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Innovative Learning Resources in Active Learning to Promote Thinking Skills as a Strategy to Achieve Occupational Safety and Health Competencies

Hasianna Nopina Situmorang[1], Saut Purba[1] and Manihar Situmorang[2*]

[1]Department of Mechanical Engineering Education, Universitas Negeri Medan, Medan, North Sumatera, INDONESIA

[2]Department of Chemistry, Universitas Negeri Medan, Medan, North Sumatera, INDONESIA

[1]hasiannanopina@unimed.ac.id , [2]msitumorang@unimed.ac.id

***Abstract*—Possessing occupational health and safety competence is key to creating a safe working atmosphere within the campus environment. This study aims to integrate innovative learning resources into a project-based learning model to foster the thinking skills necessary to achieve the target competencies of the Occupational Health and Safety course. The research involves providing digital learning resources integrated with instructional materials and projects, guiding students to understand occupational health and safety principles and to apply them during their studies and work in engineering environments. The learning resource package was designed using modern technology to align with students' digital lifestyles and serves as a medium to facilitate active learning through student-selected projects. The results demonstrate the students' ability to execute projects responsibly and to apply safety-related knowledge and skills within academic activities. Higher-order thinking skills, specifically analytical, evaluative, and creative thinking, all fell into the "good" category. Implementation of this new learning model guided students through the Occupational Health and Safety course. Competence achievement was evidenced by positive learning outcomes, derived from the cumulative results of both subjective and objective evaluations. This learning model enables students to acquire knowledge and skills simultaneously.**

***Keywords*—** Active learning; HOTS; Innovative learning resources; Learning output; OSH

I. INTRODUCTION

Occupational Safety and Health (OSH) competencies are essential for students as they are key to creating a safe environment while studying and working in mechanical engineering workshops. OSH knowledge and skills contribute to creating a sense of comfort, safety, and health for students and workers related to equipment and machinery in the short and long term (Sánchez, Peláez & Alís, 2017). OSH principles must be mastered and consistently practiced during activities in workshops, laboratories, fields, studios, and industrial internships to ensure occupational safety (Brauer, 2022; Kim, Park & Park, 2016; Jensen, 2019). Personal errors or neglect of OSH practices can be detrimental to institutions and even potentially lead to disasters for many people (Hanvold, et al., 2019). Therefore, OSH awareness and compliance must be maintained when using equipment in the work environment (Neto & Amaral, 2024). Following regulations and being aware of work strategies is necessary so that OSH principles are practiced properly in order to prevent potential injuries in the workplace, while creating efficiency and increasing work productivity (Manu, et al., 2019).

Problems related to low awareness and lack of commitment from students to good OSH principles in the workplace may be due to a lack of OSH knowledge. Limited access to learning models and innovative learning resources for OSH teaching in the engineering field also results in students not practicing OSH principles properly. The two OSH-related problems mentioned above need to be addressed through formal education or training. Good OSH knowledge and practices at universities are provided through teaching in Occupational Safety and Health courses. The implementation of an active learning model for OSH teaching is believed to have an impact on student learning activities, namely learning while practicing OSH correctly. The active learning model through project-based learning (PjBL) is effective in optimizing learning potential to achieve competency targets set in the curriculum. The PjBL guides students to learn systematically, building thinking skills as a strategy to achieve competency targets (Situmorang, et al., 2026). This learning model is also believed to be effective in achieving OSH competencies.

The OSH competency is crucial for students, namely the adequacy of OSH knowledge and skills to be practiced in real-life work environments (Threeton, Kwon, Fleck, Ketchem & Farzam, 2021). Providing innovative learning resources (ILR) to support active learning models is a good alternative in facilitating students to learn OSH. This strategy will condition a contextual learning environment, namely learning while practicing OSH knowledge in an engineering work environment (Prah, et al., 2025).

Manihar Situmorang
Jl. Willem Iskandar Psr V Medan, North Sumatra, INDONESIA 20221
msitumorang@unimed.ac.id

In short, this study aims to integrate innovative learning resources within a project-based active learning model to build thinking skills as a strategy to achieve occupational safety and health competencies. This study will develop an ILR-integrated PjBL active learning model, called Project-Based Learning with Innovative Electronic Learning Resources (PjBL-ILR).

II. LITERATURE REVIEW

The rapid development of technology and information has influenced the teaching system towards effective and enjoyable learning. Learning innovations are carried out to produce technology-based learning resources adapted to the digital daily lives of learners for offline and online learning. The use of electronic learning resources is becoming a trend because it is efficient, simple, and easily accessible for learning needs. The availability of visualization and interactivity in digital resources makes it easier for learners to understand complex concepts through simulations and facilitates active learning. Innovation in learning resources leads to a student-centered learning approach, facilitates more enjoyable learning, and can be adapted to the development and characteristics of learners (Situmorang, Purba & Situmorang, 2021). Learning resources contain comprehensive knowledge, are a combination of text and visualizations that are created concisely, are adaptive to media and multimedia facilities simultaneously, and can provide complete information and visualizations on OSH course teaching topics, thus enabling students to learn comprehensively (Evenhouse, Kandakatla, Berger, Rhoads & DeBoer, 2020; Antoniolli, et al., 2021).

Understanding and practicing occupational safety concepts is crucial for vocational and undergraduate engineering students, and supports their successful safe working practices in engineering environments, which are learning environments with the potential for workplace accidents (Neto & Amaral, 2024). Students must be competent in OSH to create a safe and healthy learning environment to achieve high work productivity (Hanvold, et al., 2019). Knowledge of OSH must become a part of the culture when conducting activities in the classroom, laboratory, studio, fieldwork, and also during industrial work practices to avoid potential injuries in the workplace and learning (Jilcha & Kitaw, 2017). Consistently practicing occupational safety in the learning environment will create a comfortable and healthy work environment, and the ability to predict potential workplace accidents that may occur becomes a strategy for optimal prevention (Atusingwize, et al., 2019). Eliminating and minimizing occupational accidents related to engineering will be possible if all workers have adequate knowledge of OSH and practice it consistently and responsibly (Neu-Baker, Eastlake & Hodson, 2022). Therefore, students must be continuously educated about OSH knowledge so that it can be applied in real life. Thinking skills are needed as a scientific guide in teaching and learning activities so that knowledge concepts can be implemented properly.

Thinking skills as life skills for scientists and engineers in solving scientific problems need to be improved, and can be built through learning (Bell, Chilvers, Jones & Badstuber, 2019). These skills as scientific steps involve analysis, evaluation, and synthesis of data-based information to be tested in solving work safety problems holistically (Demircioglu, Karakus & Ucar, 2023; Situmorang, Situmorang & Ginting, 2023). As learning skills, various types of thinking skills can be selected according to the characteristics of the problem, including critical thinking skills (CTS), complex thinking skills (CxT), and higher-order thinking skills (HOTS) (Priyaadharshini & Vinayaga-Sundaram, 2018; Martinez, 2022). HOTS components involve problem-solving, analytical thinking, evaluative thinking, and creating new thoughts to provide the best solutions to academic problems (Sharma, Murugadoss & Rambabu, 2020). HOTS category thinking skills are needed in the active learning model for OSH teaching, namely involving analytical, evaluative and creative thinking components in solving OSH-related problems in creating a safe atmosphere in the engineering work environment.

Various strategies have been implemented to teach OSH, such as active learning (Mikhailidi & Tskhvediani, 2026), the use of technology (Guimarães, Cavalcanti & Vasconcelos, 2024), and the design of learning resources (Sinyai & Barlet, 2020). The use of innovative learning resources in OSH instruction can enhance student learning outcomes (Situmorang, Purba & Situmorang, 2024). The availability of innovative learning resources facilitates students' understanding of OSH concepts and fosters a culture of safe and healthy work practices. Digitizing OSH learning resources offers flexibility in their application, allowing them to be adapted to specific OSH-related issues. Innovative learning resources integrated into the PjBL model serve as sources of OSH knowledge and skills, enabling the practical application of OSH concepts and reflecting the attainment of OSH competencies (Purba, Situmorang & Silaban, 2019).

The PjBL model is the right choice to facilitate active learning and is highly relevant for OSH teaching (Cortázar, et al., 2021; Dixit, Bedekar, Jahagirdar & Sathe, 2021). The trend of using electronic learning resources shifting from textbooks should be utilized to support the success of active learning models in OSH teaching. OSH teaching using active learning models will be effective if supported by innovative learning resources, to guide students to learn OSH systematically and responsibly to achieve teaching objectives (Situmorang, Purba & Silaban, 2020). Therefore, learning resources are needed with comprehensive OSH knowledge content, integrated with external digital sources, and packaged attractively to motivate students to learn OSH holistically according to their needs.

Based on the theoretical alignment outlined above, this study was designed to improve students' OSH competency. Occupational safety competency can be achieved through teaching activities using a project-based active learning model supported by innovative learning resources. Digital learning resources are designed to follow the latest technological advances, are packaged adaptively to students' daily lives, and are supported by OSH facilities and infrastructure for practical application in engineering work environments.

The research problems that will be answered in this study include: (1) How does the PjBL-ILR model facilitate students' active learning in studying OSH? (2) How does the PjBL-ILR model contribute to promoting HOTS through OSH projects? (3) How does the PjBL-ILR model contribute to achieving OSH competencies? (4) How does the PjBL-ILR model influence students' learning engagement?

III. METHODS

The studies have been carried out to develop a standard PjBL-ILR model and implementing them in OSH teaching following the steps of previous research with modifications (Situmorang, Sinaga, Sitorus & Sudrajat, 2022). Research stages include determining the population and sample, designing research procedures, and assessing learning outcomes. Each of these components is explained briefly.

3. *Population and Sample*

This research was conducted at the Department of Mechanical Engineering, Faculty of Engineering, State University of Medan, involving regular students. The study population was 204 students, including Vocational and Undergraduate Programs taking OSH courses (Table I). The sample was purposively selected from two parallel classes, totaling 65 undergraduate students of the Mechanical Engineering Education program. They agreed to participate as samples in the study and had completed and signed an informed consent form.

TABLE I
BRIEF DESCRIPTION OF UNDERGRADUATE STUDENTS AS POPULATION AND RESEARCH SAMPLE IN THE DEPARTMENT OF MECHANICAL ENGINEERING, FACULTY OF ENGINEERING.

No	Class	Study program	Number of students	Selected sample*	Short description
1	Mechanical Engineering (ME)	Diploma (D3)	30	0	Major in vocational mechanical engineering
2	Mechanical Engineering Education (MEEA)	Bachelor Degree (S1)	47	33	Major in mechanical engineering education
3	Mechanical Engineering Education (MEEB)	Bachelor Degree (S1)	46	32	Major in mechanical engineering education
4	Automotive Engineering Education (AEEA)	Bachelor Degree (S1)	30	0	Major in automotive engineering education
5	Automotive Engineering Education (AEEB)	Bachelor Degree (S1)	34	0	Major in automotive engineering education
6	Automotive Engineering Education (AEEC)	Bachelor Degree (S1)	17	0	Major in automotive engineering education
	Total		204	65	

*Agree to be involved in the study and have signed the informed consent form

1. *Ethical Clearance*

The implementation of the research has obtained ethical permission in accordance with the code of ethics for social humanities and education established by the University. Respondents were first given information about the aims and methods of the research, an explanation of how they were involved as data sources, and their rights and obligations in research activities were also explained. Next, respondents were asked for their willingness and agreement by filling out an informed consent form. All respondents to this research have given consent to be a sample, are willing to participate in the research, and respondents are given the freedom according to their wishes to withdraw from the stage as a sample, with a guarantee that it will not affect the academic consequences in the academic assessment.

2. *Research Procedures*

This research phase encompasses the development of the PjBL-ILR active learning model for the Occupational Health and Safety (OHS) course. The model's development is based on a needs analysis and aligned with the competency-based curriculum, followed by model standardization and the implementation of PjBL-ILR for OHS instruction, as illustrated in Figure 1.

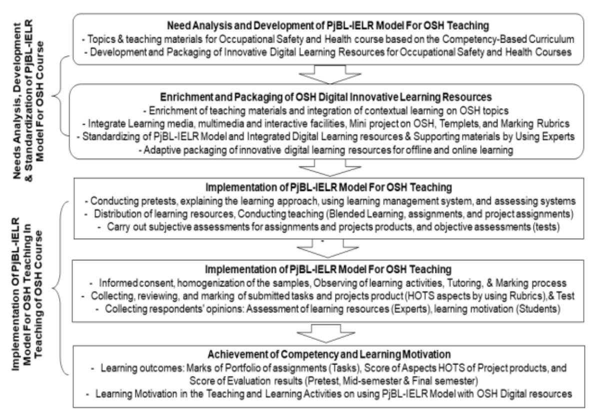

Fig. 1. Research stages in the development and implementation of the PjBL-ILR model in OSH teaching.

4. *Provision and standardization of PjBL-ILR model*

The development of the learning model was carried out to provide the PjBL-ILR model and supporting tools, namely an electronic learning resource package that is integrated in the learning model and active learning scenarios for OSH teaching. Determining the OSH topic is carried out through needs analysis, namely choosing the right OSH subject topic to be taught to undergraduate students in the Department of Mechanical and Automotive Engineering, with a study load of 2 credit units per semester, according to the competency-based curriculum. Teaching and learning materials for each OSH topic are prepared by enriching knowledge and skills, integrating illustrations and contextual case examples, completing media and multimedia facilities, examples of OSH mini projects, and hyperlinks to relevant websites. At the end of the teaching topic, questions or quizzes, project assignments, and templates for project assignment reporting are provided. The learning resource package has been packaged attractively with a coherent, compact systematic design with a simple design to make it easier for students to use it to study OSH.

The standardization of the PjBL-ILR model and supporting learning facilities is carried out professionally using lecturers and practitioners who are categorized as experts because they have experience in teaching and practicing OSH properly and correctly. Respondents were given the PjBL-ILR model, learning scenarios and project implementation guidelines for teaching OSH for one semester. They were asked for their opinion on the feasibility of the new model by filling out a questionnaire containing closed questions with four choices based on a Likert scale, following the teaching material criteria set by the Indonesian National Education Standards Board (INESB). Open opinions on each question are also provided for the opportunity to submit suggestions, revise and improve the quality of the PjBL-ILR model in OSH teaching. The feasibility of the PjBL-ILR model was assessed using a standard survey.

5. *Project tasks and assignments*

Teaching and learning activities are carried out sequentially based on the order of OSH topics. To support OSH teaching and to optimize students' learning potential, they are given routine assignments and project assignments, according to the characteristics of the OSH topics being taught. Submitting assignments is an obligation, as an assessment component, which aims to measure students' completeness in studying OSH topics. Project information and project implementation are announced during the course contract, and they are given the freedom to determine the title and topic of the OSH project. Students are asked to submit project assignments, and these project assignments can only be carried out after being approved by the supervisor. Project proposal and report templates, OSH project implementation instructions, and assessment rubrics have been provided online in the University Networked Learning System (UNLS) which they can access at any time. The project reporting system and notification of assignment submission deadlines are available on lecture handouts and at UNLS.

6. *Implementation of PjBL-ILR model in OSH teaching*

The implementation of the PjBL-ILR model in OSH teaching has been carried out in accordance with University regulations. Teaching of OSH topics is carried out in a hybrid manner through face-to-face and online learning using UNLS facilities. Teaching adjustments are made relevant to the characteristics of the OSH topic being studied. The stages of carrying out the study are sequential: conducting a pretest before teaching, explaining the use of UNLS, teaching and learning activities, assignment of project assignments, and final test at the end of the semester. Teaching of OSH topics is allocated 16 meetings in one semester, including learning evaluation.

The OSH teaching starts with the distribution of electronic learning resources, followed by short teaching and providing instructions for routine tasks and OSH project assignments. Students are asked to work on projects contextually, independently, including: selecting project topics, writing project proposals, implementing projects, presenting results and submitting reports. All assignments and project products are uploaded by students to UNLS, and then the lecturer provides an assessment using a subjective assessment rubric. Project assignment scores can be openly accessed by students. Learning outcomes are obtained from students' ability to answer objective multiple-choice test questions in the middle and end of the semester. After the lecture phase was completed, students were given a questionnaire to fill out voluntarily, aiming to collect their opinions about learning motivation through the application of the PjBL-ILR model in OSH teaching, and their responses to the availability of learning facilities at the university.

7. *Achievement of OSH competency*

OSH competency achievement is described from the learning outcomes obtained by students, namely a combination of assignment portfolio scores, project products, and tests. Assignment scores are obtained from the average subjective score of routine tasks, namely the score obtained based on the accuracy of students meeting the criteria set out in the subjective assessment rubric, with a value range of 0-100. Project scores are obtained from the assessment of project products (proposals and reports), namely the average HOTS score on three aspects of thinking skills (analytical, evaluation and creativity), which are assessed using HOTS assessment rubric criteria. Learning outcome scores are obtained from students' ability to answer questions on multiple-choice objective questions with various levels of difficulty, covering all OSH course topics, then the score is converted to a value of 0-100. Data analysis was carried out using simple statistics mean and standard deviation (M±Sdv), followed by calculating the normalized gain (NG) to determine the effectiveness of the PjBL-ILR model, the effectiveness criteria were high ($NG > 0.7$), medium ($0.3 \leq NG \leq 0.7$), and low ($NG < 0.3$) (Nissen, Talbot, Nasim Thompson & Van Dusen, 2018). Learning completion is a benchmark for achieving OSH competency, namely the cumulative mastery of OSH knowledge and skills, shown by the achievement of task portfolio scores and learning outcomes. Learning completion criteria as competent: very good (>80), good (65-79), sufficient (54-64), and incompetent <55 (Sadler, 2013).

8. *Teaching-learning activities and learning motivation*

The influence of the PjBL-ILR model on OSH teaching is assessed based on students' opinions based on learning experiences, which are captured using a questionnaire on a Likert scale with 5 options, sorted from the strongest with a score (5) to the lowest option with a score (1). Students were distributed questionnaires and asked to voluntarily answer the questions and return them to the research team in a box provided in the classroom. This strategy was chosen for objectivity and to avoid coercion and intimidation from researchers who are also lecturers of the subject. A total of 10 questions cover aspects of confidence, challenge, involvement, curiosity, relevance, and satisfaction, with a focus on academic activities from the contribution of digital learning resources in facilitating students' active learning. The results of the average opinion of respondents provide a picture of learning motivation and learning activities when implementing PjBL-ILR model.

9. *Research Instrument, Data Collection and Analysis*

The research instruments included a survey package (questionnaire), a HOTS assessment rubric, and a standardized learning evaluation (test) that was valid, reliable, had a balanced level of difficulty, and strong discriminating power. The PjBL-ILR model and learning support tools were standardized using experts using a questionnaire, a Likert scale with four criteria, with the strongest score being 4 and the weakest being 1. The survey package related to teaching and learning activities was assessed by student respondents using a Likert scale with five options: the highest criterion was given a score of 5 (Strongly Agree), and the lowest was given a score of 1 (Strongly Disagree). The HOTS rubric was designed to measure the achievement of thinking skills across three skill aspects (APPENDIX**,** Table S1). HOTS achievement, as a subjective assessment of project products (proposals and reports), includes analytical thinking, evaluative thinking, and creative abilities, each on a scale of 0-100. Learning completion is a benchmark for achieving OSH competency, namely the cumulative mastery of OSH knowledge and skills measured from the assignment portfolio and evaluation of learning outcomes based on criteria based on scores of very good (> 80), good (65-79), sufficient (55-64), and incompetent (<55) (Sadler, 2013).

IV RESULTS

1. *PjBL-ILR Model for OSH Teaching*

The PjBL-ILR model for teaching OSH has been obtained in accordance with the learning needs of students in vocational and engineering undergraduate programs. There are 12 OSH topics taught during one semester (Brauer, 2022). The OSH course topics are selected and arranged to achieve the occupational safety and health competency targets set based on the competency-based curriculum. A brief overview of the PjBL-ILR model for teaching OSH with active learning includes a brief description of the innovative learning resources integrated in the learning model, and a project assignment has been provided (APPENDIX**,** Table S2). Each OSH topic is equipped with complete and comprehensive teaching materials along with active learning scenarios for OSH teaching. The PjBL-ILR model with innovative learning resources has been implemented for hybrid teaching.

2. *Standardization of PjBL-ILR Model*

The PjBL-ILR model from the development results, and its facilities has been standardized by experts (APPENDIX**,** Table S3). Respondents gave very good scores ($M=3.52\pm0.66$) on five parameters in the PjBL-ILR model including: (1) Eligibility of the content, (2) Completeness of teaching material, (3) Systematic arrangements of digital learning resources, (4) The design and appearance of the model, and (5) The use of language and readability. All parameters have met the learning resource quality criteria, and are declared suitable for use in facilitating active learning in OSH teaching for students in the fields of mechanical engineering and automotive engineering.

3. *Implementation of PjBL-ILR Model in Teaching OSH*

The results of implementing the PjBL-ILR model in OSH teaching ensure that this learning model has proven effective in guiding students to learn actively. Innovative learning resources integrated in the model are able to facilitate students to study OSH systematically, promoting thinking skills when planning and working on project assignments. All students succeeded in completing course assignments well, and reported them via UNLS online on time. The teaching materials available in the PjBL-ILR model have been successful in teaching students OSH knowledge and skills, while the integrated mini-project examples have been effective in directing students to carry out their own OSH projects. When working on projects related to engineering assignments, students have used OSH knowledge in OSH practices in teaching and learning activities correctly and responsibly. Student participation dominates in working on OSH project assignments. Learners have used higher-order thinking skills in planning OSH projects well, and the selected OSH project topics are summarized in Table II.

TABLE II
RECAPITULATION OF OSH THEMES CHOSEN BY STUDENTS FOR PROJECT

No	Project theme	Student Choice (n)		Total
		MEEA	MEEB	
1	Potential hazards and OHS risk control in building construction	6	5	11
2	Potential dangers and OSH risk control in business units	6	5	11
3	Potential hazards and risk control of OSH in machine and automotive workshops	18	20	38
4	Observe potential hazards and control OSH risks in environmental facilities and infrastructure	3	2	5
	Total	33	32	65

Project assignment themes are selected according to interest, and based on considerations of ease in accessing data sources. Topics related to potential hazards and controlling occupational safety and health risks dominate student project themes, and the focus of the problems they choose are generally building construction, activities in business units, machine and automotive workshops, as well as environmental pollution in different locations.

4. *PjBL-ILR Model and HOTS Achievements in the Project Planning*

The main target of implementing the PjBL-ILR model in teaching is to equip students to obtain adequate OSH knowledge and skills that can be put into practice in academic activities, to be used as a guarantee of achieving safety and security in work and practice. Through implementing the OSH project, students study OSH intensively in completing the project tasks. Students have carried out and reported their chosen OSH project well. Independent inclusive teaching and learning activities have been created, namely students are directly involved in planning, selecting implementation strategies, and reporting project products by using HOTS category thinking skills. The OSH project has been planned correctly, and the subjective assessment results are listed in Table III. In sequence, the achievement of analytical thinking skills (*M*=75.39±8.79), evaluation thinking (*M*=75.41±9.64), and creative ability (*M*=78.05±7.72), are all at good category, with an average of (*M*=76.32±5.42), which is in the good category.

TABLE III
THINKING SKILLS SCORES BASED ON THE RESULTS OF THE ASSESSMENT OF THE OSH PROJECT TASK PLAN ON THREE HOTS ASPECTS.

No	Aspect of HOTS	Description assessment of thinking skills	Students' achievement (M±Sdv)*		
			MEEA (n=33)	MEEB (n=32)	Average
1	Analytical thinking	Skilled in analyzing OSH project plans to be carried out based on the scope of work and equipment used in the work environment according to the chosen topic.	78.13±5.82	72.66±11.76	75.39±8.79
2	Evaluation thinking	Skilled in evaluating the realization and feasibility of OSH project plans to be carried out based on parameters such as resource availability, ease of access, and availability of data collection devices, according to the planned topic.	73.24±10.82	77.58±8.47	75.41±9.64
3	Creative thinking	Skilled in creating new ideas creatively in planning OSH projects according to the type of tasks and work, use of equipment, and environmental conditions in the work units chosen as their own project, and able to use original techniques that are based on convincing scientific arguments that will be successful in solving problems in the chosen project topic.	80.00±7.31	76.09±8.13	78.05±7.72
Average			77.12±4.65	75.52±6.18	76.32±5.42

* Obtained from assessment of the OSH project proposal, marked by using HOTS assessment rubrics

5. *PjBL-ILR Model and HOTS Achievements in Project Implementation*

Success in OSH project planning has been continued in project work to achieve maximum learning outcomes. Students have carried out the OSH project well, namely they have succeeded in collecting main data and supporting data, have analyzed the data, discussed the findings, reported the project product, and presented the findings. Learning activities carried out through project implementation succeeded in building thinking skills to achieve OSH competency. The achievement of thinking skills in the HOTS category from the project report assessment has been obtained and is summarized in Table IV. The scores for three aspects of thinking skills have been obtained, respectively for analytical thinking skills (*M*=80.07±7.50) and evaluation thinking (*M*=83.58±4.80) which are classified as good, while creative thinking skills (*M*=85.05±7.43) is very good. Overall, the average HOTS achievement (*M*=82.93±4.57) was in the good category.

The PjBL-ILR Model and Student Learning Outcomes

The contribution of the PjBL-ILR model to the mastery of the OHS course has been studied comprehensively, namely based on the results of the assessment of learning products and learning evaluations. Students actively learn OSH using digital learning resources integrated in the model, resulting in a holistic understanding of OSH, and impacting the improvement of students' knowledge achievement in OSH concepts and practices. Guided by HOTS, students have been able to carry out their own projects contextually as a strategy to achieve competency targets. Learning mastery can be seen from OSH learning achievements as evidenced by the scores of portfolio assignments, project assignments, and learning evaluations summarized in Table V. The average score of the portfolio assignment (M=72.12±7.08) is moderate and project report (M=79.62±5.00) is classified as good. The average achievement of the midterm test (M=72.45±8.47) is moderate and the final semester test (M=82.14±10.51) is good, which is an increase compared to the initial semester test (M=24.08±3.57). The normalized gain value (NG=0.765 > 0.70) is classified as high, indicated that the PjBL-ILR model is effective in improving student learning outcomes in OSH courses. Based on the cumulative achievement of learning outcomes, it shows that students who actively learn using the PjBL-ILR model are competent in the field of OSH.

TABLE IV
HOTS ACHIEVEMENTS FROM THE ASSESSMENT OF THE OSH PROJECT IMPLEMENTATION REPORT.

No	Aspect of HOTS	Description assessment of thinking skills.	Achievement (M±Sdv)		
			MEEA (n=33)	MEEB (n=32)	Average

1	Analytical thinking	Skilled in carrying out analysis steps and determining strategies to be carried out in implementing an OSH project according to the type of work, based on the equipment used, workplace environment, determining the type of instrument used to record result data and process data on the results of OSH implementation.	85.26±8.62	74.88±6.38	80.07±7.50
2	Evaluation thinking	Skilled in evaluating the implementation of OSH projects based on the type of engineering work, use of equipment, and work environmental conditions, able to differentiate activities based on standard OSH parameters, skilled in processing and writing project results reports following templates, able to express scientific views to discuss found data, able to present findings from the results projects and assess data quality following occupational safety and health rules.	85.82±5.03	81.33±4.56	83.58±4.80
3	Creative thinking	Skilled in generating new creative ideas in implementing OSH projects according to the type of work, use of equipment, and environmental conditions, skilled at innovating and modifying the work environment to achieve work safety in the project itself. The proposed creation has been able to solve OSH problems and has been based on scientific arguments, as well as ensuring the originality of the new strategy chosen.	86.69±8.74	83.41±6.11	85.05±7.43
Average			85.92±6.00	79.93±3.14	82.93±4.57

*Obtained from assessment of the OSH project reports by using HOTS assessment rubrics

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TABLE V
ACHIEVEMENT OF STUDENT LEARNING OUTCOMES IN OSH TEACHING BASED ON ROUTINE ASSIGNMENT PORTFOLIO SCORES, PROJECT ASSIGNMENTS AND LEARNING EVALUATIONS.

No	Parallel class	Number of students	Score from objective assessment (M±Sdv)*			N-Gain	Score from subjective assessment (M±Sdv) **		Conclusion
			Pretest	Mid-test	Post-test		Portfolio assignments	Project reports	
1	MEEA	33	24.39±3.12	81.82±7.30	81.63±10.82	0.76	73.83±8.52	76.32±5.42	Competent
2	MEEB	32	23.77±4.02	63.07±9.65	82.65±10.20	0.77	70.40±5.64	82.93±4.57	Competent
Average		65	24.08±3.57	72.45±8.47	82.14±10.51	0.765	72.12±7.08	79.62±5.00	Competent

*Evaluation was carried out using an objective multiple-choice test **Project assignment scores are assessed using the HOTS rubric

6. *PjBL-ILR Model and Learning Motivation*

The application of the PjBL-ILR model influences students' learning experiences and motivation to study OSH. The contribution of learning models in facilitating the implementation of active learning and learning activities is summarized in supplementary data (APPENDIX**,** Table S4). Only a few students returned the questionnaires by the specified deadline even though they were reminded several times. Several aspects of motivation assessed include: confidence in guiding students to learn actively and carry out OSH assignments, challenge of determining and implementing projects contextually, engagement in using digital learning resources as a source of knowledge and skills, curiosity in applying knowledge and skills in implementing OSH projects, relevance for fields of mechanical and automotive engineering, and Satisfaction as a learning medium to give impression of long-remembered learning. Respondents' opinions on motivational aspects were classified as high (M=4.46±0.58). The PjBL-ILR model with its supporting facilities has been successful in facilitating students' active learning through independent projects to achieve OSH competency. Students are directly involved in teaching and learning activities in studying OSH, doing assignments, and completing OSH projects to achieve competency targets in the field of occupational safety and health specified in the curriculum.

V. DISCUSSION

The PjBL-ILR model, integrated with innovative learning resources, is designed to facilitate engineering students in learning OSH. Learning resources and supporting facilities are comprehensively designed to facilitate students in learning OSH topics. OSH teaching materials have been enriched, covering OSH knowledge and skills, facilitated by media and multimedia, equipped with OSH reminder symbols and warning signs, mini projects and OSH project implementation guidelines. Project assignments are provided at the end, guiding students to learn systematically through engineering-related OSH projects (Situmorang, et al., 2018). Relevant mini-project examples have been provided to facilitate students in understanding OSH concepts as a whole, to be practiced in academic activities as a strategy to achieve OSH competency. Innovative learning resources in the PjBL-ILR model are key to students' success in carrying out their project assignments well. Mini-project examples are intended to facilitate students in understanding OSH concepts, to be applied contextually in OSH project activities to avoid accidents and illnesses resulting from engineering work (Arezes, et al., 2020; Jensen, 2019).

The implementation of the PjBL-ILR model in OSH teaching affects student learning activities, has shifted learning from lecturer-centered learning to student-centered learning (Patil & Kamerikar, 2020; Acharya & Gayana, 2021). Working on project assignments as a strategy for students to learn OSH holistically, namely building higher-order thinking skills, increasing OSH knowledge, and getting used to working safely and correctly following OSH principles. OSH projects are carried out by students responsibly, including planning, implementing and reporting project assignments. Student-chosen OSH projects are contextual, as an opportunity for them to practice the theories learned in real activities.

The PjBL-ILR model facilitates active learning through projects, demonstrated by students' ability to successfully complete OSH project assignments on time. Students are given flexibility to determine the OSH project topic, choose the implementation location, and determine the implementation time of the OSH project. All of the above provides an opportunity for them to use HOTS as a scientific step to complete a contextual OSH project. The OSH project themes chosen by students are interesting and challenging, based on their interests, with the support of business units that receive and grant permission to access resources and data in accordance with the project objectives. The project topics are relevant to OSH best practices, namely investigating potential sources of hazards, controlling safety risks, providing and using personal protective equipment in the work environment. The business units that source data are engineering fields related to building construction, machine and automotive workshops, and environmental pollution related to engineering. The focus of the data sources is jobs that have high occupational safety risks. Good OSH knowledge empowers students to successfully identify and control potential sources of hazards, accidents, and diseases related to the work environment. The project aims to create safe conditions free from potential risks of work accidents in the work environment. Learning OSH through projects has internalized knowledge into a safe work culture. The implementation of the PjBL-ILR model is a good strategy in empowering students to be directly involved in correct work practices and fostering a health and safety culture while learning and working in an engineering work environment (Situmorang, Sinaga, Sitorus & Sudrajat, 2022; Fini, Awadallah, Parast & Abu-Lebdeh, 2018).

Working on an OSH project is a new experience of learning while doing real work. The implementation project is an opportunity to practice OSH knowledge and skills in creating security and safety in the engineering work environment. Higher-order thinking skills are used to identify potential workplace accidents, analyze and establish OSH projects (Saad & Zainudin, 2022). Students are challenged to establish their own OSH projects and successfully complete contextual projects. The output of the project assignment reflects the good practice of OSH principles in eliminating the potential for injuries and illnesses related to engineering work (Das, Naiksatam & Shama, 2020). The product of the project assignment can illustrate the realization of cognitive processes in creating occupational safety. There was an increase in HOTS achievement in the project report compared to the project plan, indicating continuous learning progress in the implementation project (Situmorang et al. 2026). The high HOTS score in the project report product is evidence that the active learning model is appropriate for guiding students to learn OSH through projects. These results indicate that the active learning model is the right choice for OSH teaching and is a good strategy in achieving OSH competency targets.

The achievement of OSH competency targets is reflected in students' mastery of OSH knowledge and skills, along with their ability to correctly apply OSH principles, create a safe work environment, and improve OSH learning outcomes (Kulkarni, Dhanvijay, Malathi, Wadhai & Sahasrabudhe, 2021). The average scores for routine assignment portfolios, project reports, and learning evaluations were good. OSH learning outcome scores on the posttest increased compared to the pretest scores, the N-Gain value was in the high category, and students were competent in the field of OSH. The results of this study support previous studies that showed the effectiveness of digital learning resources in guiding students to actively learn OSH (Situmorang, et al., 2024). The PjBL-ILR model facilitates students to learn and practice OSH through contextual projects. This learning model is accepted by students, is adaptive to the latest learning technology, and is relevant to students' digital daily lives (Situmorang, et al., 2026).

Students accepted and responded positively to the implementation of the PjBL-ILR model in teaching OSH courses. The integrated learning facilities in the model are sufficient, easy to use and appropriate to students' learning needs. This learning model challenges students to carry out contextual OSH projects, providing learning experiences while practicing OSH concepts correctly (Setiawan, et al., 2026). Cognitive and affective learning aspects have been created such as holistic mastery of OSH concepts, self-confidence in solving challenges, realizing curiosity through projects, and providing learning satisfaction after contributing to creating engineering work safety and security. This learning model creates an impressive learning process in managing occupational safety and health in the engineering work environment.

Research Limitations

This research has limitations related to the sample and research implementation. The achievement of OSH competency targets is generalized by the influence of the PjBL-ILR model in two experimental classes. Ideally, the study would be conducted by comparing it with a control to determine the effectiveness of the developed learning model, with repetition involving several classes practicing OSH. Several other factors, such as student access to other digital resources, interest and commitment to learning, which have the potential to influence student learning outcomes were not taken into account in this study. However, the sample homogenization process during the pretest provides confidence in the contribution of the PjBL-ILR model in influencing the learning process and impacting OSH learning outcomes. In addition, online learning assistance through UNLS guided and reminded students to study optimally to complete their project assignments within the specified deadline.

CONCLUSSION

An active learning model integrated with innovative learning resources for OSH teaching has been developed, known as the PjBL-ILR model. This learning model is designed to facilitate students' active learning through OSH projects. The learning resources consist of 12 OSH topics and mini-project examples, integrated with media and multimedia to visualize OSH knowledge and skills, and packaged in an e-book that adapts to students' digital lives.

The implementation of the PjBL-ILR model in OSH teaching facilitates student learning through contextual OSH projects. Working on OSH projects optimizes students' learning potential, guided by critical thinking skills in planning and implementing OSH projects. Inclusive learning is created, where students are directly involved in identifying OSH-related issues that occur in mechanical engineering business units, followed by planning and implementing relevant OSH projects. Students determine OSH topics based on the identified problems, then successfully implement and report on the implementation projects. OSH knowledge and skills are mastered and practiced in the engineering workplace. Students are competent in the field of OSH, as demonstrated by their learning completion. The average portfolio score of assignments (M=72.12±7.08) was moderate, while the OSH project report score (M=79.62±5.00) and OSH learning outcomes (M=82.14±10.51) were good. The high normalized gain (NG=0.765 > 0.70) is evidence of the effectiveness of the PjBL-ILR model in improving student learning outcomes in OSH courses. The PjBL-ILR model was accepted by students, providing a learning experience while working through their own projects, as a learning strategy for students to achieve OSH competencies. This learning model can be considered for adoption in other courses that require increased knowledge and skills to be implemented in real practice.

Research Implications

The implementation of the Project-Based Learning (PjBL-ILR) model in OSH has implications for the teaching and learning process and competency achievement. Learning through projects has transformed the way students learn, becoming inclusive, enabling them to learn while practicing knowledge in a safe and comfortable learning environment. The best practices gained from implementing this model also contribute to a holistic learning process, enabling them to learn OSH using innovative learning resources to understand OSH knowledge and then apply it in an engineering-related work environment. This active learning contributes to mastery of OSH concepts and develops thinking skills to create a work environment free from the potential for engineering-related accidents.

APPENDIX

Supplemental data is available at the last page:

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DATA AVAILABILTY

The research data are available and can be accessed from the author

REFERENCES

Acharya, S., & Gayana, M. N. (2021). Enhanced Learning and Improved Productivity of Students' using Project Based Learning Approaches for Programming Courses. Journal of Engineering Education Transformations, 34. (Special Issue), 524-530. https://doi.org/10.16920/jeet/2021/v34i0/157205

Antoniolli, S. A. C., Assenato, A. P. R., Araújo, B. R., Lagranha, V. E. D. C., Souza, L. M. D., & Paz, A. A. (2021). Construction and validation of digital education resources for the health and safety of workers. Revista Gaúcha de Enfermagem, 42: e20200032. https://doi.org/10.1590/1983-1447.2021.20200032

Arezes, P. M., Baptista, J. S., Barroso, M. P., Carneiro, P., Cordeiro, P., Costa, N., ... & Perestrelo, G. (Eds.). (2020). Occupational and Environmental Safety and Health II. Springer. https://link.springer.com/book/10.1007/978-3-030-41486-3

Atusingwize, E., Musinguzi, G., Ndejjo, R., Buregyeya, E., Kayongo, B., Mubeezi, R., ... & Ssempebwa, J. C. (2019). Occupational safety and health regulations and implementation challenges in Uganda. Archives of environmental & occupational health, 74(1-2), 58-65. https://doi.org/10.1080/19338244.2018.1492895

Bell, S., Chilvers, A., Jones, L., & Badstuber, N. (2019). Evaluating engineering thinking in undergraduate engineering and liberal arts students. European Journal of Engineering Education, 44(3), 429-444. https://doi.org/10.1080/03043797.2018.1552663

Brauer, R. L. (2022). Safety and health for engineers. John Wiley & Sons.

Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). Promoting critical thinking in an online, project-based course. Computers in human behavior, 119, 106705. https://doi.org/10.1016/j.chb.2021.106705

Das, L., Naiksatam, A., & Shama, M. (2020). Project based learning: Effective tool for a course on electronic product design. Journal of Engineering Education

Transformations, 33(Special Issue) 257-259. https://doi.org/10.16920/jeet/2020/v33i0/150157

Demircioglu, T., Karakus, M., & Ucar, S. (2023). Developing students’ critical thinking skills and argumentation abilities through augmented reality–based argumentation activities in science classes. Science & Education, 32(4), 1165-1195. https://doi.org/10.1007/s11191-022-00369-5

Dixit, B., Bedekar, M., Jahagirdar, A., & Sathe, N. (2021). Role of active learning techniques in development of problem-solving skills. Journal of Engineering Education Transformations, 34, 670-674. https://doi.org/10.16920/jeet/2021/v34i0/157241

Evenhouse, D., Kandakatla, R., Berger, E., Rhoads, J. F., & DeBoer, J. (2020). Motivators and barriers in undergraduate mechanical engineering students’ use of learning resources. European Journal of Engineering Education, 45(6), 879-899. https://doi.org/10.1080/03043797.2020.1736990

Fini, E. H., Awadallah, F., Parast, M. M., & Abu-Lebdeh, T. (2018). The impact of project-based learning on improving student learning outcomes of sustainability concepts in transportation engineering courses. European Journal of Engineering Education, 43(3), 473-488. https://doi.org/10.1080/03043797.2017.1393045

Guimarães, A., Cavalcanti, M., & Vasconcelos, B. M. (2024). Gamification using technologies for occupational safety training in the civil construction sector. Work (Reading, Mass.), 77(2), 477–485. https://doi.org/10.3233/WOR-220685

Hanvold, T. N., Kines, P., Nykänen, M., Thomée, S., Holte, K. A., Vuori, J., Wærsted, M., & Veiersted, K. B. (2019). Occupational Safety and Health Among Young Workers in the Nordic Countries: A Systematic Literature Review. Safety and health at work, 10(1), 3–20. https://doi.org/10.1016/j.shaw.2018.12.003

Jensen, R. C. (2019). Risk-reduction methods for occupational safety and health. John Wiley & Sons.

Jilcha, K., & Kitaw, D. (2017). Industrial occupational safety and health innovation for sustainable development. Engineering science and technology, an international journal, 20(1), 372-380. https://doi.org/10.1016/j.jestch.2016.10.011

Kim, Y., Park, J., & Park, M. (2016). Creating a culture of prevention in occupational safety and health practice. Safety and health at work, 7(2), 89-96. https://doi.org/10.1016/j.shaw.2016.02.002

Kulkarni, V., Dhanvijay, M., Malathi, P., Wadhai, V. M., & Sahasrabudhe, S. S. (2021). Achieving Program Outcomes through MIY model ensuring active learning and active engagement in Learning. Journal of Engineering Education Transformations, 34, 681-685. https://doi.org/10.16920/jeet/2021/v34i0/157243

Manu, P., Poghosyan, A., Mahamadu, A. M., Mahdjoubi, L., Gibb, A., Behm, M., & Akinade, O. O. (2019). Design for occupational safety and health: key attributes for organisational capability. Engineering, Construction and Architectural Management, 26(11), 2614-2636. https://doi.org/10.1108/ECAM-09-2018-0389

Martinez, C. (2022). Developing 21st century teaching skills: A case study of teaching and learning through project-based curriculum. Cogent Education, 9(1), 2024936. https://doi.org/10.1080/2331186X.2021.2024936

Mikhailidi, A., & Tskhvediani, G. (2026), Applied active learning in STEM using a strategic session in an occupational health and safety course. Frontiers in Education, 11, 1719714. https://doi.org/10.3389/feduc.2026.1719714

Neto, I. R., & Amaral, F. G. (2024). Teaching occupational health and safety in engineering using active learning: A systematic review. Safety science, 171, 106391. https://doi.org/10.1016/j.ssci.2023.106391

Neu-Baker, N. M., Eastlake, A., & Hodson, L. (2022). Results of the 2019 Survey of Engineered Nanomaterial Occupational Health and Safety Practices. International journal of environmental research and public health, 19(13), 7676. https://doi.org/10.3390/ijerph19137676

Nissen, J. M., Talbot, R. M., Nasim Thompson, A., & Van Dusen, B. (2018). Comparison of normalized gain and Cohen’sd for analyzing gains on concept inventories. Physical Review Physics Education Research, 14(1), 010115. https://doi.org/10.1103/PhysRevPhysEducRes.14.010115

Patil, M. S., & Kamerikar, U. A. (2020). Learning by doing through project based active learning technique. Journal of Engineering Education Transformations, 33(Special Issue), 125-129. https://doi.org/10.16920/jeet/2020/v33i0/150080

Prah, J., Addo-Yeboa, B., Offei-Awuku, B., Abdulai, M., Tamag, T., & Eshun, J. (2025). Evaluating Occupational Health and Safety Conditions among Security Guards in a Ghanaian Public University. International Journal of Occupational Safety and Health, 15(3), 181-191. https://doi.org/10.3126/ijosh.v15i3.76998

Priyaadharshini, M., & Vinayaga Sundaram, B. (2018). Evaluation of higher-order thinking skills using learning style in an undergraduate engineering in flipped classroom. Computer Applications in Engineering Education, 26(6), 2237-2254. https://doi.org/10.1002/cae.22035

Purba, J., Situmorang, M., & Silaban, R. (2019). The development and implementation of innovative learning resource with guided projects for the teaching of carboxylic acid topic. Indian Journal of Pharmaceutical Education and Research, 53(4), 603-612. https://doi.org/10.5530/ijper.53.4.121

Saad, A., & Zainudin, S. (2022). A review of Project-Based Learning (PBL) and Computational Thinking (CT) in teaching and learning. Learning and Motivation, 78, 101802. https://doi.org/10.1016/j.lmot.2022.101802

Sadler, D. R. (2013). Making competent judgments of competence. In Modeling and measuring competencies in higher education: Tasks and challenges (pp. 13-27). Rotterdam: SensePublishers

Sánchez, F. A. S., Peláez, G. I. C., & Alís, J. C. (2017). Occupational safety and health in construction: a review of applications and trends. Industrial health, 55(3), 210-218. https://doi.org/10.2486/indhealth.2016-0108

Sharma, G. V. S. S., Murugadoss, J. R., & Rambabu, V. (2020). Fostering higher order thinking skills in engineering drawing. Journal of Engineering Education Transformations, 34(1), 28-40. https://doi.org/10.16920/jeet/2020/v34i1/148359

Sinyai, C., & Barlet, G. (2020). Designing Occupational Safety and Health Training Materials for Clear Communication. Journal of occupational and environmental medicine, 62(6), 431–438. https://doi.org/10.1097/JOM.0000000000001857

Situmorang, H. N., Purba, S., & Situmorang, M. (2021, November). The Development of Innovative Learning Resources with Multimedia to Support Online Learning in Teaching Industrial Management. In 6th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2021) (pp. 918-925). Atlantis Press. https://doi.org/10.2991/assehr.k.211110.205

Situmorang, H. N., Situmorang, M., & Ginting, L. M. (2023). Implementation of project-based active learning to improve occupational safety and health competencies for automotive engineering education students. Proceeding of The 9th Annual International Seminar on Trends in Science and Science Education (AISTSSE), 53-763. https://doi.org/10.2478/9788367405195-096

Situmorang, H., Purba, S., & Situmorang, M. (2024). Implementation of innovative digital-based learning resources for teaching occupational safety and health in mechanical engineering. In Proceedings of the 5th International Conference on Innovation in Education, Science, and Culture, ICIESC 2023, 24 October 2023, Medan, Indonesia. https://doi.org/10.4108/eai.24-10-2023.2342271].

Situmorang, M., Bariah, K., Pardosi, I., Purwanto, R., Sitorus, M., Sutiani, A., & Simanjuntak, H. (2026). Active learning oriented to green chemistry with virtual laboratories to promote higher order thinking skills to achieve quantitative analytical chemistry competency. Chemistry Teacher International, (2026). https://doi.org/10.1515/cti-2025-0096

Situmorang, M., Purba, J., & Silaban, R. (2020). Implementation of an innovative learning resource with project to facilitate active learning to improve students' performance on chemistry. Indian Journal of Pharmaceutical Education and Research, 54(4), 905-914. https://doi.org/10.5530/ijper.54.4.184

Situmorang, M., Sinaga, M., Purba, J., Daulay, S. I., Simorangkir, M., Sitorus, M., & Sudrajat, A. (2018). Implementation of Innovative Chemistry Learning Material With Guided Tasks to Improve Students'competence. Journal of Baltic Science Education, 17(04), 535-550. https://doi.org/10.33225/jbse/18.17.535

Situmorang, M., Sinaga, M., Sitorus, M., & Sudrajat, A. (2022). Implementation of Project-based Learning Innovation to Develop Students' Critical Thinking Skills as a Strategy to Achieve Analytical Chemistry Competencies. Indian J of Pharmaceutical Education and Research. 56(1s): s41-s51. https://doi.org/10.5530/ijper.56.1s.39

Threeton, M. D., Kwon, K., Fleck, J. A., Ketchem, R. B., & Farzam, L. (2021). An investigation of instructional practices which promote occupational safety and health. International journal of occupational safety and ergonomics: JOSE, 27(3), 902–910. https://doi.org/10.1080/10803548.2019.1659000

APPENDIX

TABLE S1
HOTS ASSESSMENT RUBRIC FOR SCORING OSH PROJECT ASSIGNMENT PRODUCTS (PROJECT PROPOSAL AND REPORT).

No	HOTS aspect	Description, indicators and assessment criteria	Score scale
1	Analytical thinking	Have the knowledge to determine project activities related to OSH courses	1-24
		Have knowledge and skills in selecting and determining appropriate OSH Project activities in the OSH course	25-50
		Have knowledge and skills in selecting and determining appropriate OSH project activities to solve OSH related problems with components of planning, implementation and reporting of project products.	51-75
		Have knowledge and skills in selecting and determining contextual OSH project activities to solve OSH-related problems in the work environment, consisting of the following components: planning, implementation and reporting of project products based on problem solving in the work environment in the engineering business unit.	76-100
2	Evaluation thinking	Able to evaluate project activities related to one of the OSH teachings.	1-24
		Able and skilled in evaluating OSH project activities related to OSH teaching that is relevant to everyday life.	25-50
		Skilled in evaluating and establishing good quality OSH project activities to address OSH related issues in engineering business units.	51-75
		Skilled in selecting, evaluating and establishing good quality contextual OSH project activities for data-based OSH problem solving in the work environment in engineering business units.	76-100
3	Creative thinking	Have new ideas for OSH project activity plans.	1-24
		Having new ideas with innovation as OSH project activities in the work environment.	25-50
		Have new, innovative and creative ideas as OSH project activities in the work environment to solve OSH-related problems in the engineering business unit.	51-75
		Having new, innovative and creative ideas as contextual OSH project activities in the work environment to solve OSH-related problems in the engineering business unit, and as new ideas that can be applied to other business units.	76-100

TABLE S2
PJBL-ILR MODEL CONTAINS OSH TOPICS, BRIEF DESCRIPTIONS OF INNOVATIVE LEARNING RESOURCES, AND ACADEMIC ACTIVITIES FOR ACTIVE LEARNING.

No	Topics	Brief description of innovative learning resources	Active learning
1	Occupational Safety and Health Concepts and OSH Law.	Teaching materials include an introduction to occupational safety and health concepts based on a competency-based curriculum, and in accordance with the OSH Law. Teaching materials are equipped with media and multimedia, hyperlinks to web cases related to occupational safety and health and journal articles.	Assignment to review OSH textbooks: distributed several textbooks for review.
2	OSH Management System.	Teaching materials explain the standard OSH management system and its application in higher education. The material is equipped with flowchart media, PowerPoint, and is equipped with an online integration system between units.	Assignment to review articles about OSH: asked to select articles published in reputable journals for review.
3	OSH Risk Control Hierarchy and Personal Protective Equipment (PPE).	The teaching material contains an explanation of the OSH risk control hierarchy and the use of personal protective equipment (PPE). Teaching materials are prepared systematically and in depth, equipped with videos on the correct use of PPE, providing case study examples and web hyperlinks and relevant reputable journal articles, and providing case study assignments.	Example of a mini project identifying potential hazards in an engineering work environment, and the use of protective equipment.
4	Fire and Fire Control.	Teaching materials include topics about fire and its control, including types of fire extinguishers, how to use and maintain them. This material is prepared systematically to be able to identify sources, causes and prevention of fires, equipped with examples of fire control projects, videos and multimedia, web hyperlinks and relevant journal articles, and team based project assignments.	Example of a mini project identifying types of fire extinguishers, how to use them, checking their suitability, and maintenance strategies.
5	Building or Workshop Layout, Ventilation System, Work Climate, and Lighting.	Teaching materials are prepared to explain the layout of the building or workshop, the ventilation system, activities and work climate according to its function, and the lighting system. Teaching materials are arranged systematically, given examples of buildings and workshops that are suitable and those that do not meet the requirements in terms of the availability of supporting facilities, equipped with videos, learning media, and materials to be discussed as part of the assignment.	The task is to create a layout of the building or workshop, determine the location of ventilation and lighting systems, and create a list of activities according to the function of the building.
6	Environmental pollution.	Teaching materials explain environmental pollution caused by waste disposal activities from human activities such as from buildings, industry, workshops and machines. Teaching materials are prepared to increase knowledge and practice in environmental management and waste handling to minimize negative impacts on the environment. In this topic, videos and examples of environmental pollution are integrated, how to manage industrial and machine waste, and group assignments are given regarding environmental pollution cases.	Example of a mini project in identifying potential environmental pollution caused by waste disposal in industry, workshops and from machines.
7	Hazardous and Toxic Materials.	Teaching materials explain the existence of hazardous and toxic materials produced by industries, machines and businesses which can pollute workplaces and the environment. The material is arranged systematically, equipped with examples of the	Example of a mini project to identify potential hazardous compounds and toxic materials produced by

		entry of hazardous and toxic materials into the work environment and strategies for handling them, and relevant multimedia. There is an assignment to identify cases that can cause pollution due to dangerous and toxic materials in the work environment.	industries, machines and businesses which can pollute workplaces and the environment.
8	Occupational illness.	Teaching materials explain the occurrence of work-related diseases and workplace conditions, and strategies for preventing them. Teaching materials provide knowledge and skills in healthy and safe work, using personal protective facilities, and workplace settings. Learning resources are equipped with videos and multimedia about healthy, safe and comfortable work environments, and healthy work environment website hyperlinks.	The task of identifying the occurrence of work-related diseases and workplace conditions, and strategies for preventing occupational illness.
9	Machine Safety and Noise.	Teaching materials explain strategies for securing machines, reducing noise, and actions that need to be taken in machine workshops to keep them working safely. Learning resources are equipped with videos and media for the use of machine protective equipment and how to control noise.	Example of a mini project about strategies in securing machines, reducing noise and the actions to be taken for safety purposes.
10	Threshold Limit Value (TLV).	The teaching material explains the safe threshold limit value (TLV) for workers during each shift in the work time. Teaching materials are provided regarding TLV for several types of work in accordance with work regulations set by the government. The TLV table example is used to make it easier to study the environmental impact of the presence of chemical compounds that are safe for workers, and is equipped with multimedia.	The task of making a list of number and unit provisions for safe threshold limit values (TLV) for workers in various work places.
11	Ergonomics	Teaching materials explain ergonomic concepts that provide comfort in mechanical and automotive engineering activities, including design, equipment and comfort of use. The material is prepared systematically and completely, in depth, equipped with multimedia, videos and examples of ergonomics in the fields of mechanical and automotive engineering. Hyperlinks to electronic book websites and articles from reputable journals are provided, and ergonomics assignments are given.	Example of a mini project for ergonomic concepts that provide comfort in mechanical and automotive engineering activities, including design, equipment and comfort for users.
12	Occupational Nutrition and Health Promotion.	Teaching materials explain worker nutrition to work optimally, produce high productivity, and stay healthy. The teaching materials are well packaged, equipped with examples of nutritional formulations and work balance to make it easier to study occupational nutrition and health promotion. Website hyperlinks and scientific journal articles regarding salary settings according to type of work are provided.	The task of making a list of nutritional requirements in food to maintain balance in the worker's load.

TABLE S3

LECTURER RESPONDENTS' ASSESSMENT OF THE QUALITY OF PJBL-ILR MODEL FOR TEACHING OF OSH.

No	Description of assessment components of the PjBL-ILR model	Respondent's opinion (M±Sdv, n=12)*
1	Eligibility of Content: Completeness and depth of the content of the OSH course teaching material in a PjBL-ILR model, relevant to the needs of vocational and undergraduate students in mechanical and automotive engineering.	3.42±0.79
2	Teaching Material Completeness: Availability of an electronic learning resources in PjBL-ILR model in the form of multimedia and multimedia, examples of cases according to the topics studied, integration of OSH project examples, templates for project products (proposals and reports), project implementation guides, website hyperlinks and relevant journal articles, and the HOTS assessment rubric for project products.	3.42±0.67
3	Systematics: Systematic arrangements of digital learning resources in PjBL-ILR model include selecting contextually for the content of teaching materials, using illustrations and videos, presenting images, tables, graphs and animations in the text, in accordance with learning objectives	3.67±0.65
4	Design and Appearance: An attractive format design of the PjBL-ILR model includes appropriate typing, layout settings, color selection in images, schemes and illustrations that can strengthen the message and impression of OSH teaching materials.	3.50±0.67
5	Language and readability: Accuracy and clarity in the use of language and grammar according to the student's level of maturity, suitability for using terminology, easy to read, interesting and providing learning messages according to the topic being studied.	3.58±0.51
Average		3.52±0.66

*Assessment criteria: (4) is very good, (3) is good, (2) is poor, and (1) is very poor

TABLE S4

CONTRIBUTION OF DIGITAL LEARNING RESOURCES IN FACILITATING STUDENTS' ACTIVE LEARNING AND THEIR INFLUENCE ON MOTIVATING STUDENTS TO STUDY OSH.

No	Aspect of motivation	Question items	Motivational indicators and assessment description.	Respondent's opinion (M±Sdv, n=30)
1	Confidence	2	A complete digital learning resource package including teaching materials, project examples, multimedia and report templates is very effective in guiding students to learn actively and carry out OSH assignments and projects correctly	4.50±0.63
2	Challenge	2	The supporting facilities available in digital learning resources have guided students to complete the challenge of selecting, determining and implementing projects contextually according to their chosen OSH topic.	4.40±0.56

3	Engagement	2	Students believe in the reliability of digital learning resources as a source of knowledge and skills in occupational safety and health, to be implemented in academic activities in the field of mechanical and automotive engineering.	4.57±0.50
4	Curiosity	1	Learning resource support tools have succeeded in arousing students' curiosity in the field of occupational safety and health, and consistently applying knowledge and skills in implementing OSH projects	4.30±0.65
5	Relevance	1	The content of OSH teaching materials in digital learning resources is very relevant to occupational safety and health practices in the fields of mechanical and automotive engineering.	4.53±0.63
6	Satisfaction	2	The format, design and appearance of the digital learning resource package is very attractive, easy to access, used as a learning medium, and gives the impression of long-remembered learning.	4.43±0.50
Sum		10	Average	4.46±0.58

*Assessment criteria: (5) Strongly Agree; (4) Agree; (3) Neutral; (2) Disagree; and (1) Strongly Disagree