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LAB SAFETY REIMAGINED: BRIDGING THEORY AND PRACTICE THROUGH TASK-BASED ASSESSMENT

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ABSTRACT

Preservice science teachers often struggle to understand and apply the HIRARC framework (Hazard Identification, Risk Assessment, and Risk Control) because traditional teaching focuses heavily on theory with limited real-life laboratory practice. This gap hinders their ability to apply safety concepts effectively. This innovation presents a task-based assessment framework that engages students in authentic problem-solving by addressing safety gaps in a newly relocated laboratory without formal safety protocols. The initiative is packaged into a teaching pack containing project guidelines, assessment rubrics, tasks, and sample outputs. Students worked in groups for one month to tackle real laboratory safety issues. They collaborated with the lab assistant and coordinator to ensure practical and relevant solutions. Tasks included creating safety posters, drafting lab rules and regulations, labelling equipment and chemicals, developing inventory systems, writing standard operating procedures, and compiling a comprehensive safety manual. Outputs were showcased and evaluated during the Occupational Safety and Health (OSH) Day. Students showed improvement in understanding and applying HIRARC principles, and their work contributed directly to long-term improvements in lab safety infrastructure. This task-based approach bridges theory and practice, encouraging meaningful, ethical problem-solving. It aligns with values-based education principles such as responsibility, integrity, collaboration, and sustainability, while developing key competencies in critical thinking, problem solving, and teamwork. Several student-produced materials are now in active use, forming part of the lab's permanent safety system. This scalable model offers a practical and sustainable strategy for embedding scientific safety skills in teacher education.

Keywords: *HIRARC, Laboratory safety, Task-based assessment, Collaborative learning*

INTRODUCTION

Laboratory safety is a critical component in science education, especially for preservice teachers who will be responsible for conducting practical sessions in schools. However, numerous studies indicate that science teacher education often emphasizes theoretical knowledge, with minimal opportunities for applying safety concepts in authentic laboratory contexts (Gericke et al., 2023; Hussein et al., 2022). In Malaysia, safety-related incidents continue to occur in school laboratories due to gaps in safety awareness, inadequate training, and the lack of structured risk assessment practices such as HIRARC (Hazard Identification, Risk Assessment, and Risk Control). While the HIRARC framework is widely adopted in industrial and higher education contexts, its application in school-level science laboratories remains underexplored and inconsistently practiced (Edmondson et al., 2016).

To address this gap, this study introduces a task-based assessment model (HIRARC Project) designed to help preservice science teachers apply the HIRARC framework through real-life laboratory safety challenges. By embedding safety tasks into a final project and packaging them into a structured teaching pack—including guidelines, rubrics, and sample outputs—this innovation aims to bridge the gap between theory and practice. It also seeks to cultivate values-based competencies such as responsibility, integrity, and collaboration, in line with Education for Sustainable Development (ESD) and Sustainable Development Goals (SDG 3 & SDG 4). The main objective is to assess students' practical understanding of safety principles while contributing sustainable safety resources to the institutional lab infrastructure.

This innovation is grounded in the principles of experiential learning theory, where knowledge is constructed through meaningful, real-world experiences (Kolb, 1984). By engaging students in solving actual safety problems, the project embodies the "learning by doing" approach, encouraging active exploration, reflection, and application. It also draws on inquiry-based learning, where students investigate safety issues, consult relevant stakeholders, and co-construct solutions—mirroring the practices of professional educators and lab managers. The assessment structure follows a backward design model, beginning with the desired learning outcomes (understanding and applying HIRARC), then designing authentic tasks and rubrics aligned with those goals. These pedagogical foundations support the integration of Education for Sustainable Development (ESD) and the development of future-ready, values-driven science teachers.

METHODS

This innovation was carried out as the final assessment project for the *Science Laboratory Safety (SCE513)* course, involving 134 preservice science teachers from the Faculty of Education, Universiti Teknologi MARA. The project aimed to equip future science teachers with practical competencies in applying the HIRARC framework (Hazard Identification, Risk Assessment, and Risk Control) by addressing real safety challenges in a newly relocated laboratory that lacked formal safety protocols.

Students were organised into small groups and provided with a task-based teaching pack containing

project guidelines, real lab safety issues, assessment rubrics, and examples of expected outputs. The project ran over two months. In the initial phase, students conducted brainstorming sessions to analyse and discuss potential safety interventions based on HIRARC principles. These ideas were first presented to the course lecturer for verification in terms of relevance, educational value, and technical feasibility.

Once verified, students engaged in consultation sessions with the laboratory assistant and lab coordinator to refine their solutions and ensure that all outputs were practical, accurate, and implementable in the actual lab setting. The final products such as safety posters, SOPs, lab rules, chemical labels, inventory systems, and manuals were required to be fully functional and ready for use.

The culmination of the project was a formal presentation during the faculty's Occupational Safety and Health (OSH) Day. Here, student groups presented their products to a panel of evaluators comprising science education lecturers, science and technology experts, and industry representatives. During this session, students were required to explain how the HIRARC framework was embedded in their products, demonstrate the practicality and potential impact, and justify the quality and usability of their outputs based on real laboratory needs**.**

RESULTS AND DISCUSSION

The implementation of the task-based assessment significantly improved students' understanding and application of the HIRARC framework. As shown in figure 1, the pre- and post-assessment data showed a marked increase in mean scores across all three components: Hazard Identification, Risk Assessment, and Risk Control. Before the project, students demonstrated moderate understanding, with mean scores ranging between 2.0 to 2.5 on a 5-point scale. After completing the project, mean scores increased to approximately 4.5, indicating a high level of conceptual understanding and practical competence.

The integration of real-life safety problems encouraged students to actively engage in critical thinking, teamwork, and ethical decision-making—core competencies in Education for Sustainable Development (ESD). Through collaboration with lab assistants and coordinators, students were exposed to real-world expectations, enhancing both the relevance and impact of their work. Outputs such as SOPs, safety posters, inventory systems, and user friendly safety manuals are now actively used in the faculty laboratory, contributing to a safer and more structured working environment.

During the OSH Day evaluation, student groups were able to present how HIRARC principles guided their solutions clearly. They demonstrated not only technical understanding but also the educational and institutional value of their outputs. Evaluators from science education, technology, and industry backgrounds commended the students for producing functional, high-quality, and sustainable safety resources. These findings affirm the effectiveness of task-based assessments in bridging the gap between theoretical instruction and real-world application, while promoting values-based, future-ready science educators. Figure 2 shows some of the products of the HIRARC Project and the evaluation day, OSH Day.

The substantial improvement in student understanding and application of the HIRARC framework mirrors findings from recent research investigating preservice science teachers' laboratory safety knowledge. For instance, Bilen (2025) reported that while many preservice teachers could select correct answers on safety scenarios, they frequently failed to justify their choices accurately, indicating a gap between theoretical awareness and deep conceptual understanding. HIRARC Project intervention goes beyond mere recognition as it mandates authentic task-based application, cognitive reflection, and stakeholder consultation, resulting in both improved comprehension and student-generated safety outputs.

In contrast, prior studies on professional development in laboratory settings, such as traditional apprenticeship models (Brown & Melear, 2007), focus primarily on knowledge acquisition without translating into enduring institutional change. Unlike these models, HIRARC project ensures that outputs are not only assessed but deployed in the faculty laboratory, thereby providing tangible infrastructure improvement. This dual impact—on both student learning and institutional safety—enhances the innovation's scalability and sustainability, aligning strongly with ESD principles and SDG 3 & 4.

What sets this innovation apart from conventional project-based assessments is its structured integration of real world consultation and institutional implementation. Students not only solve authentic safety issues in an unsystematized laboratory but also engage in multiple levels of stakeholder consultation, including subject lecturers, laboratory assistants, and lab coordinators. Furthermore, the final products are formally presented to evaluators from academia and industry during OSH Day, ensuring external validation. Unlike typical classroom projects, the outputs are required to be fully functional and ready for real use, many of which are now actively implemented as part of the faculty's lab safety infrastructure.

This innovation demonstrates strong potential for commercialisation and scalability beyond its original implementation. The task-based teaching pack comprising project guidelines, rubrics, sample outputs, and real safety problems situations, can be adapted into a modular training kit for use in teacher education institutes (IPGs), universities, STEM-based schools, and professional development programs. Future developments may include transforming the teaching pack into interactive digital modules, e-learning micro-credentials, or printed lab safety kits complete with SOP posters and student-friendly manuals. Plans are also underway to explore copyright and intellectual property protection, enabling broader dissemination and potential licensing for use in national-level science safety training and teacher induction programs.

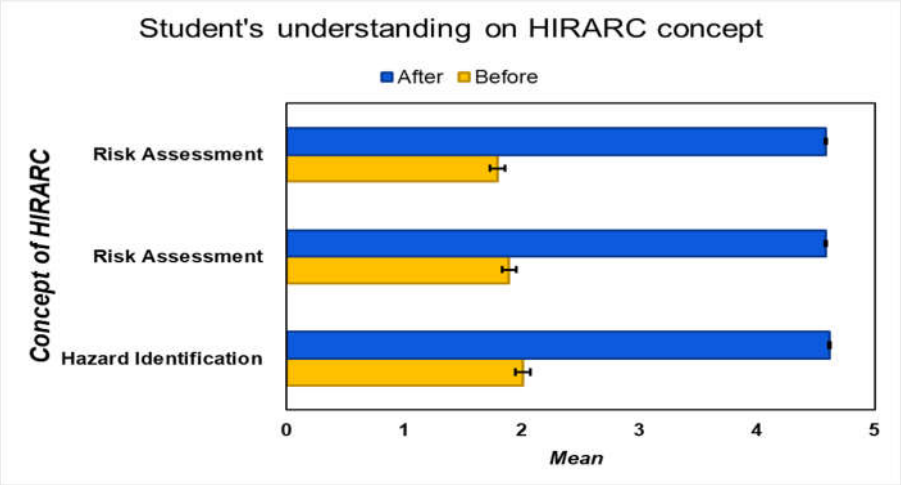

Figure 1.: Comparison of students understanding on HIRARC concept before and after HIRARC Project

Figure 2.: HIRARC Project presentation during OSH Day. (A) and (B) Students showing their product, (C) Presentation evaluation OSH Day, (E), (F) and (G) Products from HIRARC Project

CONCLUSION

This project successfully bridges the gap between theory and practice by enabling preservice science teachers to apply the HIRARC framework through real-life laboratory safety challenges. It not only enhances students' understanding and professional readiness but also produces sustainable safety resources that support institutional needs. Aligned with Education for Sustainable Development (ESD) and Sustainable Development Goals (SDG 3 & 4), this task-based assessment model offers a scalable and practical approach to nurturing responsible, future ready science educators.

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