in two different breakout rooms:

“...if you have a practicing industrial hygienist out in the real world and they're being asked to assist with infectious viral particles floating around and they don't have these courses...The two courses are instrumental in understanding aerosol science behavior of aerosols, and then the ventilation aspect of controlling those environments.”

“...[ventilation is] a vital aspect to industrial hygiene and you are expected to know it and help.”

The advisory board expressed surprise that these courses were not already part of the core curriculum (i.e., required courses) and indicated increased need for these skills with the COVID-19 pandemic. They recommended that both ventilation and aerosols be added to the core CSU IH Program curriculum.

Non-OSHA Standards & Regulations

Both interview groups and alumni surveys strongly indicated a need for graduates to be aware of non-Occupational Safety and Health Administration (OSHA) regulations. Depending on a graduate's field of work, they may need to be familiar with additional standards and regulations such as National Fire Protection Association (NFPA), Department of Energy (DOE),

and hazardous waste. This idea was reflected in the following comment from an Advisory Board member:

“...we don’t need to dive too in depth into some of these different codes and standards, but touching on things like NFPA standards or international fire codes and maximum allowable quantities of certain chemicals, based on a facility – things like that in addition to just the general OSHA standards, I think, would be beneficial to kind of expose students in the program to that...”

As this Advisory Board member points out, students do not need to understand all of these standards and regulations in detail, but it would be beneficial to gain some exposure. CSU’s IH Program currently covers OSHA 1910 and 1926 standards, International Standards Organization (ISO) 45001 and 14001, and a handful of Environmental Protection Agency (EPA) regulations. There are a number of ways that other standards and regulations could be incorporated into the curriculum; these will be further addressed in the Discussion section.

Special Topics

A number of topics were mentioned in the alumni surveys that were not brought up in the group interviews. There are limited data on the special topics, but CSU IH Program alumni expressed workplace challenges around the following topics: electrical safety, radiation safety and health physics, worker’s compensation, Lean Six Sigma, hazardous waste, and how to respond to accidents. Some of these topics are briefly mentioned in IH Program courses; however, the explicit mention of these topics by alumni indicates a potential need to provide additional training.

Applied Skills

There were four applied skills that were identified in the interviews and alumni surveys. These skills, which require elements of both technical and soft skills, were generally seen as more complex than fundamental technical skills, but were crucial in the development of successful IH/EHS professionals in all contexts. A summary of the identified applied skills can be found below:

Business Skills

A variety of business-related skills were identified through the advisory board interviews and alumni surveys as being important for IH graduates/professionals, including building a business case, project management, and communication.

Building a Business Case

The ability to build a business case for EHS initiatives that clearly shows the benefits (especially costs and savings) to the company, employees, and community was a skill identified in the interviews as well as previous advisory board meetings. Advisory board members recommended adding this topic to the curriculum.

Project Management

Project and resource management were also identified as important business skills. Alumni survey respondents indicated specific challenges with managing change and dealing with constrained budgets and resources:

“[A significant challenge I face is] managing change on large dynamic projects and verifying installation per design specifications”

“My budget is continually challenged so I am working through how to justify positions and look for what adds the most value.”

Project management challenges also appeared in the Advisory Board interviews. One board member, who was also a recent alum, thought that the field projects required in the interdisciplinary MAP ERC symposium course (ERHS 679) were beneficial because they allowed students to work together and learn how to traverse all phases of implementing a consulting project. This board member also thought it could be valuable to branch out further and pursue interdisciplinary projects with students in the business and engineering departments on campus. All of these disciplines often need to work together in many industries, and early exposure could benefit all of these students.

Communication

The interview groups and alumni surveys both identified verbal and written communication as vital skills to be successful in the workplace and thought this was a gap that could be addressed within the CSU IH Program curriculum. One advisory board member, who was a tenured supervisor in a consulting company, specifically mentioned that new consultants must be able to write effective reports:

“...if they [young IH/EHS consultants] don't have that kind of writing skill to put together a consultant report, I don't give them high marks on their annual or semiannual process to elevate them into leadership positions...”

In addition to writing skills, the ability to communicate verbally was seen as possibly more important, as evidenced by another advisory board member's comment:

“As much as writing is important, I think verbal communication of content and information is - is far more important because very few of our clients in many cases read the entire report. They read the executive summary, then they want you to tell them what they need to take away from it.”

In summary, understanding one's audience (e.g., clients, managers, operations) and concisely tailoring messages so they can be easily understood was seen as important for both written and

verbal communication. Faculty participants noted a handful of course assignments that focus on writing consulting reports or memos, and several courses require students to give formal presentations; however, there is limited discussion on selecting appropriate material to persuade a given audience.

Critical Thinking & Problem-Solving

In the group interviews, participants discussed several skill areas that could be classified as critical thinking and problem-solving skills (based on the discussion context). These critical thinking and problem-solving skills include modeling and understanding limitations, resource awareness, and data quality and analysis. Evidence to support each skill is provided below.

Modeling and Understanding Limitations

In both group interviews, a few advisory board members noted that they use modeling tools frequently in their jobs to quantitatively estimate air exposures as well as perform qualitative exposure assessments. One experienced CSU IH Program alum specifically mentioned modeling as a weakness among CSU graduates, as evidenced by the following comment:

“A weakness I’ve seen in some graduate students coming out of the program...in working with three of the graduate students out of CSU on different types of activities [is that] they all seem to struggle somewhat in understanding that those models existed and how to apply those models and even to get an accurate model out at the end of the process... Not only did I have to tell the students it was there and available, I had to go through it almost step by step...”

This comment is supported by the fact that modeling has not been incorporated into the IH curriculum. Therefore, the advisory board recommended that IH students to be introduced to modeling software, such as the American Industrial Hygiene Association’s (AIHA) IH-MOD

2.0. In addition, there was some discussion about teaching students to understand the limitations of models, as well as the importance of considering those limitations when determining and presenting solutions. This is an important component of learning how to effectively use modeling software, and should be incorporated into future instruction.

Resource Awareness

Participants from both interview groups agreed that being aware of various resources and tools is a crucial skill for assessing and solving unfamiliar problems in the workplace. Advisory board members further agreed that it would be impossible to teach students every resource and tool, but having a general idea of where to go to find the necessary information is an important skill that could be covered in the program.

Data Analysis and Quality

Related to critical thinking and problem solving, the need for mature skills in data analysis was heavily discussed by participants in both interview groups. Understanding how to determine the appropriate number of samples to collect, which methods to use, and what the results should look like are skills that require a solid technical background and ability to think critically. Several of these skills were specifically pointed out by Advisory Board members, as evidenced by the following comments:

“the ability to figure out how many data - in order to achieve a confidence level - how many samples do you need to achieve a specific objective, how do you how do you create a methodology for collecting data to achieve a specific type of model...”

“I always ask my staff, ‘If you're going to take a sample, have an expectation of what those results will look like.’ Know what's real. Don't just believe it because it's on the paper...”

Advisory board members also noted that IH/EHS professionals often have to work with limited data sets and need to be able to draw appropriate conclusions and defend subsequent decisions.

One advisory board member stated this challenge well:

“You will be challenged to explain the data. You'll be challenged because you don't have enough data. You may make an argument for some change in a program based on very limited sampling...just because you have a data point, is that enough to make a decision and cost someone money, or change process, or did you miss something?”

While many academic programs excel at providing students with a solid foundation of technical skills, it is more difficult to teach them to determine what is needed in a novel situation and how to critically interpret and make decisions with data. These applied skills require deliberate practice, but are essential for becoming competent and independent professionals.

Real-world Application

Several alumni surveys mentioned the need for more hands-on practice and real-world application in the IH curriculum, including shadowing professionals, internships, and practicing how to implement a variety of safety regulations. One alum mentioned that there is a disconnect between learning about safety regulations and being able to effectively apply that knowledge:

“...I knew [lock out tag out] LOTO [regulations] forwards and back but I didn't actually know to perform a LOTO so that I could assess our practices. I knew confined space [regulations] and had even in past jobs entered them unsafely; but when I got my job, I didn't know how to use the confined space entry equipment (vent fan, tower, harnesses).”

This alum makes an excellent point that IH/EHS professionals are expected to know what various safety regulations look like in practice; providing more opportunities for realistic practice is something that can be incorporated into the IH curriculum.

Additionally, participants in one interview group noted the variety of roles IH graduates may be asked to take on and recommended introducing students to the myriad of professional responsibilities they may have, as supported by the following advisory board member comment:

“I think, unless you work for a really large company where they do have a set IH that is in charge of all of the exposure and does all the IH assessments, you’re going to be [wearing] all the hats.”

Considering the way that the industrial hygiene profession has expanded to encompass a wide range of safety-related workplace issues over the past few decades, there is a valid need for students to understand what they may be asked to do as IH/EHS professionals.

Adult Education and Training

Participants in both group interviews and the alumni surveys identified teaching and training adults as an important part of their professional roles. As one advisory board member points out, this is a vital but difficult-to-find skill in IH/EHS professionals:

“Education in the role of an IH professional is hard to find. Training and educating others is critical. What are skills that we can develop to help students become better trainers?”

Participants also noted that IH/EHS training happens in a variety of contexts, from one-on-one teaching (e.g., explaining the reason for fitting an employee with a sampling pump or how to properly wear a harness) to classroom or lecture-style teaching for larger audiences. While students in the CSU IH Program do gain experience giving presentations and fitting other classmates or research participants with sampling equipment, adult education and training concepts and practice are not emphasized in the current curriculum.

Soft Skills

Participants in both interview groups and the alumni surveys results identified a variety of non-technical skills that were vital to success in the workplace. Some of these skills were directly identified as soft skills, management skills, and human relational skills, but additional “soft” skills appeared indirectly throughout the entire discussion. It was recognized that these skills (which will be referred to as “soft skills” from this point forward) may be difficult to teach in a classroom setting, but they are essential for executing the technical skills and getting things done in a business environment. The four identified soft skills are described below.

Interpersonal Skills

Throughout the group interview discussions and alumni surveys, it was recognized that being a successful IH/EHS professional requires highly developed interpersonal skills. With the help of the research team’s soft skills expert, the following interpersonal skills were coded from the data: conflict management and dealing with resistance to change, collaboration and negotiation, and building relationships. (Note: While not called out as a specific skill, it should be noted that effective communication is a crucial and inherent component of all of these skills.) Supporting evidence for each category is provided below.

Conflict Management and Dealing with Resistance to Change

Several advisory board members and surveyed alumni identified a recurring need for skills in conflict management and dealing with resistance to change. This was mentioned in a variety of work contexts dealing with EHS issues and included dealing with managers, operations, vendors, contractors, and the public. It was evident that these situations can be

stressful and must be handled delicately in order to achieve EHS requirements and goals, as described in the following comments from two advisory board members:

“People get really upset about some safety aspects and [IH employees] need to know how to handle that situation and know how to...not internalize it...”

“There's nothing like being screamed at - like a project manager at a petroleum refinery - to make your, you know, that you have to deal with and try to make your case.”

These sentiments were echoed in multiple alumni survey comments around workplace challenges, as demonstrated below:

“The challenge of dealing with push back/resistance when asking workers to modify the way they are performing their work tasks or research project design approach based on compliance requirements.”

“Dealing with resistance to safety requirements, obtaining buy-in to improve culture and processes, and effective communication are definitely the most difficult issues I deal with.”

One board member recognized that it would be difficult to artificially create this kind of stressful situation in the classroom; however, there are foundational skills that can be taught within the curriculum. Additionally, the CSU IH Program has close connections with the Industrial / Organizational Psychology program through the MAP ERC, which could be a valuable resource for helping students explore conflict management and resistance issues in the workplace.

Collaboration & Negotiation

Advisory board members thought that being able to collaborate and negotiate to achieve EHS goals were also important skills. There was a recognition that different departments or people may have different goals, so the ability to effectively present your case but also listen and thoughtfully consider others' points of view is necessary to finding acceptable compromises.

One advisory board member stated that being flexible was important in achieving their goals:

“Sometimes you have to, kind of, flex and pivot a little bit and be able to work collaboratively with other groups trying to get to the same or similar end goal...I find myself doing that a lot in meetings with management...”

While the current IH curriculum does not provide assignments that evaluate the specific skills of collaboration and negotiation, these skills are an inherent part of successful team work, which is required in several courses throughout the curriculum.

Building Relationships

The ability to build relationships with both management and workers was seen as a critical skill for IH/EHS professionals, given their role in building safety culture and managing uncomfortable EHS situations. One interview breakout room group pointed out that the ability to effectively build relationships can help “...break down barriers...” in difficult situations. It was also noted that building relationships is not necessarily an easy task, as one alum cited “gaining the trust of company management and workers” as a significant challenge in their current position.

The current IH curriculum attempts to help students develop the skill of relationship building through participation in interdisciplinary team projects; however, there are currently limited assessment mechanisms for evaluating this specific skill.

Self-directed Learning and Time Management

Several ideas around self-directed learning and time-management were discussed by advisory board members and also appeared in alumni surveys. Alumni survey respondents noted that much of what they do is self-taught and they had to learn on the job in a rapid manner. This kind of self-directed learning was highlighted during the pandemic-induced need to work remotely. Advisory board members indicated that in this autonomous environment, professionals need to be able to direct their own work.

Advisory board members also identified a strong need for good time management skills. They recognized that IH/EHS professionals are often inundated with never-ending workloads and e-mails that can be difficult and overwhelming to keep up with. It is important to be able to prioritize incoming work requests and disconnect from work responsibilities during time away from work, as one advisory board member pointed out:

“...teaching the work life balance and knowing when to take care of yourself and to step away and turn off the email and turn off the notifications. I know there is a high turnover and high burnout in safety, so it's important to also reflect on that balance.”

As noted above, advisory board members recognized the high level of burnout in the profession and recommended providing students with tips on time and self-management prior to entering the workplace.

Leadership

Advisory board members thought that leadership was an important skill for IH graduates, even in their first few years in the workplace. They noted that displaying leadership skills does not necessarily require an official position, but can include peer mentorship, influencing others to obtain resources or achieve EHS goals, and engaging in professional development both in and outside of the organization.

The current IH curriculum does not explicitly assess leadership skills, but indirectly encourages a handful of students to take on leadership roles in group projects.

Diversity, equity, inclusion

Foundational knowledge on diversity, equity, and inclusion (DEI) was identified as a growing need for IH/EHS professionals and a gap in the CSU IH Program curriculum. Specific

DEI topics identified by board members included gender, age, class, and culture. One professor recognized that the IH department consisted of only white males who may not feel confident in their ability to incorporate DEI concepts into their classrooms. Similarly, one Advisory Board member mentioned feeling some discomfort when training members of the opposite gender in certain contexts:

“My graduating class was all females, but in my work experience I’m often the only female in the room...if I’m teaching fall protection training and showing a bunch of guys how to properly fit a harness, I need to talk to them about putting keys in their pockets and how tight those straps should be, and any type of testicular damage and just [need] that comfort level of talking about those aspects in a gender diverse group.”

While professors and students may not feel comfortable addressing issues outside of their own identity, it is inevitable that they will need to work with people of many identities, backgrounds, and opinions. Since DEI is an area of focus in U.S. academic and workplace culture, there should be many resources available to help faculty develop their own competence and provide opportunities to help students build skill in this area.

CHAPTER 6: DISCUSSION

Phase 1: Curriculum Crosswalk

Results Summary

Using a (modified) curriculum mapping method, the researchers found one gap between ABET program criteria and IH Program course objectives and no gaps between BCSP criteria and IH Program course objectives in the nine core departmental courses in the CSU IH Program's curriculum. Additionally, no noteworthy gaps were found within individual course evaluations that mapped IH Program course objectives to course assessment mechanisms.

To address the ABET gap of attaining professional certification (ABET 6.3.10), it is recommended to add a course objective and materials to a core IH Program course that cover the process and requirements for achieving the most common professional certifications in IH and safety, such as the Graduate Safety Practitioner (GSP), which can be obtained upon graduation, and the Certified Industrial Hygienist (CIH) and Certified Safety Professional (CSP) designations, which can be obtained after 3 or more years of professional experience.

Variability & Redundancies

All instructors were provided with the course mapping and BIM Level of Achievement Framework instructions prior to course evaluations; however, it was obvious that there were differences in understanding and interpretation of the framework due to the variability in instructor responses. Additionally, individual professors' opinions and familiarity with general instructional design practices may have contributed to variability within the course maps. Given the goals, timeframe, and available resources for this research, this was considered acceptable for the current gap analysis. Future attempts at curriculum mapping should provide more robust training for faculty to encourage more consistency in evaluation.

Most ABET and BCSP criteria were found to align with several IH Program course objectives. While some overlap is necessary and beneficial throughout a program-of-study, there is the possibility of too much redundancy for some objectives. While this falls outside the scope of this project, many curriculum mapping projects do critically review redundancies for the purpose of program re-design (Chaney et al., 2017). The CSU IH Program could consider performing a more critical review in the future.

Process & Formatting Considerations

While the original intent of this project was to provide instructions such that instructors could evaluate their courses independently, it quickly became apparent that the process was confusing and time-consuming for instructors. Transitioning to facilitated course evaluation meetings proved to be a more successful strategy with regard to time, understanding, and consistency. This facilitated discussion strategy is also more in line with similar and more robust curriculum mapping projects in the literature. For example, Chaney et al. (2017) and Bell et al. (2009) created teams to develop curriculum maps for veterinary programs in Texas and Scotland, respectively. Zelenitsky et al. (2014) provided robust training for faculty to facilitate the curriculum mapping process for a pharmacy program in Manitoba. Finally, a curriculum committee worked directly with instructors to evaluate and modify engineering courses in Nebraska (Curtis et al., 2012). Future training needs analysis projects at CSU could consider implementing one of these strategies.

Based on initial struggles to apply the BIM Level of Achievement Framework to compare course objectives with accreditation criteria, the decision was made to simplify the process and place an “x” where objectives matched. While this was considered an acceptable

substitution for the current gap analysis, future projects may wish to consult a curriculum design expert to provide assistance on how to apply the BIM Framework to these curriculum maps.

While the use of multiple spreadsheets for each course was easy to understand and provided instructors with snapshots of their own courses, it could become inconvenient to keep track of so many individual spreadsheets during updates and larger analysis projects. Similarly, the spreadsheets currently require manual entry and updating, which may be cumbersome if these are used for future evaluations. At minimum, it is recommended to store these files in a shared drive to ensure access to the most current versions. Additionally, there are many existing software options for curriculum mapping that may solve some of the formatting and updating concerns.

Timing/Order Considerations

One common purpose of a curriculum map is to review the order of courses, to ensure that skills are being developed at the appropriate levels throughout the curriculum (TAMU, n.d.). While several courses in the CSU IH Program curriculum have prerequisites that encourage taking classes in a certain order, these are routinely bypassed due to the frequency of course offerings. This can make it difficult to build on previous course content without having to revisit beginner and/or intermediate-level knowledge.

Feedback from instructors

Instructors generally provided positive feedback about the curriculum mapping process and experience. They preferred facilitated meetings over independent analysis, citing time and opportunity to clarify the framework definitions as benefits to this process. Instructors also thought it was helpful to visualize their courses and see where their assignments lined up with

course objectives. The exercise also prompted some instructors to consider modifying or adding objectives with verbs that better aligned with the intended level of achievement.

Curriculum Mapping as a Tool for Reaccreditation

Several instructors both in and out of the department expressed interest in using this curriculum mapping process as a tool to assist with accreditation and/or improving their own programs. Being able to link accreditation requirements to course objectives and individual assessment mechanisms could expedite the often cumbersome process of providing evidence during reaccreditation. While this was not a driver for the gap analysis project, it was quickly identified as a primary benefit.

Recommendations

There are several recommendations to improve and expand on the curriculum mapping process performed in this study. First, more training should be provided on the BIM Level of Achievement evaluation framework and instructional design for all department instructors; this should encourage more consistency across course evaluations. In particular, the IH Program should consider consulting an expert in curriculum design to help provide more definition around how to assign B/I/M to course assessment mechanisms and to determine whether the BIM Level of Achievement Framework is appropriate and useful for mapping accreditation criteria and course objectives.

Future curriculum mapping could incorporate additional relevant experiences like electives, oral exam requirements, and out-of-class learning activities such as internships and research (TAMU, n.d.). This would provide a more complete picture of what the curriculum can accomplish. ABET and BCSP criteria focus primarily on technical skills geared toward industry; however, those skills may not represent all of the skills needed for every student. Additional

spreadsheets could be added to evaluate soft skills (as discovered in the group interviews) and skills needed for students who pursue a path in academia or research.

To address the challenge of building skills throughout the two-year curriculum, the IH Program could consider enrolling student cohorts only in the fall and develop a recommended order in which courses should be taken. This could allow instructors in more advanced courses to focus on material and assignments that promote mastery-level achievement, rather than having to cover remedial content from other courses.

The gap analysis is just one benefit of developing curriculum maps; curriculum maps can also be used as a basis for curriculum re-design (TAMU, n.d.). If a curriculum re-design is desired, the current research team strongly recommends creating a team with the appropriate expertise and resources to perform a robust and objective evaluation of the current curriculum and develop recommendations for change. Based on the literature, faculty involvement and input should be solicited throughout the process (Bell et al., 2009; Chaney et al., 2017; Zelenitsky et al., 2014).

Phase 2: Group Interviews & Alumni Surveys

Technical Skills

The CSU IH Program advisory board interviews and alumni surveys identified very few technical gaps in the IH Program's curriculum; this was expected since the program currently meets ABET and BCSP criteria. The most glaring gap identified by the interviews and surveys was a lack of required courses in ventilation and aerosols. AIHA lists ventilation as a technical core competency of IH professionals, and knowledge of ventilation principles consistently appears near the top of crucial technical skills for IH/ESH professionals in published literature (AIHA, 2018; L. Brosseau & Fredrickson, 2009; L. M. Brosseau et al., 2005; Oestenstad et al.,

1994). Several advisory board members mentioned that a solid understanding of ventilation and aerosol principles had become particularly important during the COVID-19 pandemic. Based on the relevant literature and recommendations from the advisory board and alumni surveys, ventilation should be added to the core IH curriculum, including complimentary knowledge in aerosols and particle behavior.

Knowledge of safety regulations (e.g., OSHA) are often listed among the most important technical skills for IH/EHS professionals in published needs assessment literature; they also appear in AIHA's core competencies for IH professionals (AIHA, 2018; L. Brosseau & Fredrickson, 2009; L. M. Brosseau et al., 2005; Oestenstad et al., 1994). The advisory board members noted that many graduates work in industries that follow regulations in addition to or instead of OSHA regulations, such as those from NFPA, DOE, and the Mining Safety and Health Administration (MSHA). They felt it was important to introduce students to some of the other regulations they may encounter in their IH/EHS careers. There are several ways faculty could address this gap, including a lecture or online module that introduces most other regulations, a small research project where students choose a regulation and present to their classmates, a weekly case study that covers different regulations, or the development of an electronic handout that summarizes each regulation and how to access it.

A number of technical skill gaps were mentioned in the alumni surveys, but were not discussed in the group interviews. Because of the variety of roles and industries available to IH graduates, it can be difficult to cover every technical topic that may be important in a given IH/EHS job. Rather than adding large volumes of specialized content to the curriculum, it is recommended that instructors teach students how to locate reputable resources on special topics,

such as electrical safety, biosafety, remediation, and workman's compensation, so they can feel prepared to handle novel situations.

Applied Skills

The four applied skills categories (business skills, adult education and training, critical thinking / problem solving, and real-world application) identified by the advisory board and alumni surveys were not necessarily seen as program gaps, but rather as critical workplace skills that require continuous development.

Business skills

The need for project management skills, like budgeting, building a business case, and managing resources, was seen as important in both the advisory board interviews and alumni surveys. This need was echoed in Oestenstad, et al.'s (1994) survey of manager expectations of entry-level industrial hygienists, where they found a gap in understanding and consideration of business and management issues. More recently, an AIHA survey of new EHS generalists and their employers identified a general lack of skills in project management (American Industrial Hygiene Association, 2019). While project management skills are largely developed in the workplace, there are many opportunities to prepare students in the classroom. For instance, the CSU IH Program could work with the business or engineering colleges to provide students with foundational information on business concepts and economics, as well as create opportunities for applied practice through team-based projects, case studies, and simulations.

Communication of technical information was seen as a critical skill in the advisory board interviews and needs assessment literature. Technical writing, such as consulting reports, was identified as a gap among some CSU IH graduates, but strongly developed in others. Technical writing was also identified as a gap in the AIHA 2019 survey of ESH generalist employers; they

noted that professionals must be able to present technical data and recommendations at the appropriate level of detail for a variety of audiences, especially when requesting resources (American Industrial Hygiene Association, 2019). The ability to communicate written technical information in a clear and logical manner also appeared as a vital skill in Brosseau, et al.'s (2009) survey of IH employers and graduates. Similar to written communication, verbal communication of technical and business data was identified as a crucial skill in both the advisory board interviews and literature. Oestenstad, et al.'s (1994) survey of managers identified communication as the "single most important skill" for entry-level industrial hygienists, citing specific examples in both written and verbal communication of technical material with an understanding of the business.

The current IH program does require technical writing (e.g., reports and memos) and oral presentations in several courses; however, there may be additional opportunities to practice and receive feedback on communication geared toward building a business case and targeting a less technical / more managerial audience. The department could consider reaching out to alumni or the business and engineering colleges for support in this endeavor.

Critical thinking & problem-solving

Thinking critically to solve novel IH/EHS problems in the workplace requires a robust technical background, understanding of acceptable/reasonable results in a given context, and an ability to collaborate with other employees to define problems, gather relevant data, and develop feasible solutions. The advisory board interviews identified specific critical thinking skills in understanding the limitations of data / models and being aware of resources; these are skills which can be added directly to the curriculum through the incorporation of assignments that use modeling software. Problem solving and critical thinking were defined more broadly in needs

assessment literature, but were nevertheless deemed as important applied skills as well (L. Brosseau & Fredrickson, 2009; L. M. Brosseau et al., 2005; Vincent, 2005).

Real-world application

One way to develop applied skills in school is through real-world application and hands-on experiences, both of which were heavily discussed in the group interviews and appear in IH needs assessment literature. In his framework for occupational hygiene (OH) graduate curricula, Vincent calls for “hands-on” experiences including lab work, field visits, and field projects (2005). CSU’s IH Program typically provides opportunities for field visits and field project work in several courses, including interdisciplinary projects with other occupational health disciplines. As one advisory board member noted, there could be additional opportunities for IH students to pursue interdisciplinary projects with students in other fields, such as business or engineering. Hands-on lab work is currently limited to one course and thesis projects that require sampling activities. While sample analysis is expensive, the program could consider expanding opportunities for hands-on experience through the collection and analysis of samples since it is a fundamental aspect of industrial hygiene practice. To address the issue of hands-on practice for safety programs, the IH program could consider developing a lab component of the occupational safety course (ERHS 528); additionally, the program could attempt to partner with a local safety/industrial training program to gain access to equipment (and space) that can be used to practice and assess safety regulations, such as LOTO, confined spaces, and work at heights.

Wybo and Van Wassenhove’s (2016) literature review on health, safety, and environmental (HSE) education includes recommendations for realistic case studies, professional conferences, and internships. The need for “real world” experience was also noted in the AIHA white paper; internships were a recommended solution to this need (2019). Many students in the

program have internships, but they are only required for Plan B (non-thesis) seeking students who have limited previous experience in the workplace. Implementing a formal internship program into the curriculum would require significant resources and may not be practical or feasible for non-traditional students, especially for those who already have industry experience. Instead of making this a requirement, the program could encourage students to use existing university resources (career center, etc.) to help match and prepare them for paid internships if they want to pursue that route.

Case studies, as mentioned in Wybo and Van Wassenhove (2016), can be an excellent classroom-based tool for exploring novel problems, ethics, business considerations, and interpersonal/cultural issues in workplace contexts. The IH program should consider making greater use of this tool for student assessments.

Adult education and training

In addition to business communication, the ability to communicate effectively to train employees on EHS topics was identified as an important skill and area of opportunity during the advisory board interviews. This finding was mirrored in surveys on IH/EHS graduate/professional expectations published by AIHA (2019) and Oestenstad, et al. (1994). The current CSU IH Program does not emphasize concepts of adult education, training, and communication. This gap could be addressed through a foundational eLearning module, followed by applied practice in the classroom or through extracurricular opportunities. This would also cover additional BCSP criteria and enhance ABET accreditation.

Soft Skills

Soft skills, such as communication, teamwork, leadership, time management, and interpersonal skills, have become increasingly important considerations in the hire of new employees in most workplaces (Succi & Canovi, 2020). This sentiment was echoed by the advisory board members, who highlighted several soft skills proficiencies required for IH professionals to be successful. Soft skills can be difficult to assess and are not often explicitly included in accreditation requirements or program goals; this leaves a large gap between educational program goals and employer expectations. The following discussion on the four soft skills identified from the advisory board interviews provides a starting point the CSU IH Program can use to intentionally incorporate soft skills development into the curriculum.

Interpersonal skills

While the advisory board members provided many examples of the importance of using written and verbal communication to effectively communicate technical information in business contexts, day-to-day interpersonal communication is also crucial to the success of IH professionals, who must interface with employees at all levels in a variety of situations. Effective communication for the IH professional is complex: as Brosseau and Fredrickson's (2009) survey of IH employers indicated, communication requires building a foundation of trust among employees, listening, being willing to negotiate or alter original plans, and harnessing one's charisma and sales capabilities in order to persuade others to achieve health and safety goals. As the advisory board members and surveyed alumni pointed out in several examples, EHS discussions can become tense and/or uncomfortable, and IH professionals must be prepared to handle this resistance while maintaining relationships and promoting positive safety culture.

How can a curriculum create conditions to help students develop interpersonal skills? The researchers recommend starting by teaching students the fundamentals of emotional intelligence so they can better understand themselves and others. One professor has previously required that students read *Crucial Conversations*, a popular book that provides tools for handling difficult conversations in the workplace and beyond; based on these interview data, he plans to reincorporate this activity into his classroom (Patterson et al., 2012). Additionally, role play activities or simulations of tense situations can help students practice and develop their confrontational skills in a low-stakes, safe environment before jumping into real world situations. Along with providing opportunities to practice interpersonal skills, the CSU IH Program should provide students with productive feedback so they can improve. As mentioned earlier, soft skills can be difficult to evaluate, so instructors may need some training on how to properly assess these skills.

Self-directed Learning & Time Management

Self-directed learning and time management were mentioned as important skills for early IH/EHS professionals, particularly in the context of the COVID-19 pandemic, which forced many professionals to work from home for several months. While neither skill was explicitly mentioned in existing IH needs assessment literature, they do appear as “learning skills” and “life balance skills” in Succi and Canovi’s (2020) study on assessing the importance of soft skills for young professionals in Europe. Future IH needs assessment studies should consider adding these soft skills to their survey questions, because they are both crucial to solving problems in a timely manner and gaining independence as a professional. Additionally, time management and life balance skills are critical in a profession anecdotally known for high levels of stress and burnout.

To promote self-directed learning, some courses in the CSU IH Program curriculum incorporate independent and/or open-ended projects that require students to research a chosen topic or work with companies to define and solve real occupational health issues in the workplace. Academic research required for the completion of student theses or professional papers also lends itself to self-directed learning; however, advising professors should be made aware of methods for promoting self-directed learning in this area in order to foster development of this skill. To stimulate the development of effective time-management and life balance skills, the CSU IH Program could invite industry professionals to share their work experiences and methods for prioritizing and managing workloads, e-mails, and competing priorities.

Leadership

As identified in the advisory board interviews, it is important for young EHS professionals to pursue opportunities for the development of leadership skills. In an EHS/workplace context, developing leadership skills means taking on roles of increasing ownership, responsibility, and/or influence over programs and policies, processes, projects, or people (Succi & Canovi, 2020; Vincent, 2005; Wybo & Van Wassenhove, 2016). One of the most common ways to promote leadership skills in academic curricula is through team-based projects; however, the leader position is often taken by the most assertive students, with minimal guidance on effective leadership and team/project management techniques. This can result in poor leadership and frustration on the part of many students.

To provide better opportunities for leadership development, the CSU IH Program could consider designing opportunities for each student to be the subject matter expert (SME) for a topic in class, or structure team projects so all students can take a leading role on one piece of the project. The program could also consider providing training on effective team and project

management methods and encourage students to pursue leadership roles in student and professional organizations.

Diversity, Equity, Inclusion

Another skill that received significant discussion in an unrecorded group interview was diversity, equity, and inclusion (DEI). While DEI does not appear in IH needs assessment literature, it is a topic of increasing importance in the American workplace. IH/EHS professionals are tasked with promoting a safe working environment, so having a solid understanding of DEI issues in the workplace can help achieve this goal.

To promote the development of DEI skills, the CSU IH Program could include topics such as: gender considerations when discussing certain types of personal protective equipment (PPE), workplace accommodations for different abilities and religious practices, and ensuring training is available in preferred languages and designed for a variety of learning abilities. It is also recommended that professors and students receive foundational DEI knowledge to provide a common language for classroom discussions. Certain DEI topics have the potential to become sensitive issues in the workplace, so the program should consider additional training for students and faculty on how to effectively navigate these issues.

Process Strengths and Weaknesses

Alumni Surveys

By using results from several previous alumni surveys, the research team was able to capture the experiences of CSU IH Program alumni at various points in time, which has the potential to account for the continually evolving needs of the IH/EHS profession. However, the research team recognizes that the inability to develop survey questions and follow up with

respondents are weaknesses to using these survey data. Additionally, selection bias is inherent to these data – those who responded to the survey are likely to have different opinions than those who did not respond, which makes the results less generalizable.

Advisory Board Interviews

Using Zoom for the interviews enabled wider participation, which may not have been possible in person. Additionally, using small breakout rooms allowed participants to explore many more areas than could have been discussed in a larger group; however, each group required a facilitator, so this may be difficult to reproduce.

Posing a broad, open-ended question enabled participants to bring to the table any skill they thought of and allowed the discussions to cover topics that were unanticipated by the research team. However, there are some important topics that may have been overlooked, and the research team must be careful not to overemphasize the importance of the topics that happened to be discussed during these interviews.

Selection bias was also present in the interview process; if a different group of IH professionals had been recruited, the data would have been different. Additionally, these interview data represent the opinions and experiences of members of the advisory board at a single point in time. It is recommended to conduct interviews like these on a regular basis to 1) account for the IH/EHS profession's evolving needs, and 2) gain feedback on the skills of program graduates to see if curriculum changes are producing desired results.

Qualitative Data Analysis

By partnering with adult education professionals to perform a robust qualitative data analysis, the research team was able to uncover several additional soft skills from the interview discussions that do not appear in current IH needs analysis literature. The identification of these

crucial workplace skills is an important addition to the literature, and should encourage the CSU and other IH programs to add these skills to their curricula.

CHAPTER 7: CONCLUSION

The aim of this study was to assess the gaps that exist between industry needs, ABET/BCSP accreditation criteria, and the current curriculum for the CSU IH Program, and use these data to recommend improvements to the curriculum. The curriculum mapping exercise identified one gap between ABET and IH course objectives, which can be addressed by adding relevant content to one course. More importantly, the method and tools used to perform the evaluation were developed with the intent to support a cumbersome reaccreditation process. By mapping accreditation criteria with course objectives, and course objectives with course assessment mechanisms, one can ensure that courses are in alignment with accreditation requirements and provide clear links to the evidence required to support reaccreditation. These methods and tools can be easily modified to support the reaccreditation process for other IH graduate programs, as well as other occupational health programs.

By performing a robust qualitative analysis on data collected from group interviews and alumni surveys, the research team identified several technical skills, applied skills, and soft skills that must be developed by IH graduate students in order to become successful IH/EHS professionals. These skill gaps can be incorporated into the curriculum to improve the training of IH students. Additionally, the qualitative analysis uncovered soft skills previously unidentified by IH needs assessments, providing valuable information for all IH graduate programs. It is recommended to conduct interviews with IH/EHS professionals regularly in order to gain feedback on curriculum changes and identify the need for any new skills.

REFERENCES

- ABET. (2019). *Criteria for accrediting applied and natural science programs* (No. R001).
- AIHA. (2018). *Core competencies for the practice of industrial occupational hygiene*. AIHA. <https://www.aiha.org/publications/core-competencies-for-the-practice-of-industrial-occupational-hygiene>
- American Industrial Hygiene Association. (2019). *Hiring recent EHS generalist graduates: Expectations from hiring managers, recent graduates and academics* [White Paper]. AIHA. https://aiha-assets.sfo2.digitaloceanspaces.com/AIHA/resources/Hiring-Recent-EHS-Generalist-Graduates-White-Paper_200601_131400.pdf
- BCSP. (2019). *Examination blueprint (ASP10)*. <https://www.bccsp.org/wp-content/uploads/2021/12/ASP-Blueprint.pdf>
- Bell, C. E., Ellaway, R. H., & Rhind, S. M. (2009). Getting started with curriculum mapping in a veterinary degree program. *Journal of Veterinary Medical Education*, 36(1), 100–106. <https://doi.org/10.3138/jvme.36.1.100>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Brazile, W. (2020). *ABET OEHS administrative plan*.
- Briedis, D., Rogers, G., & Warnock, J. (2017, January). *ABET IDEAL notebook*. <https://www.abet.org/wp-content/uploads/2017/02/IDEAL-Notebook.pdf>
- Brosseau, L. (1995). Results of a survey to assess curriculum needs for academic training-programs in hazardous substances. *American Industrial Hygiene Association Journal*, 56(9), 905–910.

- Brosseau, L., & Fredrickson, A. (2009). Assessing outcomes of industrial hygiene graduate education. *Journal of Occupational and Environmental Hygiene*, 6(5), 257–266.
<https://doi.org/10.1080/15459620902754372>
- Brosseau, L. M., Raynor, P. C., & Lungu, C. (2005). Employers' expectations of knowledge and skills of master's-trained industrial hygienists. *Journal of Occupational and Environmental Hygiene*, 2(1), 1–7. <https://doi.org/10.1080/15459620590894733>
- Chaney, K. P., Macik, M. L., Turner, J. S., Korich, J. A., Rogers, K. S., Fowler, D., Scallan, E. M., & Keefe, L. M. (2017). Curriculum redesign in veterinary medicine: Part I. *Journal of Veterinary Medical Education*, 44(3), 552–562. <https://doi.org/10.3138/jvme.0316-065R1>
- Curtis, E. T., Kelly, A. M., McCoy, J. I. E., Jones, D., & Schulte, D. D. (2012, June). Development of evidence management and gap analysis tools for continuous improvement of engineering programs. *2012 ASEE Annual Conference*.
<http://www.webofscience.com/wos/woscc/summary/bd134be4-1474-4bd2-955c-24addb670166-47a6f0b1/relevance/1>
- Easa, S. M. (2013). Framework and guidelines for graduate attribute assessment in engineering education. *Canadian Journal of Civil Engineering*, 40(6), 547–556.
<https://doi.org/10.1139/cjce-2012-0485>
- Golding, K. (2022, August 9). *QAP Graduation Folder from BCSP* [Personal communication].
- Kurt, S. (2019, April 24). Using Bloom's Taxonomy to Write Effective Learning Objectives: The ABCD Approach. *Educational Technology*. <https://educationaltechnology.net/using-blooms-taxonomy-to-write-effective-learning-objectives-the-abcd-approach/>

- Oestenstad, R., Boggs, R., & Perkins, J. (1994). An analysis of manager expectations for entry-level industrial hygienists. *American Industrial Hygiene Association Journal*, 55(6), 546–551.
- Patterson, K., Grenny, J., McMillan, R., & Switzler, A. (2012). *Crucial Conversations* (2nd ed.). McGraw-Hill.
- Shabatura, J. (2022, July 26). *Using Bloom's Taxonomy to write effective learning outcomes*. <https://tips.uark.edu/using-blooms-taxonomy/>
- Succi, C., & Canovi, M. (2020). Soft skills to enhance graduate employability: Comparing students and employers' perceptions. *Studies in Higher Education*, 45(9), 1834–1847. <https://doi.org/10.1080/03075079.2019.1585420>
- TAMU. (n.d.). *TAMU CTE - Create Curriculum Map*. <https://cte.tamu.edu/Faculty-Teaching-Resource/Program-ReDesign/Curriculum-Mapping>
- Turnbeaugh, T. (2017, April 18). *QAP Approval Letter* [Personal communication].
- Vincent, J. H. (2005). Graduate education in occupational hygiene: A rational framework. *Annals of Occupational Hygiene*, 49(8), 649–659. <https://doi.org/10.1093/annhyg/mei043>
- Wybo, J.-L., & Van Wassenhove, W. (2016). Preparing graduate students to be HSE professionals. *Safety Science*, 81, 25–34. <https://doi.org/10.1016/j.ssci.2015.04.006>
- Zelenitsky, S., Vercaigne, L., Davies, N. M., Davis, C., Renaud, R., & Kristjanson, C. (2014). Using curriculum mapping to engage faculty members in the analysis of a pharmacy program. *American Journal of Pharmaceutical Education*, 78(7), 139. <https://doi.org/10.5688/ajpe787139>

APPENDIX A: Curriculum Crosswalk Spreadsheet Examples

ERHS 526 Objective / Assessment Map											
Instructions (Details on Instructions Tab)											
1. Type in the course objectives in Row 1, Columns C-Q (diagonal rows)											
2. Insert the corresponding achievement level [Beginner (B), Intermediate (I), Master (M)] for each objective in Row 2, Columns C-Q											
3. Type all course assessment mechanisms into Column A, Rows 4-75											
4. For each assessment, determine which course objective(s) it is tied to											
5. Assess the achievement level of the assessment mechanism in relation to the objective(s) it covers and indicate with a B/I/M in the appropriate square											
Course Objectives	1. Identify Agents, factors, stressors generated by and/or associated with chemical, physical, and biological hazards in occupational environments	2. Describe quantitative aspects of generation of agents, factors, and stressors	3. Assess quantitative aspects of exposure assessment	4. Solve complex problems through a combination of observation, literature review, measurement and hygiene computational methods	5. Apply appropriate regulations and data analysis assessment and risk management and guidelines in occupational environments using industrial personal protective equipment to reduce or eliminate	6. Recommend and evaluate engineering, administrative, and writing interventions to reduce or eliminate hazards	7. Communicate results and recommendations effectively in writing	8. Objective	9. Objective	10. Objective	11. Objective
Expected Learning Achievement Level (B/I/M)											
Course Assessment Mechanisms											
Homework 1: Fundamental Concepts											
Homework 2: Sampling Strategy - Statistics											
Homework 3: Compliance - Lead Sampling											
Homework 4: TLVs											
Homework 5: Gas & Vapor Sampling											
Homework 6: Aerosols & Ventilation											
Homework 7: Thermal Stress											
Homework 8: Noise											
Homework 9: non-ionizing radiation											
Exam 1: Landfill exposure analysis + sampling											
Exam 2: Control strategy / Hazard mitigation scenario											
Exam 3: Final											
Technical writing draft											
Technical writing final											
in class exercises/calculations											

Figure A1: Course Objectives vs Course Assessment Mechanisms spreadsheet for ERHS 526

ABET Criteria for Accrediting Industrial Hygiene Programs (2020-2021) Instructions (Details on Instructions tab) 1. Type and/or verify the ABET program criteria and educational objectives in Row 2, Columns C-5 (diagonal boxes) 2. Type and/or verify the objectives for your course into Column A, Rows 5-19 3. For each course objective, identify which ABET criteria/objectives it is tied to by placing an "x" in the appropriate box on the matrix	ABET Program Criteria 6.3.1. Identify agents, factors, and stressors generated by and/or associated with defined sources, unit operations, and/or processes 6.3.2. Describe qualitative and quantitative aspects of generation of agents, factors, and stressors 6.3.3. Understand physiological and/or toxicological interactions of physical, chemical, biological, and ergonomic agents, factors, and stressors on human body 6.3.4. Assess qualitative and quantitative aspects of exposure assessment dose response and risk characterization based on applicable pathways and modes of entry 6.3.5. Calculate, interpret, and apply statistical and epidemiological data 6.3.6. Recommend and evaluate engineering, administrative, and personal protective equipment controls and/or other interventions to reduce or eliminate hazards 6.3.7. Demonstrate an understanding of applicable business and managerial practices 6.3.8. Interpret and apply applicable occupational and environmental regulations 6.3.9. Understand and apply applicable occupational and environmental health 6.3.10. Attain recognized professional certification									
	ABET Student Outcomes 6.4.1. Identify, formulate, and solve broadly defined technical or scientific problems by applying knowledge of mathematics, physics, chemistry, environmental and occupational health 6.4.2. Formulate or design a system, process, procedure or program to meet desired health hypotheses, analyze and interpret data and use scientific judgement to draw conclusions 6.4.3. Develop and conduct experiments or test hypotheses, analyze and interpret data and use scientific judgement to draw conclusions 6.4.4. Communicate effectively both verbally and in writing with a range of audiences 6.4.5. Understand ethical and professional responsibilities and the impact of technical and environmental, and societal context 6.4.6. Function effectively on teams that establish goals, plan tasks, meet deadlines and analyze risk and uncertainty									
Course Objectives										
ERHS 526: Industrial Hygiene										
1. Identify Agents, factors, stressors generated by and/or associated with chemical, physical, and biological hazards in occupational environments										
2. Describe quantitative aspects of generation of agents, factors, and stressors										
3. Assess quantitative aspects of exposure assessment										
4. Solve complex problems through a combination of observation, literature review, measurement and data analysis within a variety of occupational environments using industrial hygiene computational methods										
5. Apply appropriate regulations and guidelines in risk assessment and risk management to reduce or eliminate occupational exposures										
6. Recommend and evaluate engineering, administrative, and personal protective equipment controls and/or other interventions to reduce or eliminate hazards										
7. Communicate results and recommendations effectively in writing										

Figure A2: ABET Criteria vs Course Objectives spreadsheet for ERHS 526

APPENDIX B: Curriculum Crosswalk Instructions for Faculty

Document 1: Faculty Instructions

Developing Learning Objectives and Aligning Curriculum Elements Faculty Instructions

The purpose of this document is to provide instructors with the knowledge and tools needed to:

1. Develop appropriate learning objectives using Bloom's taxonomy
2. Translate learning objectives into the Level of Achievement framework in preparation for a curriculum crosswalk
3. Evaluate whether learning objectives are being met by course assessment mechanisms
4. Perform a curriculum crosswalk to ensure learning objectives are in alignment with accreditation requirements

These activities are intended to clearly link program goals with course learning objectives and assessment mechanisms (Figure B1). This is considered a best practice for instructional design and should help instructors maximize the educational value of their courses. Additionally, this exercise will help instructors provide adequate evidence that they are meeting accreditation requirements.

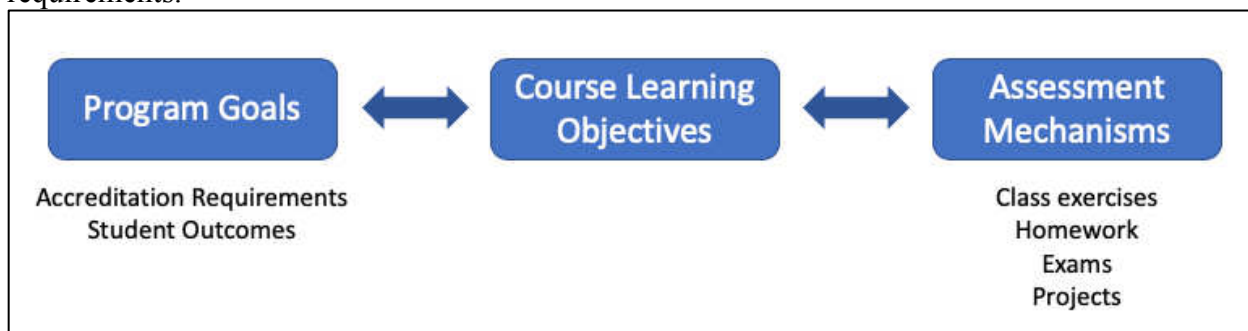


Figure B1: Linking program goals, learning objectives, and assessment mechanisms are important elements of instructional design for all courses.

Step 1: Develop appropriate learning objectives using Bloom's taxonomy

Bloom's Taxonomy is a hierarchical framework educators can use to develop and classify learning outcomes for students. You will use this framework to revise and/or develop learning objectives for a given course.

- A. Become familiar with Bloom's taxonomy and how to write effective learning objectives by reviewing the following resource documents, located in the zip file:
 - i. Resource #1_Blooms_Overview.pdf
 - ii. Resource #2_Writing_Effective_Objectives.pdf
 - iii. Resource #3_Blooms_Verb_List.pdf
- B. Review the existing learning objectives on the syllabus for your course and decide if any should be removed. For each remaining learning objective, use the following questions to ensure that each objective is appropriate and corresponds with Bloom's taxonomy:

- i. *What level of learning am I asking students to achieve with this objective?*
 - a) Your objective should fall under one of Bloom’s six levels (Remember, Understand, Apply, Analyze, Evaluate, Create) of learning (refer to Resource #1).
- ii. *Does this objective include a verb listed under the appropriate level of learning on the provided verb resource (refer to Resource #3)?*
 - a) If there is a verb present that does not correspond to the desired Bloom’s level of learning desired or does not exist on the verb list provided, replace it with a verb from the provided resource.
 - b) If there is not a verb used in the objective description, select the appropriate verb in correspondence with your answer to the previous question (identified level of learning) and incorporate it into the objective.
- iii. *Does this objective follow the “ABCD” format (refer to Resource #2)?*
 - a) At minimum, your objectives should include an audience and behavior (verb).
 - b) Specific and measurable learning objectives will help students understand learning expectations and also help you to assess whether the learning objective has been achieved.

C. Code Objectives to Bloom’s Levels of Learning

- i. Make a note next to each revised objective to indicate which of the six levels of learning that should be achieved through accomplishing that objective. (Refer to the Bloom’s verb list [Resource #3] if needed.)

D. Follow the instructions on the “ERHS XXX map” tab in the Excel spreadsheet to record each learning objective for the course you’re working on. An example of a completed section is shown below:

ERHS 637 Objective / Assessment Map	
Instructions (Details on Instructions Tab) 1. Type in the course objectives in Row 1, Columns C-Q (diagonal rows) 2. Insert the corresponding achievement level [Beginner (B), Intermediate (I), Master (M)] for each objective in Row 2, Columns C-Q 3. Type all course assessment mechanisms into Column A, Rows 4-75 4. For each assessment, determine which course objective(s) it is tied to 5. Assess the achievement level of the assessment mechanism in relation to the objective(s) it covers and indicate with a B/I/M in the appropriate square	
Course Objectives 1. Develop an ES&H management system 2. Describe the major standards/regulations applicable to an ES&H generalist position 3. Enumerate the primary requirements for major environmental regulatory agencies 4. Apply the appropriate regulatory requirements for specific ES&H conditions 5. Describe the business case for ES&H management and programs by developing and tracking meaningful metrics 6. Develop and track ES&H performance metrics and goals 7. Conduct trend analysis of events and conditions 8. Participate in crucial conversations 9 10	

Figure B2: Example of a completed course objectives section on the “ERHS XXX map” tab.

Step 2: Translate learning objectives into the Level of Achievement framework

- i. Be sure to include a short description of each assessment so you can easily remember the activity:
 - a) **Example:** Homework #1 – Review of vapors and gases
 - b) **Example:** In-class exercise – REBA assessment (with video example)
 - c) **Example:** Presentation – Environmental legislation
- B. Identify which course assessment mechanisms correlate to each learning objective.
 - i. Note: If you’re using the Excel spreadsheet (“ERHS XXX map” tab), you may want to just place an “x” in each box where a learning objective and corresponding assessment mechanism intersect.
- C. Use the Level of Achievement framework (B/I/M) to identify how each assessment mechanism relates to the achievement of the overall objective. (Refer to Resource #4)
 - i. Note: On the Excel spreadsheet (“ERHS XXX Map” tab), you’ll be replacing the “x” placeholders from the previous step with the Level of Achievement framework B/I/M indicators
- D. Follow the instructions on the “ERHS XXX map” tab in the Excel spreadsheet to record the Level of Achievement code (B/I/M) for the course you’re working on. An example of a completed section is shown below:

ERHS 637 Objective / Assessment Map											
Instructions (Details on Instructions Tab)											
1. Type in the course objectives in Row 1, Columns C-Q (diagonal rows)											
2. Insert the corresponding achievement level [Beginner (B), Intermediate (I), Master (M)] for each objective in Row 2, Columns C-Q											
3. Type all course assessment mechanisms into Column A, Rows 4-75											
4. For each assessment, determine which course objective(s) it is tied to											
5. Assess the achievement level of the assessment mechanism in relation to the objective(s) it covers and indicate with a B/I/M in the appropriate square											
	Course Objectives	1. Develop an ES&H management system	2. Describe the major standards/regulations applicable to an ES&H generalist position	3. Enumerate the primary requirements for major environmental regulatory agencies	4. Apply the appropriate regulatory requirements for major and programs by developing and tracking meaningful metrics	5. Describe the business case for ES&H management	6. Develop and track ES&H performance metrics and goals	7. Conduct trend analysis of events and conditions	8. Participate in crucial conversations	9	10
Expected Learning Achievement Level (B/I/M)		M	B	B	I	I	M	I	I		
Course Assessment Mechanisms											
OHSMS Portfolio Team Assignment		M					I				
Student Environmental Presentation				B							
Homework 1: Business Case Discussion		B				B					
Homework 2: Safety and Health Policy		I									
Class Activity: OSHA's Process Safety Management of Highly Hazardous chemicals			B		B		B				
Class Activity: What-If Analysis of a Gas Pump								B			

Figure B4: Example of an assessment mechanism list with B/I/M indicators that meet corresponding learning objectives on the “ERHS XXX map” tab.

Step 4: Perform a curriculum crosswalk to ensure learning objectives are in alignment with accreditation requirements

A curriculum crosswalk is an exercise used to prove that course learning objectives and assessments are meeting expected learning outcomes (e.g., accreditation requirements); it also allows instructors to see where gaps exist so they can make improvements.

- A. Identify which course assessment mechanisms correlate to each learning objective.
- B. Follow the instructions on the “Curriculum Map (ABET)” and “Curriculum Map (BCSP)” tabs in the Excel spreadsheet to identify (with an “x”) where a learning objective is related to an accreditation requirement. An example is shown below:

ABET Criteria for Accrediting Industrial Hygiene Programs (2020-2021)										
Instructions (Details on Instructions tab)										
1. Type and/or verify the ABET program criteria and educational objectives in Row 2, Columns C-5 (diagonal boxes)										
2. Type and/or verify the objectives for your course into Column A, Rows 5-19										
3. For each course objective, identify which ABET criteria/objectives it is tied to by placing an "x" in the appropriate box on the matrix										
Course Objectives	6.3.1. Identify agent-personal protective equipment and other interventions to reduce or eliminate occupational hazards	6.3.7. Demonstrate an understanding of applicable business and managerial practices and environmental regulations	6.3.9. Interpret and apply applicable occupational environmental regulations	6.3.10. Attain recognized fundamental occupational aspects of safety and health	6.4.1. Identify, formulate, and solve broadly defined technical & scientific problems by applying knowledge of mathematics, physics, chemistry, environmental and occupational health procedure or design a system, process, hypothesis, analyze and interpret data and use scientific judgement to draw conclusions	6.4.2. Formulate or design a system, process, hypothesis, analyze and interpret data and use scientific judgement to draw conclusions	6.4.3. Develop and conduct experiments or test writing with a range of audiences	6.4.4. Communicate effectively both verbally and in writing with a range of audiences	6.4.5. Understand ethical and professional responsibilities and the impact of local, national, and global environmental and social issues	6.4.6. Function in a global and diverse environment
ERHS 637: Environment, Safety, and Health Management										
1. Develop an ES&H management system								x		x
2. Describe the major standards/regulations applicable to an ES&H generalist position	x		x	x		x			x	
3. Enumerate the primary requirements for major environmental regulatory agencies		x		x						
4. Apply the appropriate regulatory requirements to specific ES&H conditions		x		x		x				

Figure B5: Example of a curriculum crosswalk that aligns course learning objectives with ABET accreditation requirements (“Curriculum Map (ABET)” tab).

Once you’ve revised/verified your learning objectives and filled out all three tabs on the Excel spreadsheet, save the spreadsheet and send it to Jillian Moore (jillian.moore@colostate.edu). Our research team will compile the information for all courses and use it to perform a comprehensive gap analysis of the Industrial Hygiene program. This will help our program achieve the continuous improvement requirement for ABET accreditation. Thanks for your help!

Document 2: Resource 1 – Bloom’s Overview

Adapted from:
Using Bloom’s Taxonomy to Write Effective Learning Objectives

Posted by [Jessica Shabatura](#) | Sep 27, 2013 | [Assignments & Measuring Student Learning](#)
<https://tips.uark.edu/using-blooms-taxonomy/>

Bloom’s Taxonomy is a classification of the different objectives and skills that educators set for their students (learning objectives).

What is Bloom's Taxonomy

Bloom's Taxonomy is a classification of the different objectives and skills that educators set for their students (learning objectives). The taxonomy was proposed in 1956 by Benjamin Bloom, an educational psychologist at the University of Chicago. The terminology has been recently updated to include the following six levels of learning. These 6 levels can be used to structure the learning objectives, lessons, and assessments of your course:

1. **Remembering:** Retrieving, recognizing, and recalling relevant knowledge from long-term memory.
2. **Understanding:** Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.
3. **Applying:** Carrying out or using a procedure for executing, or implementing.
4. **Analyzing:** Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing, and attributing.
5. **Evaluating:** Making judgments based on criteria and standards through checking and critiquing.
6. **Creating:** Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.

Like other taxonomies, Bloom's is hierarchical, meaning that learning at the higher levels is dependent on having attained prerequisite knowledge and skills at lower levels. You will see Bloom's Taxonomy often displayed as a pyramid graphic to help demonstrate this hierarchy. We have updated this pyramid into a "cake-style" hierarchy to emphasize that each level is built on a foundation of the previous levels.

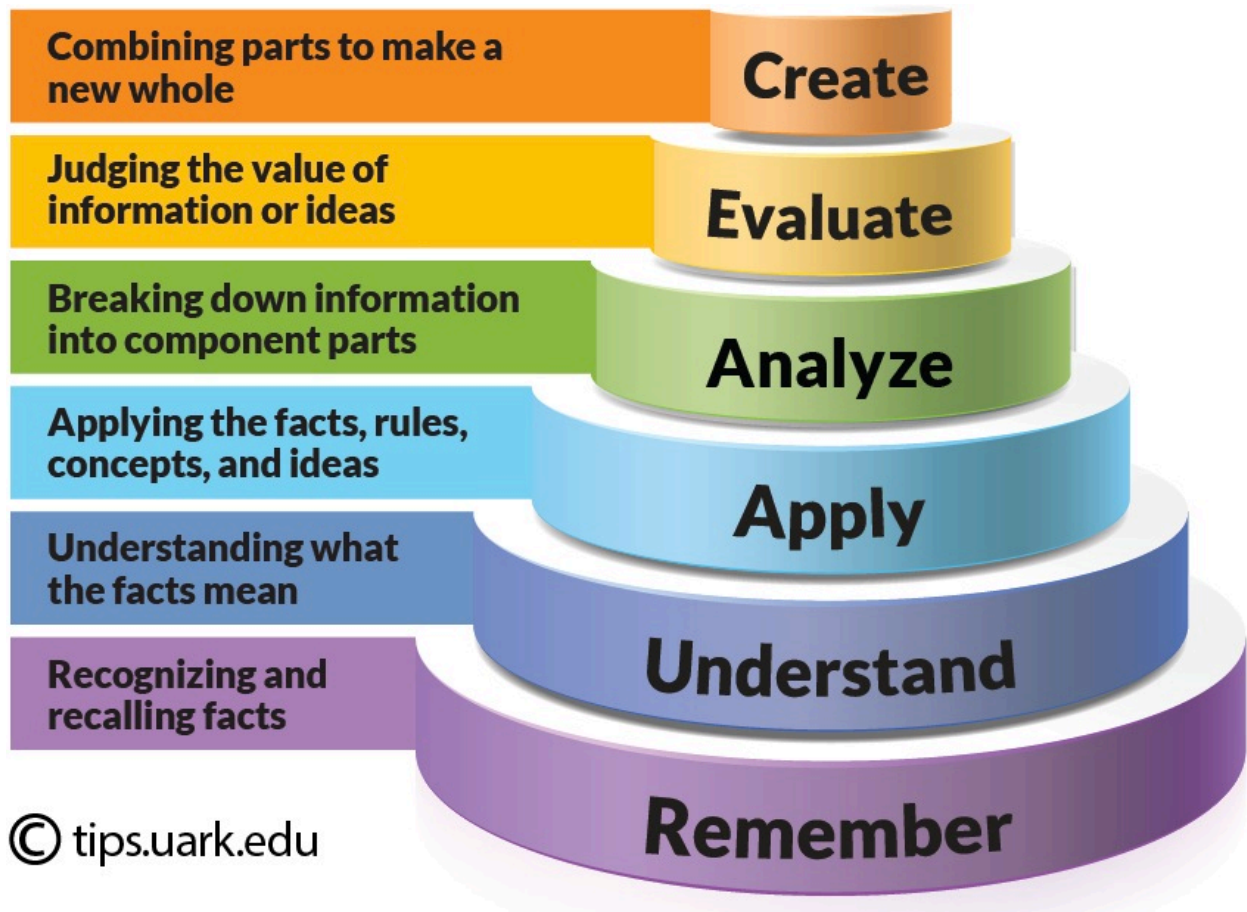


Figure B6: Bloom's Taxonomy visualization; credit to Jessica Shabatura & <https://tips.uark.edu/using-blooms-taxonomy/>

How Bloom's can aid in course design

Bloom's taxonomy is a powerful tool to help develop learning objectives because it explains the process of learning:

- Before you can *understand* a concept, you must *remember* it.
- To *apply* a concept you must first *understand* it.
- In order to *evaluate* a process, you must have *analyzed* it.
- To *create* an accurate conclusion, you must have completed a thorough *evaluation*.

However, we don't always start with lower order skills and step all the way through the entire taxonomy for each concept you present in your course. That approach would become tedious—for both you and your students! Instead, start by considering the level of learners in your course:

1. Are lots of your students freshman? Is this an “Introduction to...” course? If so, many your learning objectives may target the lower order Bloom’s skills, because your students are building foundational knowledge. However, even in this situation we would strive to move a few of your objectives into the **applying** and **analyzing** level, but getting too far up in the taxonomy could create frustration and unachievable goals.
2. Are most of your students juniors and seniors? Graduate students? Do your students have a solid foundation in much of the terminology and processes you will be working on your course? If so, then you should not have many **remembering** and **understanding** level objectives. You may need a few, for any radically new concepts specific to your course. However, these advanced students should be able to master higher-order learning objectives. Too many lower level objectives might cause boredom or apathy.

How Bloom’s works with learning objectives

Fortunately, there are “verb tables” to help identify which action verbs align with each level in Bloom’s Taxonomy.

You may notice that some of these verbs on the table are associated with multiple Bloom’s Taxonomy levels. These “multilevel-verbs” are actions that could apply to different activities. For example, you could have an objective that states “At the end of this lesson, students will be able to **explain** the difference between H₂O and OH-.” This would be an **understanding** level objective. However, if you wanted the students to be able to “...**explain** the shift in the chemical structure of water throughout its various phases.” This would be an **analyzing** level verb.

Adding to this confusion, you can locate Bloom’s verb charts that will list verbs at levels different from what we list below. Just keep in mind that it is the skill, action or activity you will teach *using that verb* that determines the Bloom’s Taxonomy level.

Bloom’s Level	Key Verbs (keywords)	Example Learning Objective
Create	design, formulate, build, invent, create, compose, generate, derive, modify, develop.	<i>By the end of this lesson, the student will be able to design an original homework problem dealing with the principle of conservation of energy.</i>
Evaluate	choose, support, relate, determine, defend, judge, grade, compare, contrast, argue, justify, support, convince, select, evaluate.	By the end of this lesson, the student will be able to determine whether using conservation of energy or conservation of momentum would be more

		appropriate for solving a dynamics problem.
Analyze	classify, break down, categorize, analyze, diagram, illustrate, criticize, simplify, associate.	<i>By the end of this lesson, the student will be able to differentiate between potential and kinetic energy.</i>
Apply	calculate, predict, apply, solve, illustrate, use, demonstrate, determine, model, perform, present.	<i>By the end of this lesson, the student will be able to calculate the kinetic energy of a projectile.</i>
Understand	describe, explain, paraphrase, restate, give original examples of, summarize, contrast, interpret, discuss.	<i>By the end of this lesson, the student will be able to describe Newton's three laws of motion to in her/his own words</i>
Remember	list, recite, outline, define, name, match, quote, recall, identify, label, recognize.	<i>By the end of this lesson, the student will be able to recite Newton's three laws of motion.</i>

Figure B7: Bloom's Taxonomy examples of learning objectives; adapted from Nelson Baker at Georgia Tech (nelson.baker@pe.gatech.edu)

How Bloom's works with Quality Matters

For a course to meet the [Quality Matters](#) standards it must have learning objectives that are measurable. Using a verb table like the one above will help you avoid verbs that cannot be quantified, like: understand, learn, appreciate, or enjoy. Quality Matters also requires that your course assessments (activities, projects, and exams) align with your learning objectives. For example, if your learning objective has an **application** level verb, such as "present", then you cannot demonstrate that your students have mastered that learning objective by simply having a multiple choice quiz.

Steps towards writing effective learning objectives:

1. Make sure there is one measurable verb in each objective.
2. Each objective needs one verb. Either a student can master the objective, or they fail to master it. If an objective has two verbs (say, *define* and *apply*), what happens if a student can define, but not apply? Are they demonstrating mastery?
3. Strive to keep all your learning objectives measurable, clear and concise.

When you are ready to write, it can be helpful to list the level of Bloom's next to the verb you choose in parentheses. For example:

Course level objective 1. (*apply*) Demonstrate how transportation is a critical link in the supply chain.

This trick will help you quickly see what level verbs you have.

Document 3: Resource 2 – Writing Effective Objectives

Tips for Writing Effective Objectives

Adapted from (Kurt, 2019)

Learning objectives can be identified as the goals that should be achieved by a student at the end of a lesson. The objectives of a lesson describe the base knowledge and skills we want our students to learn from our lesson. Simply put, it's what the student can do after they unit has been introduced. Your choice of materials, topics and logical structured presentation of a lesson has a direct influence on the objectives or goals you want your students to achieve.

Having a clear learning objective assists the facilitator or teacher in the basic course design. It helps with the creation of assessment, which in return showcases the student's ability to achieve the objectives through collecting data. Monitoring a student's progress throughout the learning process is vital to understand whether they are able to reach the learning objective or not. Furthermore, assessing students helps the teacher to realize whether teaching methods should be adjusted or not.

Having specific goals help the logical flow of a lesson. It's vital that a lesson is tailored to achieve detailed lesson objectives. In order for the lesson to have a positive and constructive outcome. Basically, to make sure that students achieve the aim of the lesson.

This process can be simplified by following a basic formula: The ABCD approach. By using this formula, you will be able to create clear and effective objectives. It consists of four key elements: **(A) Audience, (B) Behavior, (C) Condition, and (D) Degree.**

A-Audience: Determine who will achieve the objective.

B-Behavior: Use action verbs (Bloom's taxonomy) to write observable and measurable behavior that shows mastery of the objective.

C-Condition: If any, state the condition under which behavior is to be performed. (Optional)

D-Degree: If possible, state the criterion for acceptable performance, speed, accuracy, quality, etc. (Optional)

Please note that not every learning objective must contain a condition or state a degree.

Please also note that objectives may not be written in this order (ABCD).

Examples:

Below are some example objectives which include Audience, Behavior, Condition, Degree

1. “Students will be able to apply the standard deviation rule to the special case of distributions having a normal shape.”
2. “Given a specific case study, learners will be able to conduct at least 2 needs analysis.”
3. “Given a diagram of the eye, students will be able to label the 9 extra-ocular muscles and describe at least 2 of their actions.”
4. “Students will explain the social justice to ensure that adequate social services are provided to those who need them in three paragraphs.”

Audience

First you need to establish what prior knowledge your students have. Assess whether your students know any of the materials you want to present. What experiences do they have prior to coming into the classroom? By taking into account their valuable prior knowledge you will be able to create an innovative lesson, with unique content. Content that your students don't know about yet.

Prior knowledge can be assessed by giving all students a pre-test or a pre-course quiz. It's vital to accurately understand a student's prior knowledge to avoid misconceptions and misunderstandings. In this way you can avoid repeating information they already know as well as adjust your learning objectives accordingly.

This also gives you the opportunity to get to know your students that will help you adapt your teaching styles and methods. It's important to know what motivates your new audience, what are their values and personality types. You can also discover what kind of learners they are. By assessing your students' prior knowledge, you can add activities and worksheets that they will find interesting and can relate to.

Now, you can also make sure that the content you want to present are relevant to their reference frameworks. You can add extra materials and topics to challenge them and to tailor the learning objectives to the skills that they need to obtain and not the skills they already have.

After identifying your Audience by keeping the above-mentioned alternatives in mind you can start writing down your learning objectives. Usually it starts with a phrase like, “After reviewing this section, students will be able to...” or “After completing this activity, learners will be able to...”

Behavior

It's quite simple to understand the different behaviors shown by students. By using the Blooms taxonomy theory, you could classify individuals into three different groups by assessing their intellectual behavior. Behavior can be assessed by observing and measuring a student's ability to apply new skills they have learned and how they display knowledge of the new skills. Describe the task or behavior (something that is observable or can be heard) using action verbs.

Condition

The third step in the ABC procedure is looking at the different conditions. Ask yourself when writing your lesson aims and objectives – What conditions am I surrounded in?

This can also refer to specific tools and materials a student may need to apply in the lesson as well as the classroom situation. If you have a very small classroom you can't have a lesson objective where students should roam around and ask each other questions. You won't get the outcome you desire. Do your students have the necessary equipment to be able to perform and achieve the lesson objective?

Think practically – What kind of equipment is available to you, are they necessary in order for you to achieve the aim? What kind of equipment should not be allowed in the classroom? Will the conditions of having too many things in the classroom be disruptive and hinder the learning outcome?

Remember that conditions influence the learner's performance and in effect the overall behavior. The following examples does not describe conditions:

Given a three-part lecture....

After completing this unit....

Given that the student has passed an introductory course....

Degree

The last step in the ABCD Approach is 'Degree'. This basically refers to the level in which a learner should perform for it to be seen as credible. The learning objective should either be at its highest level, which means that the student can produce the aim with precision and without any mistakes. Leading to the lowest level where the student can't produce the aim at all and are making many mistakes.

To which degree should the students be assessed against to be classified as 'achieving the aim'? The degree can be described as: A student can "successfully construct" or A student can "accurately describe." Be sure to elaborate on 'successful' and 'accurate' to make sure the students are fairly assessed.

You can be more specific in your assessment criteria in stating: A student can "list all 12 moving parts" or A student can "name all parts of a machine."

When writing down the degree to which students are assessed in your learning objective make sure that it's stated accurately. Unacceptable criteria are vague for example: "must be able to make 80 percent on a multiple-choice exam" or "must pass a final exam" or "to the satisfaction of the instructor" are not precise enough and can't count as a degree.

Rather change "To the satisfaction of the instructor" to "according to an instructor-supplied checklist of criteria."

The assessment criteria should be easily measured by looking at the student's performance. Many instructors, teachers and facilitators don't value the importance of writing learning objectives. It's vital to any class and should be given some thought. Learning goals, aims and objectives should be very clear before doing any kind of lesson plan. A teacher should know

what they are working towards in order for students to reach their full potential and achieve the aim of the class. Writing a decent and thorough learning objective shows competency and skill of the instructor.

Using the ABCD method (Audience, Behavior, Condition and Degree) will help you clarify your learning objectives and ultimately help you and your students achieve a better outcome.

REVISED Bloom’s Taxonomy Action Verbs

Definitions	I. Remembering	II. Understanding	III. Applying	IV. Analyzing	V. Evaluating	VI. Creating
Bloom’s Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.
Verbs	<ul style="list-style-type: none"> • Choose • Define • Find • How • Label • List • Match • Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why 	<ul style="list-style-type: none"> • Classify • Compare • Contrast • Demonstrate • Explain • Extend • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate 	<ul style="list-style-type: none"> • Apply • Build • Choose • Construct • Develop • Experiment with • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize 	<ul style="list-style-type: none"> • Analyze • Assume • Categorize • Classify • Compare • Conclusion • Contrast • Discover • Dissect • Distinguish • Divide • Examine • Function • Inference • Inspect • List • Motive • Relationships • Simplify • Survey • Take part in • Test for • Theme 	<ul style="list-style-type: none"> • Agree • Appraise • Assess • Award • Choose • Compare • Conclude • Criteria • Criticize • Decide • Deduct • Defend • Determine • Disprove • Estimate • Evaluate • Explain • Importance • Influence • Interpret • Judge • Justify • Mark • Measure • Opinion • Perceive • Prioritize • Prove • Rate • Recommend • Rule on • Select • Support • Value 	<ul style="list-style-type: none"> • Adapt • Build • Change • Choose • Combine • Compile • Compose • Construct • Create • Delete • Design • Develop • Discuss • Elaborate • Estimate • Formulate • Happen • Imagine • Improve • Invent • Make up • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution • Solve • Suppose • Test • Theory

Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon.

Figure B8: Bloom’s Taxonomy action verbs

Document 5: Resource 4 – Level of Achievement Framework

Level of Achievement Framework

As part of the curriculum crosswalk process, we need a way to evaluate how students are moving from being introduced to a topic to effectively applying it in appropriate contexts.

We have chosen to evaluate this progression with a BIM Level of Achievement Framework:

B	Beginner	Students absorb new knowledge as a foundation for future application
I	Intermediate	Students can apply what has been learned and begin to analyze components and explore connections
M	Master	Students can effectively apply what has been learned and put it into context. Students ask questions, challenge assumptions, and make independent decisions

Based on the figure below, we can see that the BIM Level of Achievement framework is loosely aligned with Bloom’s taxonomy:

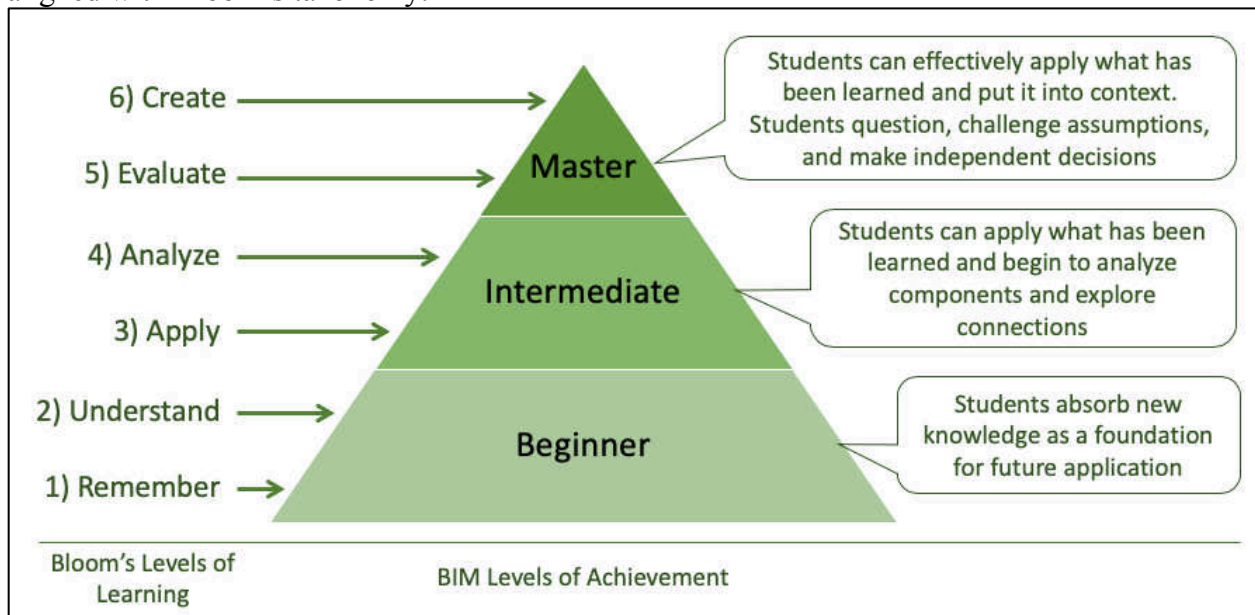


Figure B9: BIM Level of Achievement framework

The BIM Level of Achievement Framework can be used to evaluate whether individual assessment mechanisms are progressively building up to the appropriate level of learning for desired course objectives, and ultimately meeting program objectives.

Example:

Learning objective: ***Students will develop an ES&H management system***

- 1) This learning objective falls into Level 6 (Create) of Bloom’s taxonomy, which means we need to target a Master level of achievement on the BIM framework
- 2) We need an assignment that asks students to demonstrate this Master level of achievement, but we also need to ensure that we’re providing assessment mechanisms to build their level of knowledge at the Beginner and Intermediate levels as well.
- 3) Therefore, we might have the following set of assignments:

- a. **Beginner:** Homework or quiz that asks students to explain what an ES&H management system is and why it is useful
- b. **Intermediate:** During class, have student partners use the What If hazard analysis method to analyze the potential hazards at a gas pump
- c. **Master:** Using the ANSI/ASSP Z10 standard, ask student teams to develop a comprehensive safety management system for a real manufacturing plant

Important notes:

- It is possible that students may have covered the Beginner (or Intermediate) level of achievement in a previous class within the program or as an undergraduate prerequisite.
- Not all objectives require Master level of achievement.

APPENDIX C: Accreditation Comparison

BCSP (2019 accreditation vs 2021 curriculum map)

Key
On BCSP, not on prof data
On prof data, not on BCSP
Courses match

BCSP Associate Safety Professional (ASP) Examination Blueprint (ASP10 4/2019)		Course Comparison	
Domain	Topic	Blueprint Topic Referenced	Professor Data (April 2021)
1. Applied Sciences and Mathematics			
	1. General chemistry concepts (e.g., nomenclature, balancing chemical equations, chemical reactions, ideal gas law, and pH)	Note: Chemistry is typically taken at the undergraduate level for admittance into the IH Graduate Program; ERHS 526, Industrial Hygiene	ERHS 526
	2. Electrical principles (e.g., Ohms law, power, impedance, energy, resistance, and circuits)	ERHS 528, Occupational Safety	ERHS 528
	3. Principles of radioactivity (e.g., radioactive decay, half-life, source strength, concentration, and inverse square law)	ERHS 526, Industrial Hygiene; ERHS 527 IH Lab	ERHS 526, ERHS 527
	4. Storage capacity calculations		
	5. Rigging and load calculations	ERHS 528, Occupational Safety	ERHS 528
	6. Ventilation and system design	ERHS 526, Industrial Hygiene	ERHS 526
	7. Noise hazards	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 526, ERHS 527
	8. Climate and environmental conditions (e.g., WBGT, wind chill, and heat stress)	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 526, ERHS 527, ERHS 540
	9. Fall protection calculations	ERHS 528, Occupational Safety	ERHS 528

<p>10. General physics concepts (e.g., force, acceleration, velocity, momentum, and friction)</p> <p>11. Financial principles (e.g., cost benefit analysis, cost of risk, life cycle cost, return on investment, and effects of losses)</p> <p>12. Descriptive statistics (e.g., central tendency, variability, and probability)</p> <p>13. Lagging indicators (e.g., incidence rates, lost time, and direct costs of incidents)</p> <p>14. Leading indicators (e.g., inspection frequency, safety interventions, employee performance evaluations, training frequency, near miss, near hit, and close call reporting)</p>	<p>Note: Physics is typically taken at the undergraduate level for acceptance into the Graduate IH Program</p> <p>STAT 511; ERHS 526, Industrial Hygiene</p> <p>ERHS 637, ESH Management</p> <p>ERHS 537, ESH Management</p>	<p>ERHS 540, ERHS 637</p> <p>STAT 511, ERHS 520, ERHS 526, ERHS 540</p> <p>ERHS 637</p> <p>ERHS 637</p>
<p>2. Safety Management Systems</p>		
<p>1. Hierarchy of hazard controls</p> <p>2. Risk transfer (e.g., insurance and incident management)</p> <p>3. Management of change</p> <p>4. Hazard analysis methods (e.g., preliminary hazard analysis, subsystem hazard analysis, hazard and operability analysis, failure mode and effects analysis, fault tree analysis, fishbone, what-if and checklist analysis, change analysis, Energy Trace and Barrier analysis, and Systematic Cause Analysis Technique)</p> <p>5. Process safety management</p> <p>6. Fleet safety principles (e.g., driver behavior, defensive driving, distracted driving, fatigue, and vehicle safety features)</p> <p>7. Hazard Communication and Globally Harmonized System</p> <p>8. Control of hazardous energy (e.g., lockout-tagout)</p>	<p>ERHS 526, Industrial Hygiene; ERHS 637, ESH Management</p> <p>ERHS 536, Advanced Occupational Health</p> <p>ERHS 637, ESH Management</p> <p>ERHS 637, ESH Management</p> <p>ERHS 637, ESH Management</p> <p>ERHS 528, Occupational Safety</p> <p>ERHS 526, Industrial Hygiene</p> <p>ERHS 528, Occupational Safety</p>	<p>ERHS 526 ERHS 528 ERHS 536 ERHS 637</p> <p>ERHS 536</p> <p>ERHS 637</p> <p>ERHS 520 ERHS 528 ERHS 540 ERHS 637</p> <p>ERHS 637</p> <p>ERHS 526 ERHS 528</p> <p>ERHS 528</p>

9. Excavation, trenching, and shoring	ERHS 528, Occupational Safety	ERHS 528
10. Confined space	ERHS 528, Occupational Safety ERHS 526, Industrial Hygiene	ERHS 528
11. Physical security		
12. Fall protection	ERHS 528, Occupational Safety	ERHS 528
13. Machine guarding	ERHS 528, Occupational Safety	ERHS 528
14. Powered industrial vehicles (e.g., trucks, forklifts, and cranes)	ERHS 528, Occupational Safety	
15. Scaffolding	ERHS 528, Occupational Safety	ERHS 528
16. Hazard identification methods	ERHS 528, Occupational Safety, ERHS 637, ESH Management	ERHS 528 ERHS 540 ERHS 637 ERHS 679
17. Assess and analyze risks (e.g., probability and severity)	ERHS 637, ESH Management	ERHS 528 ERHS 637
18. Financial justification of hazard controls		ERHS 540 ERHS 637
19. Implementation of hazard controls	ERHS 526, Industrial Hygiene; ERHS 637, ESH Management	ERHS 526 ERHS 528 ERHS 637 ERHS 679
20. Monitor and reevaluate hazard controls	ERHS 637, ESH Management	
21. Conduct incident investigation (e.g., root cause, data collection, analysis, and chain of custody)	ERHS 528, Occupational Safety; ERHS 637, ESH Management	ERHS 528 ERHS 637
22. Conduct inspections and audits	ERHS 528, Occupational Safety; ERHS 637, ESH Management	ERHS 528 ERHS 637 ERHS 679
23. Evaluate cost, schedule, performance, and project risk Evaluate cost, schedule, performance, and project risk		
3. Ergonomics		
1. Fitness for duty (e.g., fatigue and mental health)	ERHS 540, Ergonomics	ERHS 540

<p>2. Stressors (e.g., environmental, lights, noise, and other conditions)</p> <p>3. Risk factors (e.g., repetition, force, posture, and vibration)</p> <p>4. Work design</p> <p>5. Material handling (e.g., manual, powered equipment, and lifting devices)</p> <p>6. Work practice controls (e.g., job rotation, work hardening, and early symptom intervention)</p> <p>7. Qualitative and quantitative analysis methods (e.g., anthropometry and NIOSH lift equation)</p>	<p>ERHS 540, Ergonomics; ERHS 526, Industrial Hygiene; ERHS 528, Occupational Safety</p> <p>ERHS 540, Ergonomics</p> <p>ERHS 540, Ergonomics</p> <p>ERHS 540, Ergonomics; ERHS 528, Occupational Safety</p> <p>ERHS 540, Ergonomics</p> <p>ERHS 540, Ergonomics</p>	<p>ERHS 520 ERHS 526 ERHS 536 ERHS 540 ERHS 637 ERHS 679</p> <p>ERHS 528 ERHS 536 ERHS 540 ERHS 637 ERHS 679</p> <p>ERHS 536 ERHS 540</p> <p>ERHS 528 ERHS 536 ERHS 540 ERHS 637 ERHS 679</p> <p>ERHS 536 ERHS 540 ERHS 679</p> <p>ERHS 540</p>
<p>4. Fire Prevention and Protection</p>		
<p>1. Chemical (e.g., flash point and auto ignition)</p> <p>2. Electrical (e.g., static electricity, surge, arc flash, ground fault circuit interrupter, and grounding and bonding)</p> <p>3. Hot work (e.g., welding, cutting, and brazing)</p> <p>4. Combustible dust</p> <p>5. Fire science (e.g., fire pentagon, fire tetrahedron, upper and lower explosive limits)</p> <p>6. Detection systems</p> <p>7. Suppression systems, fire extinguishers, sprinkler types</p> <p>8. Segregation and separation (e.g., flammable materials storage and ventilation)</p> <p>9. Housekeeping</p>	<p>ERHS 528, Occupational Safety</p> <p>ERHS 528, Occupational Safety</p> <p>ERHS 528, Occupational Safety</p> <p>ERHS 528, Occupational Safety</p> <p>ERHS 528, Occupational Safety</p> <p>ERHS 528, Occupational Safety</p> <p>ERHS 528, Occupational Safety</p> <p>ERHS 528, Occupational Safety</p>	<p>ERHS 528</p> <p>ERHS 528</p> <p>ERHS 528</p>
<p>5. Emergency Response Management (ERM)</p>		

1. Emergency, crisis, disaster response planning (e.g., drills)	ERHS 637, ESH Management; ERHS 526, Industrial Hygiene	ERHS 526 ERHS 528 ERHS 637
2. Workplace violence (e.g., shooting, bomb threat, vandalism, and verbal threats)	ERHS 528, Occupational Safety	ERHS 637
6. Industrial Hygiene and Occupational Health		
1. Sources of biological hazards (e.g., viral, bacterial, parasitic, fungus, and mold)	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 520 ERHS 526 ERHS 527 ERHS 679
2. Protocol for bloodborne pathogen control	ERHS 528, Occupational Safety	
3. Mutagens, teratogens, and carcinogens	ERHS 526, Industrial Hygiene	ERHS 520 ERHS 526 ERHS 528
4. Chemical hazards (e.g., sources, assessment, control strategies, symptoms, and target organs)	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 520 ERHS 526 ERHS 527 ERHS 637 ERHS 679
5. Exposure limits (e.g., Threshold Limit Value (TLV), Short-term exposure limits (STEL), Time Weighted Average (TWA), Ceiling Limit, Immediately Dangerous to Life and Health (IDLH), and Action Level (AL))	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 526 ERHS 527 ERHS 536 ERHS 637 ERHS 679
6. Routes of entry (e.g., inhalation, ingestion, absorption, and injection)	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 520 ERHS 526 ERHS 527 ERHS 536
7. Acute and chronic exposures (e.g., additive effect, synergistic effect, antagonistic effect, and potentiation effect)	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 520 ERHS 526 ERHS 536 PBHL 570
8. Noise	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 526 ERHS 527 ERHS 679
9. Radiation	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 520 ERHS 526 ERHS 527 ERHS 679
10. Heat and cold stress	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 520 ERHS 526 ERHS 527 ERHS 540 ERHS 679

11. Conduct exposure assessment	ERHS 526, Industrial Hygiene; ERHS 527, IH Lab	ERHS 520 ERHS 526 ERHS 527
7. Environmental Management		
1. Environmental hazards awareness (e.g., biological [mold], chemical, waste, and vermin)	ERHS 520, Occupational and Environmental Health Issues; ERHS 526, Industrial Hygiene	ERHS 520 ERHS 526 ERHS 637 ERHS 679
2. Water (e.g., storm, waste, and best practices)	ERHS 520, Occupational and Environmental Health Issues	ERHS 520 ERHS 637
3. Air (e.g., quality and best practices)	ERHS 520, Occupational and Environmental Health Issues	ERHS 520 ERHS 637
4. Land and conservation (e.g., solid waste, recycling, and sustainability)	ERHS 520, Occupational and Environmental Health Issues	ERHS 520 ERHS 637
5. Hierarchy of conservation (e.g., reuse, recycle, and reduce)	ERHS 520, Occupational and Environmental Health Issues	ERHS 637
6. Environmental management system standards	ERHS 637, ESH Management	ERHS 637
7. Waste removal, treatment, and disposal		ERHS 637
8. Training, Education, and Communication		
1. Adult learning theory and techniques		
2. Presentation tools (e.g., computer-based and group meeting)		
3. Safety culture/climate	ERHS 637, ESH Management; ERHS 528, Occupational Safety	ERHS 520 ERHS 540
4. Data collection, needs analysis, gap analysis, and feedback		
5. Assessing competency	ERHS 637, ESH Management	ERHS 637
9. Law and Ethics		
1. Legal liability	ERHS 526, Industrial Hygiene	ERHS 526 ERHS 536
2. Ethical behavior (e.g., professional practice, audits, record keeping, sampling, standard writing, and BCSP Code of Ethics)	ERHS 528, Occupational Safety; ERHS 526, Industrial Hygiene	ERHS 526 ERHS 536 ERHS 637 ERHS 679

3. Protection of worker privacy (e.g., information)	ERHS 526, Industrial Hygiene	ERHS 679
4. Dealing with unethical situations (e.g., employee putting others at risk)	ERHS 526, Industrial Hygiene	ERHS 679
5. Reading and interpreting regulations	ERHS 528, Occupational Safety; ERHS 637, ESH Management	ERHS 520 ERHS 526 ERHS 528 ERHS 536 ERHS 637 ERHS 679
6. Determine appropriate actions based on knowledge limitations (e.g., know when to get help)	ERHS 526, Industrial Hygiene	ERHS 520 ERHS 536 ERHS 679
TOTAL	84 Blueprint Topics Assessed	

Figure C1: 2019 vs 2021 BCSP accreditation comparison

ABET (2019 accreditation vs 2021 curriculum map)

Key	
	On ABET, not on prof data
	On prof data, not on ABET

Program Criterion Number	Program Criterion	This program criterion is addressed by these (core) courses:	Prof Data (April 2021)
6.3.1	Identify agents, factors, and stressors generated by and/or associated with defined sources, unit operations, and or processes.	ERHS 520	x
		ERHS 526	x
		ERHS 527	x
		ERHS 528	x
		ERHS 536	x
		ERHS 540	
			ERHS 637
	ERHS 679	x	
6.3.2	Describe qualitative and quantitative aspects of generation of agents, factors, and stressors.		ERHS 520
		ERHS 526	x
		ERHS 527	x
		ERHS 536	x
			ERHS 637
	ERHS 679	x	

6.3.3	Understand physiological and/or toxicological interactions of physical, chemical, biological, and ergonomic agents, factors, and/or stressors with the human body.	ERHS 520	x
		ERHS 526	x
		ERHS 527	
		ERHS 528	
		ERHS 532	
		ERHS 536	x
		ERHS 540	x
			ERHS 637
		ERHS 679	
6.3.4	Assess qualitative and quantitative aspects of exposure assessment, dose-response, and risk characterization based on applicable pathways and modes of entry.	ERHS 520	x
		ERHS 526	x
		ERHS 527	x
		ERHS 532 / PBHL 570	x
		ERHS 536	x
		ERHS 540	x
			ERHS 637
6.3.5	Calculate, interpret, and apply statistical and epidemiological data.	STAT 511/512	x
			ERHS 520
		ERHS 526	x
			ERHS 527
		ERHS 532 / PBHL 570	x
			ERHS 540
6.3.6	Recommend and evaluate engineering, administrative, and personal protective equipment controls and/or other interventions to reduce or eliminate hazards.		ERHS 520
		ERHS 526	x
		ERHS 527	
		ERHS 528	x
		ERHS 536	x
		ERHS 540	x
			ERHS 637
ERHS 679	x		
6.3.7	Demonstrate an understanding of applicable business and managerial practices.		ERHS 526
		ERHS 536	x
			ERHS 540
		ERHS 637	x
			ERHS 679
6.3.8		ERHS 520	x

			ERHS 526
	Interpret and apply applicable occupational and environmental regulations.	ERHS 528	x
			ERHS 536
		ERHS 637	x
			ERHS 679
			ERHS 526
6.3.9	Understand fundamental aspects of safety and environmental health.	ERHS 528	x
			ERHS 536
		ERHS 540	x
		ERHS 637	x
		ERHS 679	x
6.3.10	Attain recognized professional certification.	ERHS 526	
		ERHS 527	
		ERHS 528	
		ERHS 532	
		ERHS 536	
		ERHS 540	x
		ERHS 637	

Student Outcome Number	Student Outcome	This program criterion is addressed by these (core) courses:	Prof Data (April 2021)
6.4.1	An ability to identify, formulate, and solve broadly defined technical or scientific problems by applying knowledge of mathematics, physics, epidemiology, chemistry, environmental and occupational health will be evaluated by:		ERHS 520
			ERHS 526
			ERHS 527
			ERHS 528
			ERHS 532/PHBL 570
		ERHS 536	x
			ERHS 540
			ERHS 637
			ERHS 679
6.4.2	An ability formulate or design a system, process, procedure or program to meet desired needs will be evaluated by		ERHS 520
		ERHS 528	x
			ERHS 540
		ERHS 637	x

			ERHS 679
6.4.3	An ability to develop and conduct experiments or test hypotheses, analyze and interpret data and use scientific judgment to draw conclusions will be evaluated by		ERHS 526
		ERHS 527	x
			ERHS 540
6.4.4	An ability to communicate effectively both verbally and in writing with a range of audiences will be evaluated by		ERHS 520
			ERHS 526
			ERHS 527
		ERHS 528	x
		ERHS 536	x
			ERHS 540
			ERHS 637
	ERHS 679	x	
6.4.5	An understanding of ethical and professional responsibilities and the impact of technical and/or scientific solutions in global, economic, environmental, and societal contexts will be evaluated by		ERHS 520
			ERHS 526
			ERHS 528
		ERHS 536	x
			ERHS 637
			ERHS 679
6.4.6	An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty will be evaluated by		ERHS 536
			ERHS 540
		ERHS 637	x
		ERHS 679	x

Figure C2: 2019 vs 2021 ABET accreditation comparison

LIST OF ABBREVIATIONS

Abbreviation	Meaning
ABET	Accreditation Board for Engineering Technology
AIHA	American Industrial Hygiene Association
BCSP	Board of Certified Safety Professionals
BIM	Beginner, Intermediate, Master
CIH	Certified Industrial Hygienist
COVID-19	Coronavirus Disease 2019
CSP	Certified Safety Professional
CSU	Colorado State University
CTE	Center for Teaching Excellence
DEI	Diversity, Equity, and Inclusion
DOE	Department of Energy
EHS / ESH	Environmental, Health, and Safety
EPA	Environmental Protection Agency
ERHS	Department of Environmental and Radiological Health Sciences
ERIC	Education Resources Information Center
GSP	Graduate Safety Practitioner
HSE	Health, Safety, and Environmental
IDEAL	Institute for the Development of Excellence in Assessment Leadership
IH	Industrial Hygiene
IRB	Institutional Review Board
ISO	International Standards Organization
LOTO	Lock Out Tag Out
MAP ERC	Mountain and Plains Education and Research Center
MSHA	Mining Safety and Health Administration
NFPA	National Fire Protection Association
OH	Occupational Hygiene (or Health)
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
QAP	Qualified Academic Program
SME	Subject Matter Expert
STEM	Science, Technology, Engineering, & Math
TAMU	Texas A&M University