TITLE:

SITESAFE: A 3D WEB GAME FOR WORKPLACE HAZARD AWARENESS IN CONSTRUCTION

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WEB GAME DEVELOPMENT

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EXECUTIVE SUMMARY

Malaysia's construction industry faces a persistent challenge: workplace accidents account for over 30% of occupational fatalities annually, with many incidents attributable to inadequate safety awareness and improper use of personal protective equipment (PPE). Traditional safety training methods, which rely heavily on passive learning and rote memorisation, often fail to engage workers effectively or translate into practical hazard recognition skills.

This project presents **SiteSafe**, an interactive 3D web-based educational game designed to transform occupational safety training for Technical and Vocational Education and Training (TVET) institutions in Malaysia. The game simulates realistic construction site environments where players actively identify hazards, select appropriate PPE, and navigate dangerous scenarios whilst learning critical safety procedures aligned with Malaysian Department of Occupational Safety and Health (DOSH) regulations and the Occupational Safety and Health Act 1994.

SiteSafe comprises three progressive levels: PPE Selection Challenge (beginner), Hazard Identification Zone (intermediate), and Heavy Machinery Operation Zone (advanced). Built using HTML5 Canvas for 2D elements and Three.js for immersive 3D simulation, the game achieves optimised performance with load times under two seconds whilst maintaining engaging visual fidelity. The gamification approach, featuring point systems, timers, and immediate feedback, makes mandatory safety training genuinely engaging whilst ensuring educational rigour. This project demonstrates how modern web technologies can effectively bridge the gap between theoretical safety knowledge and practical workplace preparedness.

1. INTRODUCTION

The construction industry remains one of the most hazardous sectors in Malaysia, with statistics from the Department of Occupational Safety and Health (DOSH) consistently showing alarming rates of workplace injuries and fatalities. In 2023, the construction sector recorded 4,832 industrial accidents, representing approximately 15% of all reported workplace incidents nationwide. More concerning is that a significant proportion of these accidents stemmed from preventable causes: failure to use appropriate PPE, inability to recognise common hazards, and lack of awareness regarding safe working procedures around heavy machinery.

Traditional occupational safety training in TVET institutions typically relies on classroom-based instruction, printed materials, and occasional site visits. Whilst these methods provide foundational knowledge, they often fail to create lasting impressions or develop practical hazard recognition skills. Students may memorise safety rules for examinations but struggle to apply them in real-world scenarios where quick decision-making is essential. Furthermore, the passive nature of conventional training frequently results in disengagement, particularly among younger learners accustomed to interactive digital experiences.

This project addresses these limitations by developing **SiteSafe**, an educational web game that leverages gamification principles to transform safety training from a passive exercise into an engaging, interactive experience. The game provides a risk-free virtual environment where students can make mistakes, learn from consequences, and develop practical safety awareness without real-world dangers. By aligning all content with Malaysian DOSH regulations, OSHA 1994 requirements, the Fire Services Act 1988, and the Environmental Quality Act 1974, SiteSafe ensures that gameplay directly supports official TVET curriculum objectives and prepares students for actual workplace compliance requirements.

2. GAME CONCEPT

2.1 Overview

SiteSafe places players as a construction site safety officer ensuring workplace safety across three distinct areas. The gameplay revolves around observation, decision-making, and quick response, with immediate feedback reinforcing correct behaviours.

2.1 Level Design

Level 1: PPE Selection Challenge (Beginner)

Players select appropriate PPE for various construction scenarios using a drag-and-drop interface built with HTML5 Canvas. A 90-second timer creates urgency whilst scoring rewards correct selections. Items include safety helmets, boots, high-visibility vests, goggles, welding masks, hearing protection, and gloves.

Level 2: Hazard Identification Zone (Intermediate)

Players navigate an interactive construction scene containing 15 hidden hazards: unsecured scaffolding, improperly stored materials, electrical hazards, and unsafe behaviours. Upon identification, educational modals display hazard information and relevant DOSH regulations.

Level 3: Heavy Machinery Operation Zone (Advanced)

An immersive 3D experience using Three.js where players navigate a construction environment, avoiding moving equipment and staying within safe zones. First-person controls (WASD movement) teach spatial awareness and machinery safety concepts.

2.3 Learning Outcomes

Upon completing SiteSafe, players will be able to:

(a) Identify appropriate personal protective equipment for specific construction site tasks and hazards, demonstrating knowledge aligned with DOSH Industry Code of Practice requirements.

(b) Recognise common workplace hazards across physical, chemical, ergonomic, and biological categories, applying systematic hazard identification skills essential for workplace safety compliance.

(c) Demonstrate safe behaviour around heavy machinery, including awareness of exclusion zones, understanding of warning signals, and appropriate emergency response procedures as specified in OSHA 1994.

3. TECHNICAL DESIGN AND IMPLEMENTATION

3.1 Technology Stack

SiteSafe is built entirely on web technologies, ensuring maximum accessibility without requiring software installation. The technology stack was carefully selected to balance capability with performance:

Technology	Purpose
HTML5	Document structure, semantic markup, and Canvas API for 2D rendering
CSS3	Visual styling, responsive design, animations, and UI transitions
JavaScript (ES6+)	Core game logic, event handling, state management, and DOM manipulation
Three.js	3D graphics rendering, scene management, camera controls, and object interactions
HTML5 Canvas	2D game rendering for Levels 1 and 2, sprite handling, and collision detection

3.2 System Architecture

The game follows a modular architecture separating concerns into distinct components. The main entry point (index.html) loads the appropriate game module based on level selection. Each level operates as an independent module with its own rendering context, game loop, and state management, communicating with a shared scoring and progression system through a centralised game manager.

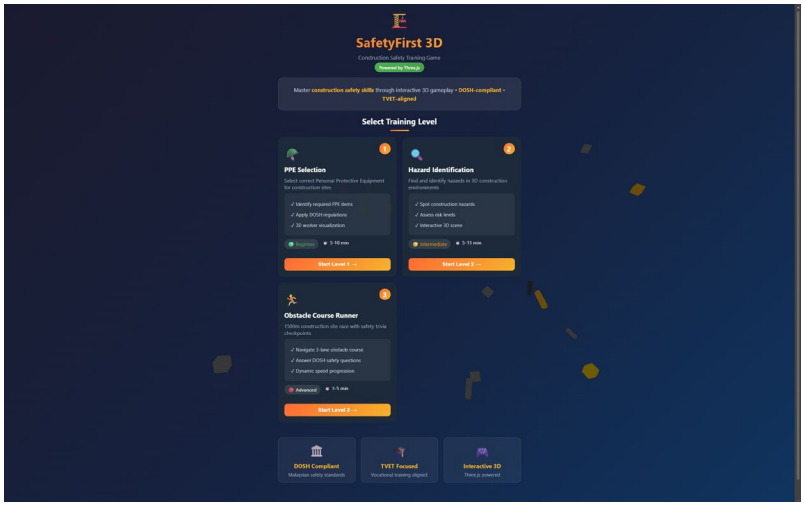
The architecture comprises four primary layers: the Presentation Layer (HTML/CSS) handles user interface elements and visual styling; the Game Engine Layer manages rendering loops, timing, and frame updates; the Logic Layer processes game rules, scoring algorithms, and level progression; and the Data Layer maintains game state, player progress, and educational content databases.

3.3 Key Implementation Features

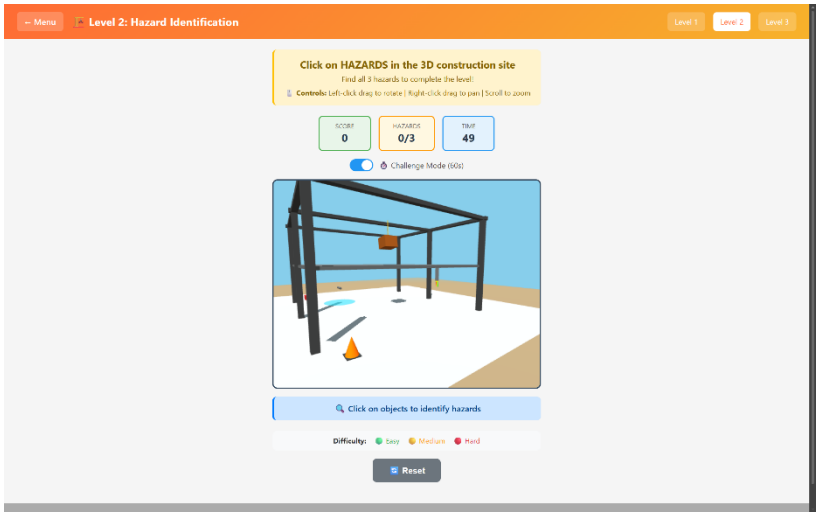
- **Level 1:** Drag-and-drop PPE selection with mouse events, collision detection, and CSS-based geometric shapes for consistent cross-device rendering.
- **Level 2:** Clickable hazard regions with bounding box detection, educational modals with regulatory references, and progress tracking.
- **Level 3:** Three.js 3D environment with first-person camera, WASD controls, dynamic hazard zones, and optimised scene rendering.

3.4 User Interface Design

The user interface prioritises clarity and accessibility, featuring a consistent navigation structure across all levels. The main menu provides clear level selection with difficulty indicators and progress tracking. In-game HUD elements include score display, timer, level progress indicators, and a pause menu with options to resume, restart, or exit to the main menu.



Responsive design ensures playability across devices from desktop computers to tablets. CSS media queries adjust layout proportions, font sizes, and interactive element sizing based on viewport dimensions. Touch controls supplement mouse/keyboard input for mobile compatibility.



4. TVET INTEGRATION AND RELEVANCE

4.1 Curriculum Alignment

Each game element maps to specific TVET competencies and Malaysian safety regulations:

Game Element	TVET Competency	Regulatory Reference
PPE Selection (Level 1)	Identify and use appropriate PPE for specific tasks	OSHA 1994 Section 15; DOSH Industry Code of Practice on PPE
Hazard Recognition (Level 2)	Conduct workplace hazard identification and risk assessment	OSHA 1994 Section 16; Guidelines on Hazard Identification, Risk Assessment and Risk Control (HIRARC)
Machinery Safety (Level 3)	Implement safe work procedures around heavy machinery	Factories and Machinery Act 1967; DOSH Guidelines on Safe Use of Lifting Equipment

4.2 Regulatory Compliance

All educational content within SiteSafe has been developed with reference to authoritative Malaysian occupational safety legislation and guidelines. The primary regulatory frameworks informing game content include the Occupational Safety and Health Act 1994 (OSHA 1994), which establishes employer and employee duties regarding workplace safety; the Factories and Machinery Act 1967, governing safe operation of machinery; the Fire Services Act 1988, addressing fire safety requirements; and the Environmental Quality Act 1974, concerning workplace environmental hazards.

Additionally, DOSH guidelines including the Guidelines on Hazard Identification, Risk Assessment and Risk Control (HIRARC), the Industry Code of Practice on Personal Protective Equipment, and the Guidelines on Safe Use of Lifting Equipment have informed specific game mechanics and educational feedback content. This regulatory grounding ensures that skills developed through gameplay directly transfer to real workplace compliance requirements.

4.3 Classroom Integration

SiteSafe can serve as an introductory activity before theoretical instruction or as a revision tool. The progressive level structure supports differentiated instruction, and scoring data provides formative assessment for educators.

5. TESTING AND CHALLENGES

5.1 Testing Methodology

Testing followed a systematic approach encompassing functionality testing, performance testing, usability testing, and educational validity testing. Functionality testing verified that all game mechanics operated as intended, including scoring calculations, timer functions, collision detection, and level progression logic. Test cases were developed for each level, covering both expected user behaviours and edge cases.

Performance testing utilised browser developer tools to measure frame rates, memory usage, and load times across multiple devices and browsers. Target benchmarks included maintaining 30+ frames per second during gameplay and load times under 3 seconds on standard hardware. Usability testing involved peer evaluation sessions where fellow students played through all levels whilst observers noted points of confusion or difficulty.

5.2 Key Challenges and Solutions

Challenge 1: 3D Performance Optimisation

The most significant technical challenge involved Level 3 performance. Initial implementation achieved visually impressive results but suffered from unacceptable load times (8-15 seconds) and inconsistent frame rates. Analysis revealed multiple contributing factors: excessive polygon counts in 3D models, computationally expensive shadow calculations, and inefficient scene graph structure with over 150 objects.

Solution: A comprehensive optimisation strategy was implemented. Shadow systems were disabled entirely, as the educational objectives did not require realistic lighting effects. Materials were switched from MeshStandardMaterial (which requires complex lighting calculations) to MeshBasicMaterial (which renders with flat colours). Scene complexity was dramatically reduced from 150+ objects to approximately 30 essential elements, with decorative details removed or simplified. These changes reduced load times to under 2 seconds whilst maintaining full gameplay functionality.

Challenge 2: Cross-Browser Consistency

Initial development used emoji characters for certain visual elements (such as hazard icons and PPE items). Testing revealed inconsistent rendering across browsers and operating systems, with some emoji appearing differently styled or entirely missing on certain platforms.

Solution: All emoji-based elements were replaced with CSS-based geometric shapes and custom-styled HTML elements. This approach ensures consistent visual presentation regardless of the user's browser, operating system, or installed fonts, improving the professional appearance of the game whilst eliminating rendering inconsistencies.

6. CONCLUSION AND FUTURE WORK

6.1 Project Summary

SiteSafe successfully demonstrates the potential of web-based educational games to transform occupational safety training for TVET institutions. The project delivers a fully playable three-level game that progressively develops player competencies from basic PPE knowledge through hazard identification to complex machinery safety awareness. Built on accessible web technologies (HTML5, CSS3, JavaScript, and Three.js), the game requires no software installation and performs effectively across a range of devices.

The gamification approach, incorporating points, timers, achievements, and immediate feedback, successfully addresses the engagement limitations of traditional safety training methods. By aligning all content with Malaysian DOSH regulations and OSHA 1994 requirements, SiteSafe ensures that gameplay directly supports official curriculum objectives and prepares students for real workplace compliance demands. The project demonstrates that educational rigour and engaging gameplay are not mutually exclusive but can be mutually reinforcing.

6.2 Future Enhancements

SiteSafe successfully demonstrates web-based educational games can transform occupational safety training for TVET institutions. The project delivers a fully playable three-level game that develops competencies from PPE knowledge to machinery safety awareness, with optimised performance across devices.

Future Enhancements:

- Emergency Response Scenarios – fire evacuation and first aid procedures
- Multiplayer Mode – cooperative safety management reflecting real teamwork
- LMS Integration – progress tracking and customisation for educators

REFERENCES

Department of Occupational Safety and Health Malaysia. (2008). Guidelines on Occupational Safety and Health Management Systems. Ministry of Human Resources Malaysia.

Department of Occupational Safety and Health Malaysia. (2019). Guidelines on Hazard Identification, Risk Assessment and Risk Control (HIRARC). Ministry of Human Resources Malaysia.

Department of Occupational Safety and Health Malaysia. (2005). Industry Code of Practice on Personal Protective Equipment. Ministry of Human Resources Malaysia.

Government of Malaysia. (1994). Occupational Safety and Health Act 1994 (Act 514). Percetakan Nasional Malaysia Berhad.

Government of Malaysia. (1967). Factories and Machinery Act 1967 (Act 139). Percetakan Nasional Malaysia Berhad.

Government of Malaysia. (1988). Fire Services Act 1988 (Act 341). Percetakan Nasional Malaysia Berhad.

Government of Malaysia. (1974). Environmental Quality Act 1974 (Act 127). Percetakan Nasional Malaysia Berhad.

Kapp, K.M. (2012). The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education. Pfeiffer.

Stuart, G. (2017). Introducing JavaScript Game Development: Build a 2D Game from the Ground Up. Apress.

Three.js Documentation. (2025). Three.js Fundamentals. Retrieved from https://threejs.org/docs/

Uzayr, S.B. (2023). Conquering JavaScript: The Practical Handbook. CRC Press.

W3Schools. (2025). HTML5 Canvas Tutorial. Retrieved from https://www.w3schools.com/html/html5_canvas.asp