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Mobile Augmented Reality (AR) for Automotive Vocational Training: Development and Technological Readiness Analysis of MY MOTOR Application

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ABSTRACT

Facial recognition has become one of the most widely implemented biometric technologies, with applications ranging from identity authentication to human-computer interaction. Despite the remarkable performance under controlled conditions, recognition accuracy degrades significantly in unconstrained environments because of variations in illumination, pose, facial expression, and background complexity. However, current facial recognition research remains subject to several limitations. First, most studies are evaluated primarily on controlled or semi-constrained benchmarks, resulting in limited evidence of robustness under fully unconstrained real-world conditions. Second, the integration of quantum image processing techniques into facial recognition pipelines remains scarce, despite the considerable advances in quantum image processing. Finally, existing studies primarily investigate image representation and feature extraction independently, leaving their interaction within facial recognition pipelines largely unexplored. A dual-branch hybrid framework is proposed that integrates quantum image representation with classical and quantum-based feature extraction. The framework employs two quantum encoding methods, followed by feature fusion and Principal Component Analysis (PCA)-based dimensionality reduction. The resulting feature representations are evaluated using both classical and quantum machine learning classifiers. The proposed hybrid feature combinations achieved up to 81.96% recognition accuracy on the in-the-wild dataset while maintaining competitive performance on the controlled dataset. These results demonstrate the practical value of hybrid classical–quantum facial recognition frameworks and provide a foundation for future quantum machine learning research in computer vision.

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1. Introduction

The integration of emerging technologies into educational environments has advanced rapidly in recent decades. In practical and vocational technical education, hands-on physical experience forms the bedrock of skill learning [1,2]. However, vocational institutions worldwide face severe budget constraints, primarily due to the high acquisition and maintenance costs of mechanical units, such as operational vehicles and engines [3,4]. As a result, students are usually limited to passive verbal instruction and 2D textbook theories, which do not promote correct mental spatial modeling of real-world mechanical systems [5,6].

Recent socioeconomic policies in Malaysia have gradually shifted technical and vocational learning paths from secondary-level options to premium alternatives. To comply with these updated criteria, structural instructional frameworks must be modernized [7]. When interacting with digital learning environments rather than traditional print media, the majority of teenagers and young adults exhibit much higher levels of engagement [8].

Mobile Augmented Reality (MAR) is a promising way to reduce these educational limitations. By overlaying interactive computer-generated 3D virtual visuals directly over a live physical viewport, MAR enables safe, repeatable, and fully immersive engagement with complex vehicle components [9]. While much research has been conducted on AR in general higher education, studies specifically focusing on automotive skill development within mobile frameworks for technical and vocational instructional ecosystems remain rare [10,11].

To bridge this gap, this article proposes MY MOTOR, a unique MAR application designed specifically for basic motorcycle engine mechanics training. The research seeks to answer two key questions:

1. How can mobile AR frameworks be systematically mapped onto a vocational automotive curriculum using an instructional design approach?
2. What are the baseline user competencies and technological readiness levels of the target group when introducing mobile AR into automotive troubleshooting?

2. Literature Review

2.1 Augmented Reality in Pedagogical Contexts

Augmented Reality (AR) is formally defined by three key characteristics: the integration of real and virtual items in a live context, real-time interactive execution, and precise 3D registration [12]. Originally based on industrial maintenance paradigms, such as the landmark KARMA project developed by MacIntyre and Seligman [13], which offered wireframe overlays for repair methods, AR has rapidly evolved into diverse educational applications [14].

2.2 Vocational Training Challenges and MAR as a Learning Tool

The fundamental philosophy of technology instruction states that structural technical competence necessitates a systemic cognitive link between symbolic concepts and haptic attributes [15]. Dynamic visualization is mandatory for automotive maintenance components, such as complex subsystem assemblies (e.g., valves, gear mechanisms, and electrical circuits) [16]. Traditional teaching methods frequently fall short due to structural constraints or equipment scarcity. MAR solutions directly address these issues by providing visual "X-ray" depictions of hidden mechanics without the risk of equipment damage or student physical injury [17].

3. Methodology

This study applied the conventional ADDIE Instructional Design Model to thoroughly operationalize the transition from physical curriculum guidelines to digital visual interactions [18]. Figure 1 depicts the educational design model.

Fig. 1. ADDIE Instructional Design Model

3.1 Analysis

The analysis stage focused on the practical requirements of the target population. Initially designed as an in-person workshop trial at a vocational school, local public health restrictions forced a transition to digital deployment. Online surveys were provided to assess the target population's technology readiness, previous AR experience, and overall automotive literacy.

3.2 Design

The design phase structured the user interface (UI) and user experience (UX) layout via multi-tiered storyboards reviewed by academic advisors. The architecture was divided into three primary functional engines:

- The Maintenance Engine (Pembaikan): Segmented into six essential motorcycle sub-assemblies: Tires, Brakes, Sprockets, Batteries, Engines, and Spark Plugs.
- The Instructional Advice Engine (Tip): Scrollable interfaces outlining procedural advice (e.g., specific battery maintenance rules and selection matrices).
- The Assessment Engine (Kuiz): An integrated quiz system to check knowledge retention.

3.3 Development

Software assets were created using the cross-platform Unity game engine. Virtual 3D mechanical models were created, textured, and set to meet automotive curriculum technical requirements [19]. Interactive visual assets, typography, and contrast attributes were tuned to promote operational legibility in dynamic workstation lighting settings.

Fig. 2. Menu page of the My Motor application

Figure 2 shows the main page includes the menus available to be selected by potential users. From here, there are included 'Pembaikan' menu, 'Tip' menu, 'Kuiz' menu, and exit menu.

Fig. 3. Arrangement of buttons of the selected menu

Figure 3 depicts the information in the repairing menu, which provides six options for repairing a motorcycle. There are tire menu, brake menu, sprocket menu, engine menu, and spark plug menu. Included in the option, the application also puts an icon representing all options.

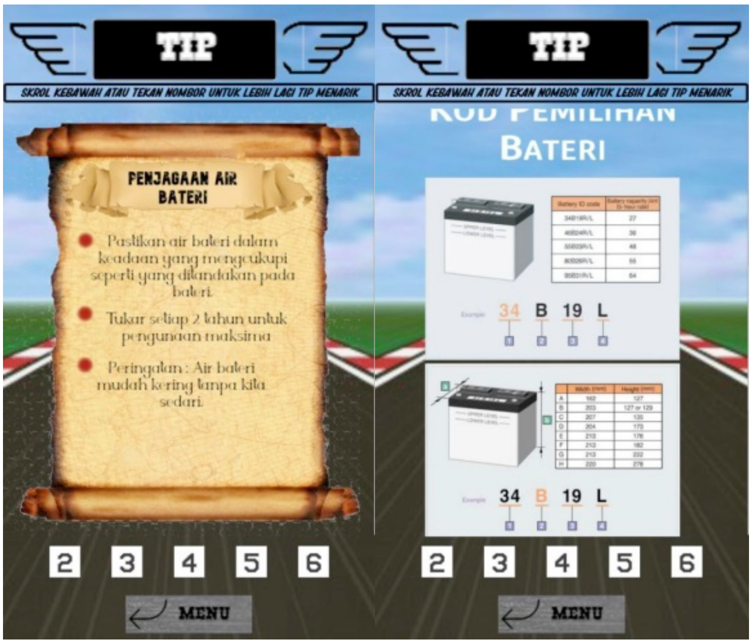

Fig. 4. Information about the motorcycle engine and parts

Figure 4 illustrates the tip menu interface. Expanded details (e.g., battery metrics) are displayed here to help students learn accurate instructional information visually.

3.4 Implementation

Alpha prototype builds were distributed to a controlled testing network for initial system validation. User-reported problems, interface slowness, and registration discrepancies were all noted [20]. Debugging processes were iterated until stability and target tracking accuracy metrics were met.

3.5 Evaluation

The evaluation phase focused on analyzing the baseline competencies, prior immersive technology exposure, and specific training needs of the participant pool (N=128). This data was utilized to evaluate the pedagogical necessity and target-user readiness for the developed MAR application [21].

4. Result and Discussion
4.1 Quantitative Baseline Profile Analysis

The demographic and technological readiness profiles revealed notable trends across the baseline dataset (N=128).

Table 1
Quantitative baseline profile analysis

Measured Parameter Evaluation	Positive Response (%)	Negative Response (%)
Baseline Automotive Mechanical Competence (Prior knowledge of vehicle maintenance procedures)	21.1%	78.9%

Table 1 (*Continued*)

Prior Immersive Technology Exposure (Past interaction with AR software/hardware frameworks)	6.2%	93.8%

Table 1 presents the evaluation of measurement parameters for the demographic and technological preparedness profiles associated with the MY MOTOR application. The baseline assessment revealed a major training gap; 78.9% of potential learners lacked baseline proficiency in motorcycle engine mechanics. Furthermore, an astounding 93.8% had never used AR technology. This suggests that, while being aimed at digital natives, immersive educational applications are still relatively new [22].

4.2 Usability and Curricular Discussion

Quantitative research demonstrates that conventional classroom methods fail to develop high mechanical literacy. When migrating to mobile AR, 3D representations of parts, such as battery configuration codes (34 B 19 L), bridge the gap between abstract theory and immediate observation.

Crucially, because the target user population has little prior experience with AR (93.8%), unambiguous on-screen training and clear assistance sequences, as created in the MY MOTOR Assessment Engine, are essential. Without these educational scaffolds, users may feel cognitive overload, reducing the application's pedagogical value.

5. Conclusions

This study systematically documented the design and implementation of the MY MOTOR mobile augmented reality application, which used the ADDIE instructional approach to increase mechanical skill acquisition in technical training settings. The baseline assessment reveals that target users have a significant deficiency in automotive literacy and limited exposure to immersive learning techniques.

This framework provides a practical solution to resource constraints in technical schools by transforming large, multi-component subsystems into interactive, mobile-accessible 3D tracking layouts. A future study will expand on this deployment to quantify the explicit learning gains and differences in usability metrics between standard student cohorts and AR-assisted experimental groups.

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