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CONCEPTUAL INTEGRATION OF INDUSTRY SCENARIO CARDS AND HAZARD CARD IN MACHINING ENGINEERING LEARNING: A LITERATURE REVIEW ON OSH-ORIENTED TECHNICAL EDUCATION

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ABSTRACT

Machining engineering learning in higher education faces challenges in balancing technical competency development with occupational safety and health (OSH) awareness. Existing instructional practices in machining workshops are still predominantly product-oriented and procedural, resulting in limited integration of systematic hazard identification and risk analysis during practical activities. This study aims to conceptually examine the integration of industry scenario cards and hazard cards as contextual learning media to support OSH-oriented technical education in machining engineering. This study employed a systematic literature review approach using databases published between 2015 - 2025. The search used keywords including "scenario-based learning", "hazard card", "occupational safety and health", "machining education", and "engineering education". The findings indicate that scenario-based learning effectively improves critical thinking, contextual problem solving, and work readiness, while hazard-based visual media strengthen students' abilities in hazard identification, risk assessment, and safety decision-making. However, previous studies generally implemented both approaches separately and rarely integrated contextual industrial scenarios with systematic workplace hazard analysis in machining education. Therefore, this study proposes a conceptual integration model combining industry scenario cards and hazard cards to support holistic learning involving cognitive, psychomotor, and affective domains. The proposed model contributes theoretically to contextual OSH-oriented vocational pedagogy and practically provides an alternative instructional framework for machining engineering courses in higher education.

Keywords: *machining engineering education, occupational safety and health, scenario-based learning, hazard card, literature review*

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BACKGROUND

The increasingly complex development of the manufacturing industry demands that higher education graduates, especially in the field of engineering, possess competencies that not only focus on technical skills but also include critical thinking, problem-solving abilities, and awareness of occupational safety and health (OSH). In this context, the course on Machining Engineering plays a strategic role in equipping students with the operational skills of machine tools while also fostering a professional and safe work attitude. The machining process that involves rotating equipment, mechanical pressure, and metal materials has a high level of risk that can lead to workplace accidents if not balanced with adequate understanding of occupational health and safety (International Labor Organization, 2020).

However, the approach that focuses on product outcomes and procedural skills still dominates the learning of machining techniques in higher education. During practice, students often focus too much on completing workpieces according to specifications without considering the potential hazards that may arise. This shows that the element of occupational safety has not been well integrated into the learning process. In fact, the industrial world needs employes who can combine technical skills with the ability to identify risks and make safe decisions in the workplace (World Health Organization, 2021).

Along with the development of educational paradigms, student-centered learning approaches are increasingly being implemented to enhance the quality of education. One of the relevant approaches is scenario-based learning, which presents real-life situations or problems into the learning process. This approach allows students to understand the work context more deeply and to train their analytical and decision-making skills in complex situations (Clark, 2020). Research shows that scenario-based learning can enhance students' critical thinking skills and job readiness (Petersen et al., 2022).

On the other hand, K3 learning requires media that can facilitate students in systematically identifying and analyzing risks. One of the media that can be used is the hazard card, which is a visual aid containing information about potential hazards, risk levels, and mitigation steps. The use of visual media in learning has been proven effective in enhancing concept understanding and hazard identification skills (Dyreborg et al., 2022).

Nevertheless, the implementation of scenario-based learning and the use of hazard cards in engineering education are still tend to be done partially. There are still not many studies that integrate both approaches into a comprehensive learning model, especially in the context of machining engineering. In fact, the integration between the industrial context and work risk analysis is very important to produce more comprehensive, contextual, and job-relevant learning.

The theoretical gap lies in the absence of an integrated conceptual framework connecting contextual technical learning with systematic workplace hazard analysis in machining education. Meanwhile, the pedagogical gap concerns the lack of learning media capable of simultaneously facilitating technical problem solving and safety-oriented decision-making during machining practices.

To address these gaps, this study proposes the conceptual integration of industry scenario cards and hazard cards as contextual and risk-based learning media in machining engineering education. Industry scenario cards are designed to present authentic industrial problems encountered during machining processes, while hazard cards guide students in identifying hazards, assessing risks, and determining mitigation strategies systematically. The integration of these two media is expected to support holistic learning involving cognitive, psychomotor, and affective domains, while simultaneously strengthening students' professional competence and workplace safety awareness.

RESEARCH METHOD

The research method used in this study is a literature review with descriptive analysis. The literature review method involves activities related to the collection of library data, reading, noting, and processing research materials (Yulia et al., 2022). To collect, analyze, and synthesize relevant literature or information sources, the literature review method involves searching various types of literature, such as books, articles, reports, and others (Jamaludin et al., 2023). The data sources used in this study are articles relevant to the research topic. This study employed a systematic literature review approach using databases published between 2015 - 2025. The search used keywords including "scenario-based learning", "hazard card", "occupational safety and health", "machining education", and "engineering education.

RESULT AND DISCUSSION

1. Learning Machining Techniques In Higher Education

The study of machining techniques in higher education represents a crucial component of engineering education, particularly within manufacturing and mechanical engineering programs. This field of study is designed to equip students with essential competencies related to manufacturing processes, especially those involving the operation of machine tools such as lathes, milling machines, and grinding machines. These competencies are not limited to technical proficiency in operating machinery but also encompass a comprehensive understanding of cutting parameters, tool selection, material characteristics, and the interpretation of technical drawings and product specifications. Therefore, machining education is inherently multidisciplinary, requiring the integration of theoretical knowledge and practical application.

In the context of learning domains, machining technique education involves the development of cognitive, psychomotor, and affective aspects simultaneously. The cognitive domain includes the understanding of machining theory, such as cutting mechanics, tool geometry, and process optimization. The psychomotor domain is reflected in students' ability to operate machines accurately, safely, and efficiently. Meanwhile, the affective domain involves attitudes such as discipline, responsibility, safety awareness, and professional ethics in workshop environments. The integration of these three domains makes machining education unique and complex, requiring carefully designed instructional strategies to ensure balanced competency development.

However, the rapid advancement of the modern manufacturing industry has significantly transformed the competency requirements expected from engineering graduates. The emergence of Industry 4.0, automation, and digital manufacturing systems has shifted the focus from merely operating machines to mastering complex problem-solving, critical thinking, and adaptability skills. According to Billett (2021), the contemporary workforce demands individuals who are not only technically skilled but also capable of responding to dynamic changes in technology and workplace environments. This indicates that traditional learning approaches, which are predominantly lecturer-centered and procedural, are no longer sufficient to meet industry expectations.

Conventional teaching methods in machining education often emphasize step-by-step procedures demonstrated by instructors, followed by students replicating those procedures. While this approach may be effective in introducing basic operational skills, it tends to limit students' ability to think critically and independently. Students may become passive learners who rely heavily on instructions rather than actively engaging in problem-solving processes. Consequently, there is a need to transform the learning approach into one that promotes active participation, critical inquiry, and contextual understanding.

To address these challenges, various student-centered learning approaches have been introduced and widely implemented in engineering education. Among these, problem-based learning (PBL), project-based learning (PjBL), and case-based learning (CBL) have gained significant attention due to their effectiveness in enhancing learning outcomes. These approaches emphasize active student engagement, collaboration, and the application of knowledge in real-world contexts.

Problem-based learning, for instance, encourages students to learn through the process of solving complex and authentic problems. In this approach, students are presented with a problem scenario that does not have a straightforward solution. They are required to identify what they need to learn, gather relevant information, and develop possible solutions. Hmelo-Silver (2020) explains that PBL fosters higher-order thinking skills by engaging students in analysis, synthesis, and evaluation processes. In machining education, PBL can be implemented by presenting students with real manufacturing challenges, such as optimizing machining parameters for a specific material or minimizing production defects.

Similarly, project-based learning provides students with opportunities to work on extended projects that simulate real industrial tasks. Through PjBL, students can design, plan, and execute machining projects, such as producing a mechanical component based on given specifications. This approach not only enhances technical skills but also develops soft skills such as teamwork, communication, time management, and project management. Guo et al. (2020) highlight that project-based learning offers meaningful learning experiences by connecting theoretical knowledge with practical application in a structured manner.

Case-based learning, on the other hand, involves the analysis of real or simulated cases related to machining and manufacturing processes. Students are required to examine the case, identify problems, and propose solutions based on their understanding. This approach is particularly effective in developing analytical and decision-making skills, as it exposes students to real-world complexities and uncertainties.

In addition to these active learning strategies, the incorporation of experiential learning principles is essential in machining education. Experiential learning, as proposed by Kolb (2015), emphasizes learning through experience, reflection, conceptualization, and experimentation. In machining workshops, students gain direct hands-on experience by operating machines, observing machining processes, and dealing with practical challenges such as tool wear, machine vibrations, and material inconsistencies.

The experiential learning cycle begins with concrete experience, where students actively engage in machining tasks. This is followed by reflective observation, where students reflect on their experiences, identifying what worked well and what did not. The next stage, abstract conceptualization, involves linking these experiences with theoretical concepts. Finally, in the active experimentation stage, students apply their new understanding to improve their performance in subsequent tasks. This continuous cycle enhances both practical skills and conceptual understanding.

Furthermore, experiential learning helps bridge the gap between theory and practice, which is often a challenge in engineering education. Students who actively engage in practical experiences are more likely to develop a deeper understanding of machining concepts compared to those who rely solely on theoretical instruction. Reflection plays a critical role in this process, as it allows students to internalize their experiences and develop meaningful insights.

The integration of active learning approaches and experiential learning principles requires a holistic design of machining education. Educators must create learning environments that encourage exploration, collaboration, and critical thinking. This includes designing authentic learning tasks, providing adequate resources and facilities, and facilitating meaningful interactions between students and instructors. Assessment methods should also be aligned with these approaches, focusing not only on technical outcomes but also on the learning process and the development of higher-order skills.

In conclusion, machining technique education in higher education must evolve to meet the demands of the modern manufacturing industry. It should no longer rely solely on traditional, lecturer-centered approaches but instead adopt active, contextual, and experiential learning strategies. By integrating cognitive, psychomotor, and affective domains with innovative teaching methods such as problem-based learning, project-based learning, and experiential learning, educators can better prepare students for the complexities of the industrial world. This holistic approach ensures that graduates possess not only technical expertise but also the critical thinking, adaptability, and professional competencies required in today’s rapidly changing manufacturing landscape.

2. Ocupational Safety and Health in Machining Techniques

Occupational Safety and Health (OSH) constitutes a fundamental aspect of machining engineering activities that cannot be separated from both learning and practical processes in laboratory and industrial environments. The machining process inherently involves direct interaction between humans, machines, and materials, creating a complex system in which potential hazards are always present. These hazards, if not properly managed, can lead to workplace accidents and long-term health issues. Therefore, the integration of OSH principles into machining education is essential to ensure that students develop not only technical competence but also a strong awareness of safety and risk management.

Machining activities such as turning, milling, and grinding involve the use of high-speed rotating machinery and sharp cutting tools, which significantly increase the risk of accidents. For instance, operators may experience injuries due to entanglement with rotating parts, contact with cutting tools, or being struck by flying metal chips produced during the cutting process. These incidents can result in severe injuries, including lacerations, fractures, or even permanent disability. Furthermore, environmental factors such as excessive noise, machine vibration, high temperatures, and inadequate lighting conditions can negatively affect the health, concentration, and performance of operators (International Labour Organization, 2020). Prolonged exposure to such conditions may lead to occupational illnesses, including hearing loss, musculoskeletal disorders, and fatigue-related errors.

In the framework of modern occupational safety management, the implementation of OSH has evolved from a reactive approach responding to accidents after they occur to a more proactive and preventive system. This transformation is reflected in international standards such as ISO 45001 (2018), which emphasizes a systematic approach to managing occupational health and safety risks. According to this standard, effective OSH management involves three key stages: hazard identification, risk assessment, and risk control. These stages form a continuous cycle that aims to minimize risks and improve workplace safety performance.

Hazard identification is the initial and crucial step in the OSH management process. It involves recognizing all potential sources of danger in the machining environment. These hazards may include mechanical risks from moving machine components, physical risks such as noise and heat, chemical risks from cutting fluids, and ergonomic risks related to posture and repetitive movements. In machining laboratories, hazard identification should be conducted systematically before any practical activity begins, ensuring that students are aware of the potential dangers associated with each task.

Following hazard identification, risk assessment is conducted to evaluate the likelihood of occurrence and the severity of potential consequences associated with each hazard. This process enables educators and students to prioritize risks and determine which hazards require immediate attention. Risk assessment often involves qualitative or quantitative methods, such as risk matrices, to classify risks into categories ranging from low to high. By understanding the level of risk, appropriate preventive measures can be designed and implemented effectively.

The final stage, risk control, focuses on implementing strategies to eliminate or reduce identified risks. According to Manuele (2020), risk control measures can be categorized into several levels, including elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE). In machining practices, engineering controls may include machine guards, emergency stop systems, and proper ventilation. Administrative controls involve the establishment of standard operating procedures (SOPs), safety training, and supervision. Meanwhile, PPE such as safety glasses, gloves, ear protection, and protective clothing serves as the last line of defense against hazards.

In the context of machining engineering, hazards can be broadly classified into several categories. Mechanical hazards are among the most common and arise from moving parts of machines, such as spindles, chucks, gears, and cutting tools. These hazards pose risks of entanglement, crushing, and cutting injuries. Physical hazards include exposure to high levels of noise, vibration, and heat, which can affect both short-term comfort and long-term health. Material-related hazards involve sharp metal chips, hot surfaces, and the use of cutting fluids that may cause burns or skin irritation. Additionally, ergonomic hazards emerge from improper working postures, repetitive motions, and poorly designed workstations, leading to musculoskeletal strain and fatigue (World Health Organization, 2021).

Despite the recognized importance of OSH, its implementation in machining engineering education at the university level still faces several challenges. One of the primary issues is the separation between theoretical instruction and practical application. OSH concepts are often delivered in classroom settings without sufficient integration into workshop activities. As a result, students may understand safety principles in theory but fail to apply them effectively during practical work. This gap reduces the effectiveness of safety education and may lead to unsafe behaviors in laboratory settings.

Moreover, students often perceive safety procedures as rigid rules that must be followed rather than as essential practices grounded in risk awareness. This perception can lead to compliance without understanding, where students follow instructions mechanically without recognizing the underlying reasons. Consequently, their ability to identify hazards, assess risks, and make safe decisions independently remains limited. This condition highlights the need for a more contextual and integrative approach to OSH learning.

Recent studies suggest that integrating OSH learning with hands-on practice significantly improves students' safety awareness and behavior. Kines et al. (2021) found that experiential and practice-based safety training enhances the ability of learners to recognize hazards and respond appropriately to risky situations. When students are actively involved in identifying hazards and implementing safety measures during practical activities, they develop a deeper understanding of the importance of OSH.

In addition, the use of visual-based learning media, such as videos, simulations, and virtual reality, has proven to be effective in improving hazard recognition skills. Burke et al. (2021) emphasize that visual and interactive learning tools can provide realistic representations of workplace hazards, allowing students to experience potential risks in a controlled environment. These tools not only enhance engagement but also facilitate experiential learning by enabling students to observe, analyze, and reflect on safety-related scenarios.

Furthermore, incorporating reflective practices into OSH learning can strengthen students' understanding and awareness. After completing practical activities, students can be encouraged to reflect on the risks they encountered, the safety measures they applied, and the outcomes of their actions. This reflective process helps reinforce learning and promotes the internalization of safety values.

Therefore, OSH learning in machining engineering should be designed systematically and integrated seamlessly with practical activities. Educators need to develop instructional strategies that combine theoretical knowledge with hands-on experience, ensuring that students can apply safety principles in real-world contexts. This integration can be achieved through approaches such as problem-based learning, project-based learning, and simulation-based training, which emphasize active participation and contextual understanding.

In addition, assessment methods should also be aligned with OSH learning objectives. Evaluation should not only focus on technical outcomes but also consider students' ability to identify hazards, assess risks, and demonstrate safe work behavior. By incorporating safety performance into assessment criteria, educators can reinforce the importance of OSH and encourage students to prioritize safety in their work.

In conclusion, Occupational Safety and Health is an integral component of machining engineering education that plays a vital role in preventing accidents and promoting a safe working environment. The effective implementation of OSH requires a systematic, preventive, and integrated approach that combines hazard identification, risk assessment, and risk control. By integrating OSH learning with practical activities and adopting innovative instructional methods, universities can enhance students' safety awareness, critical thinking, and professional responsibility. Ultimately, this approach not only reduces the risk of accidents but also contributes to the development of a safety-oriented culture that aligns with the demands of the modern industrial world.

3. Scenario-Based Learning on Engineering Education

Scenario-based learning (SBL) is an educational approach that places students in structured situations that closely resemble real-world conditions, particularly those encountered in professional and industrial environments. This approach is designed to provide contextual and meaningful learning experiences, enabling students to apply theoretical knowledge and technical skills in complex, dynamic, and often uncertain situations. In engineering education, scenario-based learning is highly relevant because it addresses one of the most persistent challenges in teaching and learning, namely the gap between classroom theory and industrial practice.

Traditional instructional approaches in engineering education often rely on lectures and demonstrations that emphasize conceptual understanding and procedural knowledge. While these approaches are important for building foundational knowledge, they may not adequately prepare students for the complexities of real-world problem-solving. In contrast, scenario-based learning introduces students to authentic problems that require them to think critically, analyze multiple variables, and make informed decisions. By simulating real-life conditions, SBL allows students to experience the cognitive and practical demands of professional work before entering the workforce.

At the core of scenario-based learning is the use of realistic scenarios or cases that reflect actual challenges in the field. These scenarios are carefully designed to include elements of complexity, ambiguity, and uncertainty, which are characteristic of real-world situations. Students are typically presented with a problem, such as a system failure, process inefficiency, or quality defect, and are required to analyze the situation, identify underlying causes, and propose appropriate solutions. This process encourages active learning, as students must engage with the material, collaborate with peers, and apply their knowledge in a practical context.

According to Clark (2020), scenario-based learning promotes the development of higher-order thinking skills, including critical thinking, analytical reasoning, and decision-making. Unlike traditional problem-solving exercises that often have clear and predetermined answers, scenarios in SBL may have multiple possible solutions. This open-ended nature requires students to evaluate different alternatives, consider potential consequences, and justify their decisions. As a result, students develop a deeper understanding of the subject matter and become more capable of handling complex and unstructured problems.

Research also indicates that scenario-based learning can significantly enhance student engagement and motivation. When students are presented with realistic and relevant problems, they are more likely to perceive the learning process as meaningful and valuable. Petersen et al (2021) highlight that the integration of technology, such as simulations and virtual environments, can further enhance the effectiveness of scenario-based learning. Technology-supported SBL provides immersive experiences that allow students to interact with virtual systems, observe the consequences of their actions, and receive immediate feedback. This interactive environment not only improves conceptual understanding but also facilitates knowledge transfer to real-world contexts.

In addition to cognitive benefits, scenario-based learning also supports the development of soft skills that are essential in the workplace. These include communication, teamwork, adaptability, and the ability to work under pressure. In many SBL activities, students work in groups to analyze scenarios and develop solutions collaboratively. This collaborative process mirrors the teamwork required in professional environments, where engineers must often work with multidisciplinary teams to solve complex problems.

In the context of machining engineering, scenario-based learning can be effectively applied to simulate various challenges encountered in manufacturing processes. For example, students can be presented with a scenario involving poor surface finish on a machined component. They must analyze possible causes, such as incorrect cutting parameters, tool wear, machine vibration, or material inconsistencies. Based on their analysis, students propose solutions, such as adjusting feed rate and cutting speed, replacing worn tools, or improving machine setup.

Another example involves scenarios related to cutting parameter errors. Students may be asked to evaluate a machining process where excessive tool wear occurs prematurely. They must identify whether the issue is caused by inappropriate cutting speed, feed rate, depth of cut, or cooling conditions. Through this process, students learn to connect theoretical concepts with practical outcomes, enhancing their understanding of machining principles.

Machine failure scenarios can also be incorporated into SBL activities. For instance, students may analyze a case where a lathe machine suddenly stops during operation. They must investigate possible causes, such as electrical faults, mechanical breakdowns, or improper maintenance. This type of scenario not only develops technical troubleshooting skills but also raises awareness of maintenance practices and workplace safety.

Furthermore, scenario-based learning can be integrated with occupational safety and health (OSH) considerations in machining education. Scenarios can include potential hazards, such as flying metal chips, tool breakage, or improper use of personal protective equipment (PPE). Students are required to identify these hazards, assess the associated risks, and propose appropriate control measures. This integration ensures that students develop both technical competence and safety awareness simultaneously.

One of the key strengths of scenario-based learning is its ability to support systematic problem-solving. Students are encouraged to follow structured steps, such as problem identification, data collection, analysis, solution development, and evaluation. This systematic approach aligns with engineering practices and helps students develop a disciplined way of thinking. Over time, students become more confident in their ability to tackle complex problems and make informed decisions. Despite its advantages, the implementation of scenario-based learning requires careful planning and design. Scenarios must be realistic, relevant, and aligned with learning objectives. They should be challenging enough to stimulate critical thinking but not so complex that they overwhelm students. Instructors also play a crucial role in facilitating SBL by guiding discussions, providing feedback, and encouraging reflection.

Assessment in scenario-based learning should also be designed to capture both the process and the outcome of learning. In addition to evaluating the correctness of solutions, assessments should consider students' reasoning, problem-solving strategies, and ability to justify their decisions. Reflective activities, such as journals or group discussions, can be used to deepen learning and reinforce key concepts.

In conclusion, scenario-based learning represents an effective and innovative approach to improving the quality of engineering education, particularly in machining engineering. By providing realistic and contextual learning experiences, SBL helps bridge the gap between theory and practice, enabling students to apply their knowledge in meaningful ways. This approach not only enhances technical competencies but also develops higher-order thinking skills, adaptability, and professional readiness. As the demands of the workforce continue to evolve, scenario-based learning offers a powerful tool for preparing students to navigate the complexities of modern industrial environments.

4. Hazard Card As A Risk Based Learning

A hazard card is a type of instructional and safety-oriented learning media designed to assist in the identification, analysis, and management of potential hazards within a specific work activity. Fundamentally, a hazard card functions as a concise yet informative tool that presents key safety-related information, including the type of hazard, its potential impact, the level of risk involved, and recommended mitigation or control measures. In industrial settings, hazard cards are widely used as part of occupational safety and health (OSH) management systems to promote awareness, standardize safety communication, and support preventive safety practices among workers.

The concept of hazard cards is closely aligned with risk-based thinking, which is central to modern safety management frameworks. Rather than merely reacting to accidents, hazard cards encourage proactive identification of potential dangers before work activities are carried out. This approach supports the broader goal of minimizing workplace incidents by embedding safety awareness into routine tasks. In practice, hazard cards are often displayed near workstations, attached to equipment, or distributed to workers prior to task execution, serving as constant reminders of the risks associated with specific operations.

In the context of engineering education, particularly in machining engineering, hazard cards can be adapted as an effective pedagogical tool to enhance students' understanding of workplace safety. Unlike traditional teaching methods that rely heavily on theoretical explanations, hazard cards provide a more concrete and contextual learning experience. They allow students to visualize potential hazards associated with specific machining processes, such as turning, milling, and grinding, and to understand how these hazards can be managed effectively.

The use of hazard cards in educational settings supports the development of systematic thinking in hazard identification and risk analysis. Students are trained to observe a given task, identify possible sources of danger, evaluate the level of risk, and determine appropriate control measures. This process not only strengthens their cognitive understanding of safety concepts but also fosters analytical and critical thinking skills. By engaging with hazard cards, students move beyond passive learning and become active participants in the safety management process.

Moreover, hazard cards contribute to the development of risk-based decision-making skills, which are essential in modern engineering practice. In real-world situations, engineers and technicians are often required to make quick yet informed decisions regarding safety. Through repeated exposure to hazard identification and risk analysis using hazard cards, students can develop the ability to assess situations critically and choose the safest course of action. This aligns with the demands of the industrial workforce, where safety awareness and decision-making capabilities are highly valued.

From a learning theory perspective, the effectiveness of hazard cards can be explained through multimedia learning principles. Mayer (2021) emphasizes that learning is more effective when information is presented through both visual and verbal channels simultaneously. Hazard cards typically combine text descriptions with visual elements such as icons, diagrams, or color codes to represent different types of hazards and risk levels. This dual representation helps students process information more efficiently, leading to better comprehension and retention.

Visual learning media also play a significant role in enhancing students' engagement and motivation. Compared to purely textual materials, hazard cards are more attractive and easier to understand, especially for complex or abstract safety concepts. The use of symbols and color coding—such as red for high risk, yellow for medium risk, and green for low risk—enables students to quickly grasp the severity of hazards. This immediacy is particularly important in machining environments, where quick recognition of risks can prevent accidents.

Empirical research further supports the effectiveness of visual-based safety learning tools. Kines et al. (2021) found that the use of visual aids in safety training significantly improves individuals' ability to identify hazards and respond appropriately to risky situations. Visual tools help bridge the gap between theoretical knowledge and practical application by providing realistic representations of workplace conditions. In this regard, hazard cards serve as an accessible and practical medium for safety education.

In machining engineering, hazard cards can be designed to cover a wide range of potential hazards associated with different processes and equipment. Mechanical hazards, for example, may include risks related to rotating parts such as spindles, chucks, and cutting tools. These hazards can lead to serious injuries if proper precautions are not taken. Physical hazards, such as noise, heat, and vibration, can also be highlighted in hazard cards to raise awareness of their long-term health impacts. Additionally, material-related hazards, including sharp metal chips and hot surfaces, can be clearly illustrated to emphasize the need for protective measures.

Ergonomic hazards can also be incorporated into hazard cards, particularly those related to improper working postures, repetitive movements, and poorly designed workstations. By including these aspects, hazard cards provide a comprehensive view of workplace risks, encouraging students to consider not only immediate dangers but also long-term health implications. This holistic perspective is essential for developing a strong safety culture among future engineers.

The implementation of hazard cards in machining education can take various forms. For instance, instructors can use hazard cards as part of pre-practical briefings, where students are required to review and discuss potential hazards before starting a task. Hazard cards can also be integrated into group activities, where students collaborate to identify hazards in a given scenario and propose appropriate control measures. This collaborative approach enhances communication skills and promotes shared responsibility for safety.

Furthermore, hazard cards can be used as an assessment tool to evaluate students' understanding of safety concepts. Students may be asked to create their own hazard cards based on specific machining activities, demonstrating their ability to identify hazards, assess risks, and recommend control measures. This task not only reinforces learning but also encourages creativity and deeper engagement with the subject matter.

Despite their advantages, the effectiveness of hazard cards depends on proper design and implementation. Hazard cards must be clear, concise, and relevant to the specific context in which they are used. Overly complex or ambiguous information may reduce their effectiveness and lead to misunderstandings. Therefore, educators must ensure that hazard cards are developed based on accurate risk assessments and aligned with established safety standards.

In addition, the use of hazard cards should be complemented by other instructional strategies, such as demonstrations, simulations, and hands-on practice. While hazard cards provide valuable information, they cannot replace direct experience in handling machinery and managing risks. Instead, they should be viewed as part of an integrated learning approach that combines theory, visualization, and practical application.

In conclusion, hazard cards represent an effective and practical learning medium for supporting risk-based learning in machining engineering education. By facilitating hazard identification, risk analysis, and decision-making processes, hazard cards help students develop essential safety competencies. Their visual and structured format enhances understanding and retention, while their application in practical settings promotes active and contextual learning. The integration of hazard cards into machining education not only reduces the risk of accidents but also contributes to the development of a systematic and proactive safety culture. Ultimately, this approach prepares students to become competent professionals who prioritize safety in their engineering practices.

CONCLUSION

This conceptual study concludes that machining engineering education still faces challenges in integrating technical competencies with occupational safety and health (OSH). Current instructional practices primarily emphasize product quality and machining accuracy, while safety competencies such as hazard identification, risk assessment, and safe decision-making are often addressed separately or receive less attention. As a result, students may develop strong technical skills but lack the ability to systematically recognize and manage workplace hazards. This limitation highlights the need for a more holistic instructional approach that simultaneously develops cognitive, psychomotor, and affective competencies. The proposed integration of industry scenario cards and hazard cards offers a promising solution by embedding safety considerations directly into technical learning activities. Industry scenario cards provide authentic industrial contexts that encourage students to analyze realistic machining problems, whereas hazard cards support systematic hazard identification, risk evaluation, and the selection of appropriate control measures. Together, these learning media promote contextual learning, critical thinking, problem-solving, and the development of a safety-oriented mindset that reflects the demands of modern manufacturing industries.

Despite its theoretical contribution, the proposed model has not yet been empirically validated. Future research should evaluate its effectiveness through experimental studies comparing the integrated approach with conventional teaching methods in terms of technical competence, safety awareness, hazard identification skills, critical thinking, and employability skills. Development studies are also recommended to refine the design of both learning media so that they align with curriculum requirements and current industrial standards. Furthermore, integrating this approach with digital technologies, such as simulation software or virtual reality, may increase the authenticity and interactivity of learning experiences while strengthening students' preparedness for industrial practice. Overall, the integration of industry scenario cards and hazard cards provides a strong conceptual foundation for improving machining engineering education by combining contextual problem-solving with systematic risk analysis. This approach has the potential to produce graduates who are not only technically competent but also safety-conscious, critical thinkers who are better prepared to meet the challenges of contemporary industrial workplaces.

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