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ANALYZING OCCUPATIONAL HEALTH AND SAFETY TEACHING PRACTICES IN TECHNICAL UNIVERSITIES: A CONVERGENT MIXED METHODS STUDY

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Abstract

Background: Occupational health and safety (OHS) education in engineering programs faces persistent challenges in developing students' risk-based decision-making competencies. Despite established curricula, gaps remain between what is taught and what students can actually apply in professional contexts.

Objective: This study investigates current OHS teaching practices in technical universities, examining the alignment between content, pedagogical methods, and assessment approaches, and identifying specific barriers to student competency development.

Methods: A convergent mixed methods design was employed across multiple technical universities. Data collection included structured classroom observations (n=15 sessions), student surveys (n=247), and semi-structured interviews with instructors (n=10) and students (n=18). Analysis followed a content-technology-assessment framework with triangulation of quantitative frequency data and qualitative thematic coding.

Results: Classroom observations revealed a predominance of traditional lecture-based instruction (68% of class time) with limited use of case-based learning (12%), problem-based learning (8%), and simulation exercises (5%). Student surveys indicated significant difficulties in four core areas: risk assessment with evidence (71% reporting difficulty), justifying control measures (64%), documentation of safety analyses (58%), and transferring knowledge to new contexts (69%). The content-technology-assessment framework analysis revealed systematic gaps: while theoretical content was comprehensively covered, pedagogical approaches rarely employed scaffolded progression (Model→Guided→Independent), and assessment practices relied heavily on recall-based tests rather than artifact-based evaluation.

Conclusion: Current OHS teaching practices demonstrate a content delivery orientation that inadequately develops students' risk-based decision-making competencies. The identified gaps are not attributable to student deficiencies but to systematic misalignment between instructional methods and competency outcomes. Findings support the need for structured pedagogical interventions incorporating authentic tasks, scaffolded learning cycles, and indicator-evidence-criteria assessment frameworks.

Keywords: Occupational health and safety education; engineering education; risk-based decision making; competency-based assessment; mixed methods research; pedagogical innovation.

Introduction

Occupational health and safety (OHS) education constitutes a critical component of engineering curricula, yet persistent gaps exist between classroom learning and workplace application (Jørgensen, Remmen, & Mellor, 2016; Milhem, Mearns, & Flin, 2021). While engineering students typically receive comprehensive instruction in safety regulations, hazard identification, and risk assessment principles, their ability to make evidence-based safety decisions in authentic professional contexts remains inadequately developed (Hale & Guldenmund, 2019; Swuste et al., 2020).

The theoretical foundations of OHS education have been extensively documented. Conceptual frameworks emphasizing risk-based thinking (ISO 31000, 2018), hierarchy of controls (NIOSH, 2015), and systems thinking approaches (Leveson, 2011) provide robust models for understanding workplace safety. However, research consistently demonstrates that knowledge of these frameworks does not automatically translate into competent professional practice (Choudhry, Fang, & Mohamed, 2007; Wilkins, 2011). Students may successfully recall safety principles in examinations yet struggle to apply them when confronted with complex, context-dependent workplace scenarios.

Recent scholarship in engineering education highlights the necessity of aligning pedagogical methods with desired learning outcomes (Borrego & Henderson, 2014; Streveler & Menekse, 2017). In the OHS domain specifically, this alignment requires instructional approaches that develop not merely declarative knowledge but procedural competencies: the ability to analyze hazards systematically, evaluate risks with supporting evidence, select appropriate controls with justified reasoning, document decisions professionally, and transfer learned frameworks to novel situations (Blair, 2004; Fernández-Muñiz, Montes-Peón, & Vázquez-Ordás, 2012).

Despite this recognized need, empirical investigations of actual OHS teaching practices in technical universities remain limited. Most existing research focuses either on curricular content analysis (what topics are covered) or student outcome assessment (what students know), with insufficient attention to the pedagogical processes that mediate between input and output (Hämäläinen, Oksanen, & Tuominen, 2009; Mulholland & Turnock, 2015). Understanding these processes—the specific instructional methods employed, their implementation patterns, and their relationship to student competency development—is essential for evidence-based improvement of OHS education.

This study addresses this gap through systematic examination of OHS teaching practices in engineering programs. We employ a content-technology-assessment analytical framework that examines not only what content is taught but how it is taught and how student learning is evaluated. The framework enables identification of specific misalignments between instructional approaches and competency development goals, moving beyond global assessments of teaching quality to actionable insights for pedagogical innovation.

1.1 Research Questions

This investigation is guided by three interrelated research questions:

- RQ1: What pedagogical methods and technologies are currently employed in OHS instruction in technical universities, and how are they distributed across class time?

- RQ2: What specific difficulties do students experience in developing risk-based decision-making competencies, and how do these difficulties relate to instructional practices?
- RQ3: How do current assessment practices align with the procedural competencies central to professional OHS practice?

2. Methods

2.1 Research Design

This study employed a convergent mixed methods design (Creswell & Plano Clark, 2018), collecting quantitative and qualitative data concurrently and integrating findings through triangulation. This approach allows for comprehensive examination of teaching practices by combining frequency-based observations of instructional methods with in-depth exploration of participant experiences and perspectives.

The analytical framework organizing data collection and analysis focused on three dimensions: (1) content—what is taught and its professional relevance, (2) technology—pedagogical methods and their implementation, and (3) assessment—how student learning is evaluated and whether evaluation methods align with competency goals. This framework enables systematic identification of gaps between intended outcomes and actual practice.

2.2 Participants and Setting

The study was conducted across four technical universities in Uzbekistan offering engineering programs with required OHS coursework. Participating institutions represented diverse engineering specializations including mechanical engineering, chemical technology, oil and gas engineering, and industrial automation.

Data collection involved three participant groups:

- Classroom observations: 15 OHS class sessions (8 lectures, 7 practical sessions) across four institutions
- Student survey: 247 students enrolled in OHS courses across multiple engineering disciplines

- Interviews: 10 OHS instructors and 18 students selected through purposive sampling to represent diverse engineering specializations

This sample size aligns with recommendations for mixed methods research in educational contexts, providing sufficient breadth for identifying patterns while enabling depth of qualitative exploration (Onwuegbuzie & Collins, 2007).

2.3 Data Collection Instruments

2.3.1 Observation Protocol

Classroom observations employed a structured protocol adapted from the COPUS (Classroom Observation Protocol for Undergraduate STEM) framework (Smith et al., 2013) but customized for OHS education. The protocol recorded:

- Time allocation across instructional methods (recorded in 10-minute intervals): lecturing, question-answer exchanges, case discussions, problem-based learning activities, simulations, debriefing sessions, and artifact development (e.g., Job Safety Analysis, risk registers)
- Content-technology-assessment markers (0-2 scale): presence of professional context in content, implementation of hazard-risk-controls chain, artifact-based outcomes, clarity of assessment criteria, evidence of scaffolding (Model→Guided→Independent progression)

Observations were conducted by the researcher with inter-rater reliability established through double-coding of 20% of sessions (Cohen's $\kappa = 0.82$).

2.3.2 Student Survey

A structured questionnaire with 28 items organized into four blocks was administered:

- Professional relevance and motivation (7 items, $\alpha = 0.84$)
- Context and pedagogical methods (8 items, $\alpha = 0.79$)
- Assessment transparency and fairness (6 items, $\alpha = 0.81$)
- Specific difficulties in competency areas (7 items, $\alpha = 0.86$): risk assessment, control selection, justification, documentation, and transfer

Items employed 5-point Likert scales (1 = strongly disagree to 5 = strongly agree). The instrument was piloted with 30 students and revised for clarity before main data collection.

2.3.3 Interview Guides

Semi-structured interviews explored:

Instructor interviews: Content selection rationale, pedagogical method choices, resource and time constraints, assessment design challenges, approaches to contextualizing content across engineering disciplines, and perceived student needs.

Student interviews: Helpful and unhelpful instructional formats, specific barriers in risk assessment, decision justification, documentation, and knowledge transfer, clarity of assessment expectations.

Interviews lasted 30-45 minutes, were audio-recorded with participant consent, and transcribed verbatim for analysis.

2.4 Data Analysis

Analysis proceeded through integrated quantitative and qualitative procedures:

- Observation data: Frequency distributions and percentages of time allocation; mean scores for content-technology-assessment markers
- Survey data: Descriptive statistics (M, SD) for each scale; ranking of difficulty areas by mean scores; open-response coding for emergent themes
- Interview data: Thematic coding following Braun and Clarke's (2006) approach, organized around cause-consequence-barrier-recommendation framework
- Triangulation: Convergent findings validated across all three data sources; divergent findings explored through re-examination of primary data

MAXQDA 2020 was used for qualitative coding and SPSS 26 for quantitative analysis.

2.5 Ethical Considerations

The study received institutional review board approval. All participants provided informed consent. Classroom observations were non-participatory and minimally disruptive. Participant anonymity was maintained through code identifiers in all reporting.

3. Results

Results are organized according to the content-technology-assessment framework, integrating findings from observations, surveys, and interviews to address each research question.

3.1 Current Pedagogical Methods (RQ1)

3.1.1 Time Allocation Across Instructional Methods

Classroom observations revealed a marked predominance of traditional instructional approaches. Table 1 presents the distribution of class time across different pedagogical methods.

Table 1. Distribution of Class Time Across Pedagogical Methods (n=15 sessions)

Instructional Method	Frequency (episodes)	Time (%)	M (SD)
Lecture/explanation	102	68%	6.8 (1.9)
Reproductive Q&A	28	7%	1.9 (1.2)
Case discussion	18	12%	1.2 (0.8)
Problem-based learning	12	8%	0.8 (0.6)
Simulation/scenario	7	5%	0.5 (0.5)
Debriefing/reflection	3	<1%	0.2 (0.4)

Traditional lecture dominated instructional time (68%), supplemented by recall-focused questioning (7%). Case-based learning, while present, occupied only 12% of class time. More interactive methods—problem-based learning (8%), simulations (5%), and debriefing activities (<1%)—were markedly underutilized. Instructor interviews provided context for this pattern. Time constraints emerged as the primary explanation: "We have to cover a lot of material in limited hours. Lectures are the most efficient way to get through the content" (Instructor 4). Resource limitations also factored prominently: "We would like to do more simulations, but we don't have the equipment or software" (Instructor 7). Several instructors acknowledged awareness of active learning methods but expressed uncertainty about implementation: "I've heard about PBL, but I'm not sure how to structure it for safety topics" (Instructor 2).

3.1.2 Content-Technology-Assessment Markers

Observations coded for specific quality markers revealed systematic gaps in pedagogical implementation (Table 2).

Table 2. Content-Technology-Assessment Quality Markers (0-2 scale, n=15 sessions)

Quality Marker	Mean Score	Interpretation
Professional context in content	1.3 (0.6)	Partially present
Hazard→Risk→Controls chain implemented	0.9 (0.7)	Rarely complete
Artifact-based outcomes (JSA, risk registers)	0.6 (0.5)	Minimal
Clear assessment criteria (IDM framework)	0.7 (0.6)	Generally unclear
Scaffolding (Model→Guided→Independent)	0.5 (0.5)	Rarely systematic

Note. Scale: 0 = absent, 1 = partially present, 2 = clearly implemented. IDM = Indicator-Evidence-Criteria framework.

While professional context appeared in content (M=1.3), its integration remained superficial—typically isolated examples rather than sustained scenario-based work. The fundamental risk management sequence (identifying hazards, assessing risks, implementing controls) was rarely implemented as a complete chain (M=0.9). Artifact development activities—creating Job Safety Analyses, risk registers, or other professional documents—were minimal (M=0.6). Assessment criteria were generally unclear (M=0.7), with students uncertain about evaluation standards. Scaffolded learning progressions were rarely systematic (M=0.5).

3.2 Student Competency Difficulties (RQ2)

3.2.1 Pattern of Difficulties

Survey data revealed consistent patterns of difficulty across risk-based decision-making competencies (Table 3).

Table 3. Student-Reported Difficulties in Core Competency Areas (n=247)

Competency Area	% Reporting Difficulty	M (SD)
Hazard identification	38%	2.8 (1.1)
Risk assessment with evidence	71%	3.9 (0.9)
Justifying control measures	64%	3.7 (1.0)
Professional documentation	58%	3.5 (1.1)
Transferring to new contexts	69%	3.8 (0.9)

Note. Difficulty scale: 1 = not at all difficult to 5 = extremely difficult. Percentage represents students scoring ≥4 on difficulty scale.

A clear pattern emerged: basic hazard identification was manageable for most students (38% difficulty), but higher-order competencies proved substantially more challenging. Seventy-one percent of students reported difficulty with evidence-based risk assessment, 64% with justifying control selection, 58% with professional documentation, and 69% with knowledge transfer to new contexts.

3.2.2 Nature of Difficulties: Qualitative Evidence

Student interviews illuminated the specific nature of these difficulties:

Risk assessment with evidence: Students distinguished between understanding risk matrices conceptually and applying them with supporting rationale. "I can use the matrix if someone tells me the likelihood and severity. But deciding those numbers myself—I don't know what evidence to use" (Student 12). "We memorize that high likelihood times high severity equals high risk. But when you're looking at an actual situation, how do you know it's 'high' versus 'medium'?" (Student 7).

Justifying control measures: Students struggled particularly with comparing alternative controls using hierarchy principles. "I understand you should use engineering controls before PPE. But in the real case, when both are possible, how do you justify choosing one?" (Student 15). "The hierarchy makes sense in theory. In practice, I just write down controls without explaining why they're the best option" (Student 4).

Professional documentation: Students reported uncertainty about documentation structure and appropriate detail level. "We know what JSA means. But when we have to create one, we don't know the format, what goes in each section, how much detail" (Student 9). "I don't have models to follow. Each time I write a risk assessment, I'm guessing about the structure" (Student 18).

Knowledge transfer: Students recognized their tendency to rely on superficial features rather than underlying principles. "When we study a chemical plant example, I can solve similar chemical problems. But if the next question is about construction, I struggle" (Student 11). "Each new scenario feels completely different, even though the safety principles should be the same" (Student 16).

3.3 Assessment Practices and Alignment (RQ3)

Both quantitative and qualitative data revealed significant misalignment between assessment practices and competency development goals.

3.3.1 Predominant Assessment Methods

Instructor interviews indicated heavy reliance on traditional assessment formats. Nine of ten instructors reported using primarily multiple-choice or short-answer tests ("They're efficient to grade and objective," Instructor 6), supplemented occasionally by oral examinations. Only three instructors regularly employed performance-based assessments, and these were typically one-time final projects rather than formative artifacts throughout the course.

Survey data corroborated this pattern: 78% of students reported that course grades derived primarily from tests measuring knowledge recall, while only 22% indicated substantial weight given to authentic safety analyses or documentation products.

3.3.2 Clarity of Assessment Criteria

Students expressed considerable uncertainty about evaluation standards for higher-order competencies. On survey items addressing assessment transparency, mean scores were 2.3/5.0 (SD=1.1) for "I understand what constitutes a good risk assessment" and 2.1/5.0 (SD=1.2) for "Assessment criteria are clearly explained before tasks."

Interview data revealed this manifested as anxiety and strategic compliance rather than competency focus: "I'm never sure what the instructor wants. I try to include everything so I don't miss points" (Student 5). "Sometimes I get full marks, sometimes I lose points, but I don't understand the difference in what I did" (Student 13).

Instructors acknowledged this challenge but attributed it to difficulty articulating tacit expertise: "I know a good risk analysis when I see one, but writing out specific criteria is hard" (Instructor 3). Several noted absence of standardized rubrics or exemplars as an institutional gap: "We don't have shared assessment tools. Everyone creates their own" (Instructor 8).

3.4 Triangulated Synthesis

Integration across data sources revealed convergent evidence for systematic pedagogical gaps. Observation data showed predominance of content delivery over competency development activities. Student surveys quantified specific difficulties in risk assessment, justification, documentation, and transfer. Instructor interviews explained these patterns through resource constraints, time pressures, and pedagogical uncertainty. Together, these streams established that current difficulties stem not from student deficits but from instructional approaches inadequately aligned with competency goals.

A clear causal chain emerged: Limited use of scaffolded, scenario-based instruction → Students develop declarative knowledge without procedural competency → Assessment focused on recall does not reveal this gap → Cycle continues without correction.

4. Discussion

4.1 Interpretation of Findings

This study's central finding—that OHS instruction emphasizes content delivery while students struggle with application competencies—aligns with broader patterns documented in engineering education research. The predominance of lecture-based instruction (68% of class time) and recall-focused assessment mirrors findings from multiple disciplinary contexts showing persistent resistance to pedagogical innovation despite extensive evidence supporting active learning approaches (Freeman et al., 2014; Prince, 2004).

However, this study extends beyond documentation of the lecture-activity gap by revealing specific mechanisms through which instructional approaches fail to develop competencies. The content-technology-assessment framework analysis identified not a single missing element but a systematic misalignment across the pedagogical system. Content emphasizes theoretical principles over authentic contexts; instructional methods provide limited opportunities for scaffolded practice; assessment measures recall rather than application. Each element individually might appear reasonable, but their interaction produces an educational experience poorly suited to developing risk-based decision-making expertise.

4.2 The Scaffolding Gap

Student difficulties were most pronounced in areas requiring procedural fluency: applying risk assessment frameworks with supporting evidence, comparing and justifying control options, and transferring learned approaches to new contexts. These are precisely the competencies that cognitive theories of skill acquisition indicate require extensive deliberate practice with gradually decreasing support (Collins, Brown, & Newman, 1989; van Merriënboer & Kirschner, 2018).

The observed instructional pattern—explanation followed by independent application—lacks the intermediate guided practice essential for competency development. When instructors did employ case discussions or problem-solving activities (Table 1), these typically occurred as isolated episodes rather than systematically scaffolded progressions. Students were expected to move directly from observing an instructor demonstrate risk analysis to independently performing the same analysis, without structured opportunities to attempt the task with coaching, feedback, and gradual responsibility transfer.

This pattern is particularly problematic for risk-based decision making, which requires not algorithmic application of rules but adaptive expertise—the ability to recognize relevant principles, select appropriate frameworks, and justify decisions with context-appropriate evidence (Hatano & Inagaki, 1986). Developing such expertise requires cycles of performance, feedback, and reflection that were largely absent from observed instruction.

4.3 The Assessment Feedback Loop

Assessment practices compound the scaffolding gap through a pernicious feedback mechanism. When tests emphasize recall of safety principles and definitions, students who have developed only declarative knowledge can perform acceptably. This masks the competency deficit until students encounter authentic workplace demands requiring application, at which point the educational system has already validated their preparation as adequate.

This finding resonates with literature on assessment validity in professional education (Baartman et al., 2007; Messick, 1995). Assessments that focus on content coverage rather than authentic performance provide unreliable signals about student readiness. The reported student uncertainty about quality criteria (M=2.3/5.0 for understanding good risk assessment) suggests assessment is functioning primarily for grading rather than as a developmental tool providing actionable feedback on competency progress.

Moreover, instructor acknowledgment of difficulty articulating tacit evaluation criteria reveals a deeper issue: without explicit frameworks for what constitutes competent performance, instructors cannot design learning experiences that systematically develop those competencies, nor can they provide students with clear targets for their development efforts. The absence of standardized rubrics or exemplars noted by instructors represents not merely a resource gap but a conceptual one—lack of shared understanding about what competency looks like.

4.4 Implications for Practice

These findings carry several implications for OHS education improvement:

First, instructional design must prioritize scaffolded competency development over content coverage. This does not necessarily require reducing content but rather organizing it around authentic scenarios that provide context for applying theoretical principles. Rather than lecture on hierarchy of controls followed by practice problems, instruction might present a realistic workplace situation, guide students through collaborative analysis using hierarchy principles, provide feedback on their reasoning, and progressively reduce support across multiple cases until students can perform independently.

Second, assessment must shift from measuring knowledge recall to evaluating application competency through authentic artifacts. Developing shared rubrics that make competency criteria explicit would serve dual purposes: providing students with clear performance standards and helping instructors design instruction targeting those standards. Portfolio-based assessment including Job Safety Analyses, risk registers, and other professional documents would better align evaluation with learning goals.

Third, instructor development must address not only awareness of active learning methods but practical implementation skills. Instructor comments revealed familiarity with terms like "problem-based learning" but uncertainty about structuring such activities for safety content. Professional development should move beyond conceptual introduction to supported practice designing and facilitating competency-focused instruction.

Fourth, institutional support systems need strengthening. Instructor references to time constraints and resource limitations point to systemic barriers that individual pedagogical skill cannot overcome. Addressing these requires institutional commitment to supporting instructional innovation through curriculum design time, access to simulation and case resources, and assessment tool development.

4.5 Limitations

Several limitations should be considered when interpreting these findings. The study was conducted within a specific national context (Uzbekistan) where engineering education structures and safety regulations may differ from other contexts, potentially limiting generalizability. The observation sample, while representing diverse institutions, was relatively small (n=15 sessions), and observer presence may have influenced instructor behavior despite efforts to minimize disruption.

Student self-reported difficulty measures may be influenced by factors beyond actual competency, including confidence and prior experience. While triangulation with observation data strengthens conclusions, direct assessment of student competency through standardized performance tasks would provide additional validity evidence.

The cross-sectional design captures a snapshot of current practice but cannot determine whether observed patterns represent stable practices or transitional states. Longitudinal investigation tracking changes in teaching practices and student outcomes over time would provide stronger evidence for causal relationships between pedagogical approaches and competency development.

4.6 Future Research Directions

This study's diagnostic findings create foundation for intervention research. Key questions include:

- What specific scaffolding structures (e.g., worked examples, collaborative problem-solving protocols, think-aloud modeling) most effectively support development of risk assessment and decision justification competencies?

- How can artifact-based assessment be implemented efficiently given instructor time constraints, and what professional development approaches best support instructors in this transition?
- Do competencies developed through scaffolded scenario-based instruction transfer effectively to actual workplace performance, and what additional supports facilitate this transfer?
- How do engineering discipline differences (mechanical vs. chemical vs. civil) influence optimal OHS instructional approaches, and should pedagogical frameworks be discipline-specific or discipline-general?

Comparative research examining OHS education across international contexts could identify whether observed patterns are context-specific or represent more universal challenges in professional competency development.

5. Conclusion

This convergent mixed methods investigation provides empirical evidence that current OHS teaching practices in technical universities demonstrate systematic misalignment between instructional approaches and competency development goals. While students acquire adequate declarative knowledge about safety principles, they struggle with procedural competencies essential for professional practice: evidence-based risk assessment, justified decision making, professional documentation, and knowledge transfer.

These difficulties are not attributable to student deficiencies but to pedagogical approaches that emphasize content delivery over scaffolded skill development and assessment practices that measure recall rather than application. The predominance of traditional lecture-based instruction, limited use of authentic scenario-based learning, absence of systematic scaffolding progressions, and reliance on recall-focused assessment create a system that validates theoretical knowledge while leaving application competencies underdeveloped.

Addressing these gaps requires not incremental adjustments to current practice but systematic restructuring of the content-technology-assessment framework. Instruction must be organized around authentic scenarios providing context for theoretical principles. Pedagogical methods must incorporate scaffolded progressions with extensive guided practice. Assessment must employ artifact-based evaluation with explicit criteria that make competency standards transparent.

The study's diagnostic findings provide foundation for evidence-based innovation in OHS education. By identifying specific mechanisms through which current approaches fail to develop competencies, results point toward targeted interventions: developing shared rubrics and exemplars, creating scenario banks for scaffolded instruction, providing instructor development in facilitating competency-focused learning, and establishing institutional supports for pedagogical innovation.

Occupational health and safety remains a critical concern in engineering practice, with real consequences for worker wellbeing. Ensuring that engineering graduates possess not merely knowledge about safety but genuine competency in risk-based decision making is both an educational and ethical imperative. This study demonstrates that achieving this goal requires fundamental rethinking of how we design, deliver, and assess OHS education.

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