Work-in-Progress:Designing for Safety: A Backward Design Approach to Engineering Safety Education

Dr. Aparajita Jaiswal, EPICS, College of Engineering, Purdue University – West Lafayette

Dr. Aparajita Jaiswal is a Lecturer in the Engineering Projects in Community Service (EPICS) program at Purdue University. Her teaching and research focus on engineering education, teamwork, and experiential learning. She integrates project-based design, human-centered approaches, and technology-enhanced pedagogy to prepare students as ethical, and world-ready professionals.

Dr. Gaurav Nanda, Purdue University – West Lafayette (College of Engineering)

Dr. Gaurav Nanda is an Assistant Professor in the School of Engineering Technology at Purdue University. His research focuses on machine learning and natural language processing applications for data analytics and decision support in areas of safety, education, healthcare, and supply chain. He completed his Ph.D. in Industrial Engineering and postdoc in Engineering Education from Purdue University. He earned his Masters and Bachelors degrees from Indian Institute of Technology (IIT) Kharagpur, India and worked in the software industry for five years before moving to academia.

Md Sharifuzzaman, Purdue University at West Lafayette (PPI)

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1.0 Background

Safety engineering is a foundational aspect of professional engineering practice, encompassing the prevention of accidents, mitigation of hazards, and design of systems that operate reliably under varied conditions. Effective safety practice requires the integration of technical analysis, human factors, organizational processes, and regulatory frameworks. Across industries from manufacturing and warehousing to transportation, energy systems, and product design engineers are expected to anticipate risks, understand how people interact with their environment, comply with safety standards, and make decisions that prioritize the well-being of workers and communities. Yet despite its importance, safety is often underemphasized in undergraduate engineering programs. Students typically encounter safety through isolated laboratory rules or compliance-oriented lectures rather than through sustained instruction that frames safety as a socio-technical, ethical, and professional responsibility. A substantial body of literature highlights that safety failures rarely arise from technical flaws alone. Instead, they often reflect deeper issues such as inadequate communication, poor risk perception, or weaknesses in organizational culture. The concept of *safety culture* commonly defined as the shared attitudes, values, assumptions, and behaviors related to safety within a group is central to understanding these failures [1], [2]. Safety culture is shaped not only by formal procedures but also by tacit norms, collective experiences, and patterns of behavior that influence how individuals recognize and respond to hazards. Research consistently shows that attitudes toward safety are linked to safety behaviors and outcomes [3], [4], yet measuring safety culture is challenging due to its intangible nature. Various approaches have been proposed, including qualitative assessments, survey-based analyses, and pragmatic evaluations of organizational systems. Regardless of method, these studies collectively demonstrate that cultivating positive safety attitudes is an essential precursor to building strong safety cultures.

Despite this evidence, the state of safety education in engineering curricula remains uneven. Although professional codes of ethics emphasize safety as a primary obligation of engineers, there is no consistent requirement across programs for safety-specific coursework [5], [6]. Existing research suggests that exposure to safety concepts varies widely by discipline, with fields such as chemical engineering offering more structured process safety education while others provide minimal or inconsistent coverage [7], [8]. Studies of academic laboratory environments reveal that even when students express positive attitudes toward safety, their behaviors may not reflect a deep understanding of risk, suggesting gaps between awareness and practice [9], [10]. These gaps have implications for the workforce. Employers increasingly expect graduates to enter industry with foundational safety knowledge and the ability to contribute meaningfully to organizational safety systems, yet evidence from multiple countries indicates a mismatch between student preparation and industry needs [11]. Given these persistent challenges, engineering education must adopt more intentional approaches to cultivating safety knowledge, attitudes, and behaviors. Instructional design frameworks particularly backward design offer a promising mechanism for addressing this need. Backward design emphasizes clear articulation of learning outcomes, alignment of assessments with those outcomes, and deliberate planning of learning activities that build toward demonstrated understanding. This structure is well-suited for safety education, where the goal is not only knowledge acquisition but also the development of reflective habits, systems thinking, and an internalized safety mindset. By aligning technical content with scenario analysis and reflective activities, backward design can support students in making meaningful connections across human, organizational, and regulatory dimensions of safety.

The present work-in-progress paper responds to these gaps by developing a self-paced online safety engineering module grounded in backward design principles. The module integrates foundational safety concepts, OSHA regulatory frameworks, cultural influences on risk perception, organizational safety culture, and applied hazard identification. Through a combination of micro-lectures, authentic workplace examples, an AI-supported 5S activity, case studies, scenario-based quizzes, and reflective prompts, the module aims to shift students from compliance-oriented thinking toward a holistic, mindset-driven understanding of safety. By documenting the design and structure of this module, this study contributes to broader efforts to embed safety as a core competency in engineering education and prepare students to engage responsibly in future workplace safety cultures.

Research Question: How does backward design inform the development of an online module that enables students to connect technical safety concepts, regulatory frameworks, and reflective reasoning?

2.0 Backward Design as the Instructional Framework

Backward design is a widely used instructional design framework that emphasizes intentional alignment among learning goals, assessments, and instructional activities [12]. Unlike traditional approaches that begin with content coverage and then layer assessments and activities on top, backward design starts with a clear articulation of what learners should understand, be able to do, or value by the end of a learning experience. From these desired outcomes, educators work backward to determine what evidence will demonstrate that learning has occurred, and only then develop the lessons, activities, and materials that will support students in achieving those outcomes.

The backward design model is typically structured around three stages. In the first stage, instructors identify the long-term learning goals often referred to as “enduring understandings” that represent the concepts, skills, or mindsets learners should retain beyond the course. These outcomes are intentionally broad, meaningful, and framed in terms of understanding rather than recall. The second stage focuses on determining acceptable evidence of learning. Assessments are designed to measure the specific outcomes identified in stage one and may include performance tasks, scenario-based evaluations, reflective writing, or other demonstrations of understanding. The final stage involves planning the instructional experiences that will guide learners toward the desired outcomes and prepare them to perform successfully on the assessments. Backward design is especially valuable in contexts where the goal extends beyond content mastery to include changes in reasoning, mindset, or professional identity. Because it prioritizes clarity and alignment, the framework helps avoid fragmented instruction and ensures that each component of a learning experience contributes directly to the intended outcomes. It also encourages instructors to consider how students make meaning, how they transfer knowledge to new situations, and how reflective activities or authentic tasks can support deeper understanding.

As a pedagogical approach, backward design aligns with constructivist principles, emphasizing that learners build understanding through purposeful engagement with ideas, tasks, and problems. By centering learning goals and evidence of understanding, the framework supports the creation of coherent, integrated, and intentionally scaffolded educational experiences. Its emphasis on alignment makes it particularly well-suited for teaching complex, interdisciplinary competencies such as engineering safety, ethical decision-making, design thinking, and systems reasoning.

3.0 Methods

This work-in-progress project uses a design-oriented methodology in which the primary outcome is the creation of a coherent, mindset-oriented online module on engineering safety. Consistent with design research and instructional development approaches, the methods focus on documenting the systematic process used to develop the module, the guiding principles behind design decisions, and the alignment strategies that supported the integration of technical, regulatory, and reflective components. The goal of the methods section is therefore not to evaluate student learning outcomes, but to articulate *how* the module was deliberately constructed using backward design principles.

3.1 Design Methodology

The development of the module followed the three stages of backward design: (1) identifying desired results, (2) determining acceptable evidence of learning, and (3) planning instructional activities and materials. This systematic structure provided a foundation for aligning module components with the conceptual, regulatory, and reflective dimensions of safety engineering.

Stage 1: Identifying Desired Results

The instructional team began by defining the core competencies students should take away from the module. These included:

- understanding foundational principles of safety engineering,
- gaining familiarity with major OSHA regulatory frameworks,
- recognizing how human and organizational factors shape safety outcomes, and
- developing the ability to articulate strategies for contributing to a positive safety culture.

These learning outcomes reflect both technical knowledge and mindset-oriented development, aligning with the broader goal of shifting students from compliance-based thinking to a more holistic safety orientation.

Stage 2: Determining Acceptable Evidence

Once outcomes were defined, the team identified the types of evidence that would demonstrate students' progress toward the desired competencies. These evidence sources were intentionally aligned with the mindset-oriented focus of the module and included:

- short scenario-based quizzes to assess regulatory understanding,
- reflective prompts designed to elicit reasoning and awareness,
- a case-study analysis centered on organizational culture, and
- an interactive hazard-identification simulation to demonstrate applied competence.

These assessments served as design anchors, guiding the selection and sequencing of instructional materials.

Stage 3: Planning Instructional Activities and Materials

With outcomes and evidence established, the team developed the five-module sequence. Each module was intentionally crafted to support a specific portion of the safety mindset progression:

1. **Introduction to Safety Engineering** - foundational concepts, 5S, and an AI-based image analysis task.
2. **Key Safety Regulations (OSHA)** - AcciMap introduction, OSHA eTool exploration, and application quizzes.
3. **Risk Perception and Safety Attitudes** - cultural scenarios, personal reflections, and risk-identification tasks.
4. **Developing a Safety Culture** - case study analysis and creation of an individual action plan.
5. **OSHA Hazard Finder Simulation** - practice-based hazard identification in a realistic virtual environment.

Instructional materials included micro-lectures, curated videos, workplace images, simulations, and reflective activities. These elements were selected not as standalone components but as interconnected pieces of a coherent conceptual trajectory.

3.2 Design Team Roles

The design process was collaborative, involving coordinated contributions from multiple team members. Responsibilities included video development, scenario collection, quiz creation, simulation testing, and reflection design. This distributed expertise supported the integration of technical content, regulatory interpretation, human factors perspectives, and instructional design.

4.0 Results

Module description
The engineering safety module consists of five interconnected components designed to move students from foundational safety awareness toward applied hazard identification and reflective

reasoning. Each module reflects the backward-design process by linking its activities to the core outcomes: understanding safety principles, recognizing OSHA regulatory frameworks, interpreting human and cultural factors in risk, and articulating strategies for contributing to safety culture. The module integrates lecture videos, curated workplace scenarios, AI-assisted analysis, case study reasoning, quizzes, and simulation-based assessment to support a coherent progression of learning.

Module 1: Introduction to Safety Engineering

Module 1 provides students with core safety engineering principles and introduces safety as a systems-oriented and design-relevant competency. A short lecture video (3–5 minutes) created by the instructional team gives an overview of hazard types, the hierarchy of controls, and the role of systematic workplace organization in preventing incidents. A screenshot of the video lecture is provided in Figure 1.

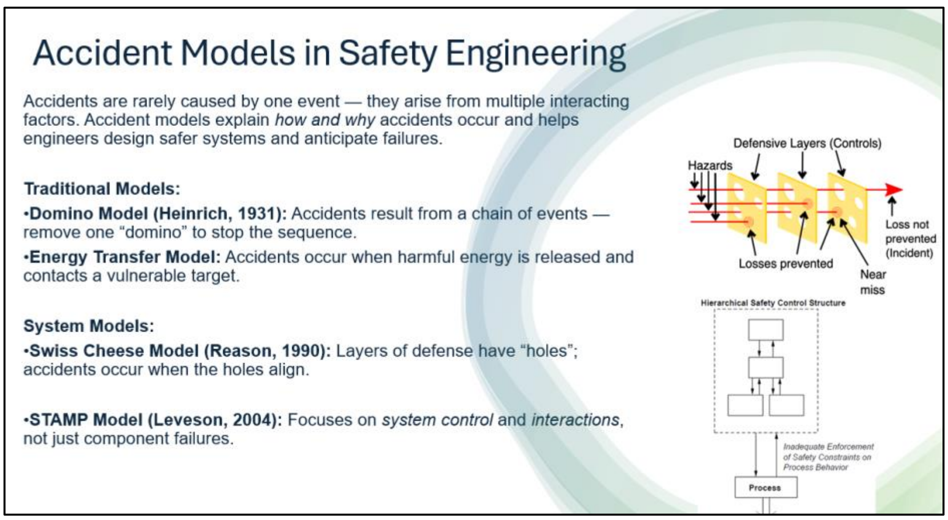


Figure 1: Screenshot of video lecture in Module 1 on basics of safety engineering

To illustrate the relationship between workspace organization and hazard identification, the module incorporates ***5S concept*** (Sort, Set in Order, Shine, Standardize, Sustain). Students complete a hands-on 5S activity using photos of manufacturing and warehouse environments. They identify issues such as clutter, misplaced tools, unclear labeling, blocked walkways, and workflow inefficiencies. A short quiz assesses students' ability to identify 5S-related safety issues in these videos and images.

A distinctive component of this module is an ***AI-supported 5S image analysis***. Students upload an image either of their own workspace or a provided warehouse scene and the AI detects potential 5S violations and recommendations. This module then asks students to compare their own analysis of 5 S compliance about the image (human analysis) and compare that with AI-based detection, reflecting on whether the AI identified issues they overlooked and evaluating how AI might augment hazard identification in workplace safety contexts. A sample of AI-based 5S image analysis is provided in Figure 2.

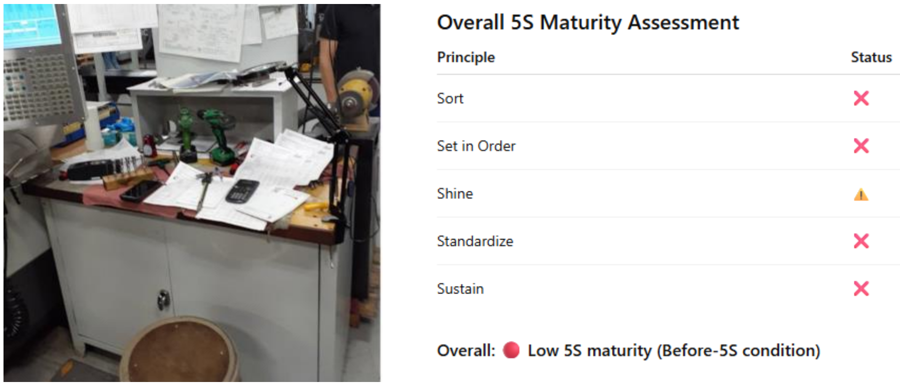


Figure 2: Screenshot of AI based image analysis of 5S implementation

Module 2: Key Safety Regulations - OSHA

Module 2 builds foundational regulatory literacy. A 3–5 minute lecture video introduces the ***AcciMap*** causal analysis framework, illustrating how accidents emerge from interactions across multiple system levels from equipment design to organizational decision-making. Students are asked to create an AcciMap based on a familiar scenario, connecting the immediate situation to causes at higher levels of the organization. This enables them to recognize that addressing challenges at the organizational level creates a more sustainable and far-reaching impact than resolving issues superficially. Figure 3 shows an example AcciMap.

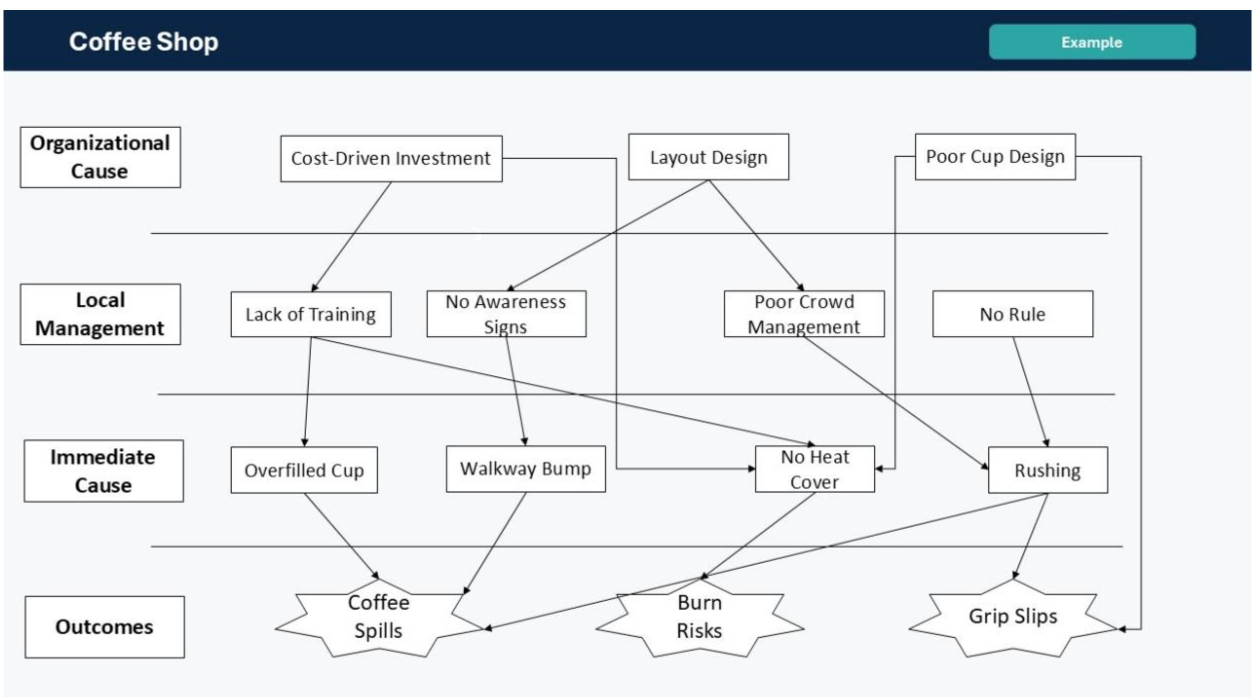


Figure 3: Screenshot of an AcciMap example from class lecture

A second brief lecture introduces OSHA's ***Grocery Store Warehousing eTool*** (shown in Figure 4), highlighting common hazards related to lifting, manual material handling, ergonomics, storage, and walkway management. Students explore the eTool and then complete an OSHA-focused quiz developed using eTool scenarios. The quiz includes items on:

- proper depalletizing techniques (e.g., layer-by-layer method),
- the importance of comprehensive safety training for new employees,
- benefits of scheduled breaks for fatigue reduction,
- footwear requirements (supportive, non-skid soles),
- avoiding shortcuts such as reaching across pallets with a load,
- aisle housekeeping to prevent slips and trips, and
- the purpose of medical management programs in incident reporting and return-to-work support.

The module concludes with a **reflection prompt**: *How do improper safety training and lack of compliance influence the outcomes of workplace scenarios?*

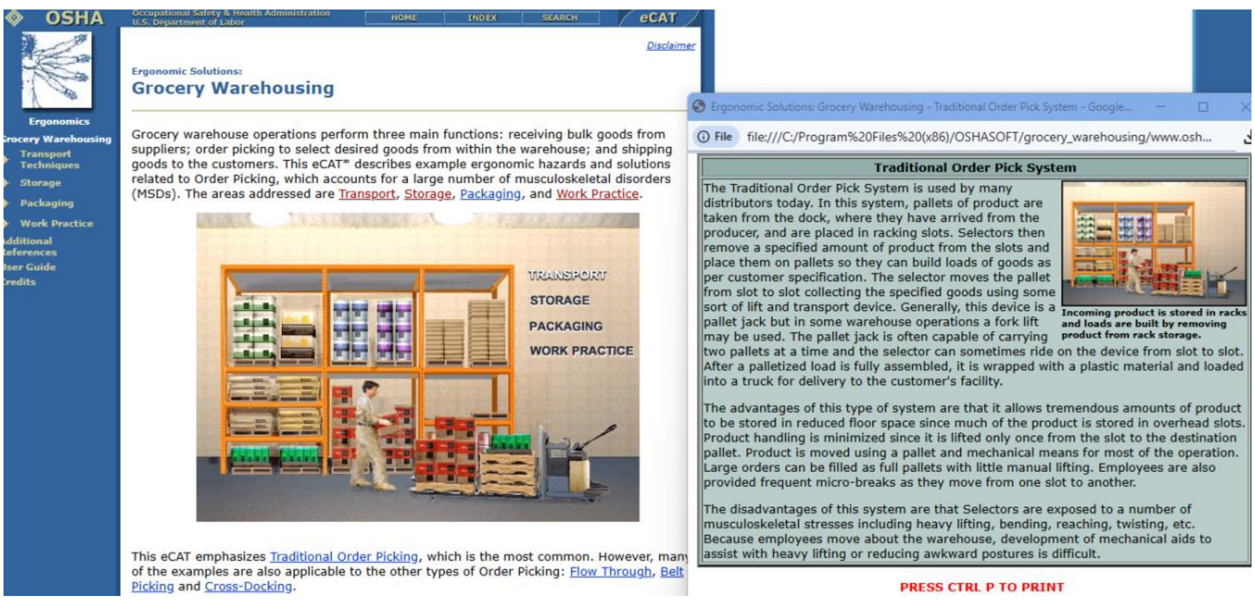


Figure 4: Screenshot of OSHA Grocery Warehousing eTool

Module 3: Risk Perception and Safety Attitudes

Module 3 foregrounds human factors and cultural influences in safety behavior. Students first write a ***pre-activity reflection*** describing a time they personally underestimated a risk such as bypassing PPE, rushing through a task, or ignoring ergonomic strain and consider how improved risk perception might have changed the outcome.

Next, students examine ***2-3 curated images or short video clips,*** see Figure 5 illustrating safety practices from our day-to-day life e.g., kitchen, garage, playground, walkway, storage area instructional team provides a questionnaire prompting students to:

- identify hazards present in the scenes,
- infer why certain unsafe practices may be normalized,
- compare observed behaviors with OSHA expectations, and
- reflect on how cultural norms, socioeconomic factors, and resource constraints shape risk attitudes.

Figure 5: Screenshot of some pictures to identify hazards in those

This module challenges students to examine the social and cultural dimensions of safety and to question assumptions about universal safety standards. This practice enables students to develop the ability to identify safety concerns in various scenarios and address them effectively, recognizing that an issue must first be identified before it can be resolved.

Module 4: Developing a Safety Culture

Module 4 shifts from individual knowledge to organizational systems. A lecture video explains key elements of ***safety culture***, including leadership communication, reporting structures, accountability, and the role of management expectations, see Figure 6.

Figure 6: Screenshot of a slide in a class lecture about safety culture

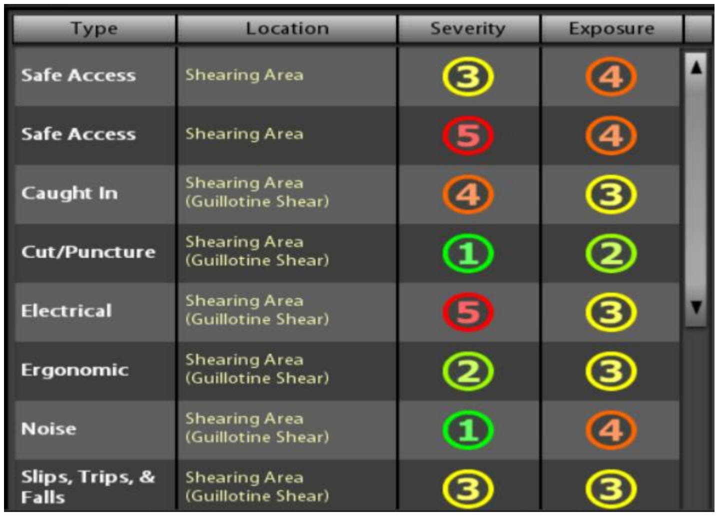
Students then complete a case study based on the *Apollo 1 Fire*, reviewing selected excerpts from investigation documents. The case foregrounds issues such as communication barriers between engineers and management, schedule pressure, normalization of deviance, and inadequate escalation of safety concerns. Guided prompts ask students to evaluate:

- how organizational structure contributed to risk escalation,
- what communication failures prevented engineers' warnings from reaching decision-makers, and
- how values and pressures shaped safety decisions.

Students conclude by submitting a *Safety Culture Action Plan* outlining steps they would implement in a manufacturing or warehousing environment such as strengthening near-miss reporting, standardizing onboarding safety training, or integrating design reviews.

Module 5: OSHA Hazard Finder Interactive Simulation

The final module is application-focused, requiring students to engage with a virtual OSHA Hazard Finder Simulation, see Figure 7. The instructional team tested the simulation for accessibility and created *step-by-step installation instructions*, including screenshots and screen-recordings. The simulation lets students explore different areas to find hazards and safety problems. It works like a game where the goal is to earn the highest profit while keeping the workplace safe. Fixing safety issues costs money, which is taken from the profit, so students must decide which problems to fix first and manage them wisely.



Type	Location	Severity	Exposure
Safe Access	Shearing Area	3	4
Safe Access	Shearing Area	5	4
Caught In	Shearing Area (Guillotine Shear)	4	3
Cut/Puncture	Shearing Area (Guillotine Shear)	1	2
Electrical	Shearing Area (Guillotine Shear)	5	3
Ergonomic	Shearing Area (Guillotine Shear)	2	3
Noise	Shearing Area (Guillotine Shear)	1	4
Slips, Trips, & Falls	Shearing Area (Guillotine Shear)	3	3

Figure 7: Screenshot of OSHA hazard finder simulation (the simulation categorizes hazards and ranks their impact)

Within the simulation, students navigate a warehouse environment and identify hazards such as:

- extension cords stretched across walkways,
- overloaded shelving and unstable pallets,
- improperly stored chemicals,
- unsecured ladders,
- malfunctioning equipment, and
- blocked emergency exits.

Students record each hazard, categorize it (e.g., fall, electrical, struck-by), and connect it to the relevant OSHA guideline. This serves as the culminating performance assessment, synthesizing technical knowledge, regulatory understanding, and hazard recognition.

5.0 Discussion

The design of this module demonstrates how backward design principles can be leveraged to create a coherent and mindset-oriented learning experience in engineering safety. Traditional approaches to safety education often present safety as a collection of rules or procedural requirements, which may limit students' ability to understand how safety operates within complex socio-technical systems. The module's design counters this limitation by intentionally integrating regulatory knowledge, human factors, case-based reasoning, and reflective activities. One of the key insights emerging from the design process is the value of sequencing learning from individual perception to organizational systems. Beginning with personal risk perception grounds safety in students' lived experiences, making subsequent regulatory content more meaningful. Likewise, ending with applied hazard identification and action planning reinforces transfer to future workplaces. This scaffolding aligns with backward design's emphasis on aligning activities with the cognitive and affective shifts required to achieve the intended learning outcomes. Another important design insight involves the use of reflective activities. While technical knowledge and regulatory compliance are essential, safety attitudes and cultural awareness play an equally significant role in shaping professional behavior. Embedding reflections throughout the module encourages students to examine not just *what* they know but *how* they think about safety, which is essential for cultivating a safety mindset. Finally, the inclusion of authentic digital tools such as AI-assisted 5S analysis and the hazard identification simulation supports experiential learning in an accessible online format. These technologies allow students to practice hazard recognition and systems evaluation without requiring physical laboratory environments, increasing scalability and accessibility.

6.0 Conclusion

This work-in-progress paper presents the design of an online engineering safety module developed using backward design principles. The module integrates technical safety concepts, OSHA regulatory frameworks, cultural perspectives on risk, and organization-focused case studies to support the development of a holistic safety mindset. By aligning learning outcomes, assessments, and instructional activities, the module encourages students to move beyond compliance-based understandings and engage with safety as an ethical, professional, and systems-oriented responsibility.The primary contribution of this work is the module itself, along with the documented design process that explains how backward design can guide the creation of coherent and integrated safety education experiences. Future work will involve piloting the module with undergraduate students, gathering feedback through reflections and usability surveys, and iteratively refining the design. Ultimately, this project aims to inform broader efforts to embed safety engineering more meaningfully across engineering curricula and support the preparation of graduates who can contribute to safe and responsible workplaces.

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