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IMPLEMENTATION OF AREFI TO IMPROVE BASIC KNOWLEDGE OF EFI

Komarudin[1], Widiyanti*[2)], Mahfudi Sahly Subandi[3)], Dianna Ratnawati[4)], Sudirman Rizki Ariyanto[5)], Tiwit Nor Hidayat[6)], Achmad Chairuddin[7)], Risca Zahra Permatahat[8)]

1. Automotive Engineering Education Department, Faculty of Engineering, State University of Malang, Indonesia
2. Automotive Engineering Education Department, Faculty of Engineering, State University of Malang, Indonesia
3. Automotive Engineering Education Department, Faculty of Engineering, State University of Malang, Indonesia
4. Automotive Engineering Education Department, Faculty of Engineering, State University of Malang, Indonesia
5. Automotive Engineering Technology, Faculty of Vocational Studies, Universitas Negeri Surabaya, Indonesia
6. Light Vehicle Engineering, Vocational School of Kepanjen, Indonesia
7. Light Vehicle Engineering, Vocational School of Kepanjen, Indonesia
8. Automotive Engineering Education Department, Faculty of Engineering, State University of Malang, Indonesia

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* Corresponding author.
Corresponding Author
E-mail address:
widiyanti.ft@um.ac.id

ABSTRACT
Many students do not demonstrate optimal mastery because EFI material is considered complex and abstract, while conventional learning using engine stands has limited accessibility outside school hours. This innovation is designed to create an immersive learning experience focused on reinforcing foundational knowledge regarding the identification of components, functions, and the operational flow of the EFI system. The study employs a quantitative method with a quasi-experimental design of the Non-equivalent Control Group Design type. The research sample consisted of 80 students in the 11th grade of Light Vehicle Engineering, divided into an experimental group and a control group. Data were collected through pre-tests and post-tests, then analysed using ANOVA with a significance level of α=0.05. The results of the study indicate that the use of AREFI media has a significant positive impact on student learning outcomes. There was an increase in the average score from 44.73 in the pre-test to 70.92 in the post-test. The ANOVA test results showed an F value of 90.217 with a significance level of 0.000 ($p < 0.05$), proving that the difference in learning outcomes between the two groups was caused by the use of the AREFI media. Therefore, it can be concluded that the AREFI learning media has proven to be effective as an innovative solution for visualizing abstract EFI concepts, enhancing interaction, and facilitating deep understanding among vocational high school students.

I. INTRODUCTION

Vocational education, particularly at Vocational High Schools (SMK), plays a crucial role in preparing graduates who are ready to work in their respective fields of expertise. For SMK students in the automotive department, mastering the competency of Electronic Fuel Injection (EFI) maintenance is an essential requirement, especially since this competency is tested in the Vocational Competency Exam (UKK). However, initial observations in the field reveal significant challenges, as few students demonstrate optimal mastery of EFI maintenance competencies. Success in this competency heavily depends on students' ability to accurately identify the location of electrical components, understand the names and functions of each component, and analyse the overall operation of the injection system.

One of the identified root causes of the problem is that EFI material is often perceived as complex and abstract by students, making it unpopular. This perception, as indicated by [1], contributes to suboptimal learning outcomes and highlights the urgent need for innovative learning strategies. EFI learning in schools is still conventional, relying on physical media such as machine stands, which have limitations, especially due to limited access outside the school environment. This hinders students' opportunities to learn independently and in-depth outside of class hours. The low mastery of EFI maintenance competencies requires a solution through the development of learning media that is not only informative but also capable of motivating and facilitating students in learning material that is considered difficult.

With the rapid advancement of information technology, which has brought transformative changes to various sectors including education [2], [3]. Technology-based learning innovations have become a necessity. The use of smartphones, which have now become ubiquitous devices among students [4], [5]. It offers great potential as a flexible and personalized learning tool. Android-based smartphones, with their ability to support interactive applications, can serve as an ideal platform to support the learning process, particularly in explaining complex concepts such as the operation of an injection machine. As emphasized by [6], smartphones have great potential as a learning resource relevant to the needs of today's generation, where Android applications can be designed to present material in a more engaging and easily digestible manner, while empowering teachers in delivering educational content.

In this context, Augmented Reality (AR) technology offers a promising solution. AR has the ability to visualize abstract concepts into interactive three-dimensional (3D) representations that can be projected into the real world through a smartphone camera. demonstrated have the potential of the Android platform as a learning medium for AR-based injection machine control systems[7]. Specific advantages of AR in EFI learning include its ability to: (1) display the precise locations of EFI components virtually on images or even physical engine models; (2) present the names and descriptions of component functions through touch interaction (tapping); and (3) simulate the operation of the injection system, such as fuel flow and sensor signals, which are difficult to observe directly on an engine stand. Furthermore, AR can be designed to guide students through basic troubleshooting steps, fostering practical understanding from the outset.

Therefore, this study aims to implement an Augmented Reality-based Electronic Fuel Injection (AREFI) learning application, operated via an Android smartphone. The implementation of AREFI is aimed at creating a more enjoyable and immersive learning experience, with a focus on strengthening essential basic EFI knowledge, such as component identification, understanding of functions, and system workflow. The novelty of this research lies in the implementation of AR media specifically designed to address the difficulties of learning EFI material at the vocational high school level.

II. Research Method

This research method was systematically designed to ensure that the evaluation of the effectiveness of AREFI media was conducted objectively.

A. Type and Design of Research

This study uses a quantitative approach with a quasi-experimental method and a Non-equivalent Control Group Design. This design is used because the researcher provides treatment to one group (experimental class) and compares the results with another group that does not receive treatment (control class), but without randomly assigning subjects. The structure of the research design can be described as shown in Table 1.

TABLE I
RESEARCH DESIGN

Class	Pre-test	Treatment	Post-test
Experiment	O1	X	O2
Control	O3	C	O4

O1 & O3: Pre-test. X=Treatment in the form of learning using AREFI media.
C =Learning using an engine stand. O2 & O4= Post-test.

B. Research Population and Sample

The population in this study was all 11th grade students majoring in Light Vehicle Engineering (TKRO) at SMKN 1 Kepanjen, who were studying Electronic Fuel Injection maintenance competencies. The research sample was taken using purposive sampling, in which two classes were selected based on considerations of equality in average initial abilities. Of the two classes, one class was designated as the experimental class and one class as the control class. The sample consisted of approximately 80 students divided into the two classes.

C. Research Procedure

The research was conducted through three main stages:

1. Preparation Stage: This included literature review, development of the AREFI learning media, and the design and validation of the learning outcome test instruments to ensure the validity and reliability of the test questions.
2. Implementation Stage:

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a. Administering a pre-test to both groups.
b. Conducting the learning process during the specified period. The experimental class learned using the AREFI application, while the control class learned using conventional methods. AREFI was used during learning (theory and practice) and at home.
   Students install the AREFI application and then use it. The application has several specifications: the application size is 125MB, it does not require an internet connection, and it is easy to access and use. The front menu of the application is shown in Figure 1.

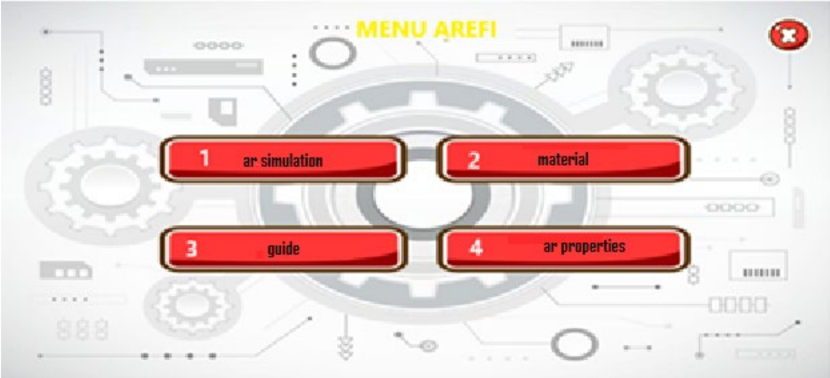

Fig 1. AREFI Dashboard

The AR simulation menu displays (1) the components and electrical diagram of the control system, making it easy for instructors to explain the relationship between the sensor and the ECM; (2) materials that can be used to enrich knowledge. This AR-based EFI is easy to use and comes with a guide; (3) the guide contains instructions on how to use the AREFI application.

Fig 2. Application Simulation

The EFI components on the media can be tapped to display an explanation of the component. The guide menu contains procedures for using the AREFI application as shown Figure 3. The application usage guide plays an important role in enabling users to utilize this application to support learning activities at school.

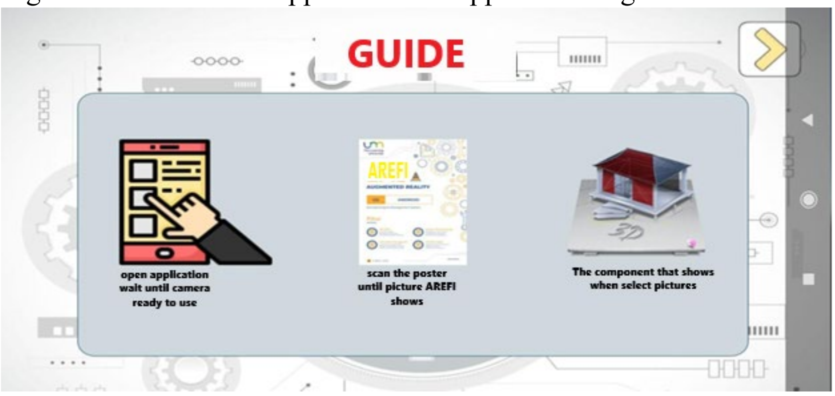

Fig 3 Guide To Using The AREFI Application

The material menu contains information about component names, locations, and functions. Ease of use is one of the factors expected in the development of this application. Ease of use means that the application can be used without restrictions on time and place.

c. Administering a post-test to measure learning outcomes improvement.

3. Analysis Stage: Collecting pre-test and post-test data, then analysing it using relevant statistical techniques.

D. Data Collection Techniques

The main data collection technique is the use of a Learning Outcome Test. The test instrument consists of multiple-choice questions based on the EFI core competency framework. The same test is used for both the pre-test and post-test to consistently measure changes in students' knowledge.

E. Data Analysis Techniques

Data analysis is conducted to test the research hypothesis and answer the research questions. The analysis techniques used are:

1. Descriptive Statistics: Used to present data concisely, including the mean, standard deviation, minimum value, and maximum value of pre-test and post-test scores for each group.
2. Hypothesis Testing: Hypothesis testing was conducted using Analysis of Variance (ANOVA) at a significance level of $\alpha=0.05$. The ANOVA test was used to determine whether there was a statistically significant difference in the average learning outcomes (post-test) between students who learned using the AREFI media and students who learned using conventional methods. This analysis directly led to the results presented in the ANOVA Table.

III. RESEARCH RESULTS

The effectiveness of AREFI media was measured using pre-test and post-test methods. The results of this research as Table 2.

TABLE 2
DESCRIPTIVES DATA OF PRE-TEST AND POST-TEST

Test		Statistic	Std. Error	Test		Statistic	Std.Error
Pre-test	Mean	44.73	180.756	Post-test	Mean	70.92	208141
	5% Trimmed Mean	44.29			5% Trimmed Mean	70.90	
	Median	42.11			Median	71	
	Variance	130.69			Variance	173.20	
	Std. Deviation	1.143.201			Std. Deviation	13.16	
	Minimum	31			Minimum	52	
	Maximum	68			Maximum	89	
	Range	37			Range	37	

There was a surge in the average score (mean) from 44.73 in the pre-test to 70.92 in the post-test. This indicates the positive impact of using AREFI media on student understanding.

TABLE 3
ANOVA

AREFI results					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13712.092	1	13712.092	90.217	.000
Within Groups	11855.252	78	151.990		
Total	25567.345	79			

The analysis of variance (ANOVA) test in Table 3 confirmed that this increase was statistically significant. The test results showed an F value of 90.217 with a significance level (Sig.) of .000, which is much smaller than 0.05. This proves that the difference in learning outcomes did not occur by chance, but rather because of the treatment using AREFI media.

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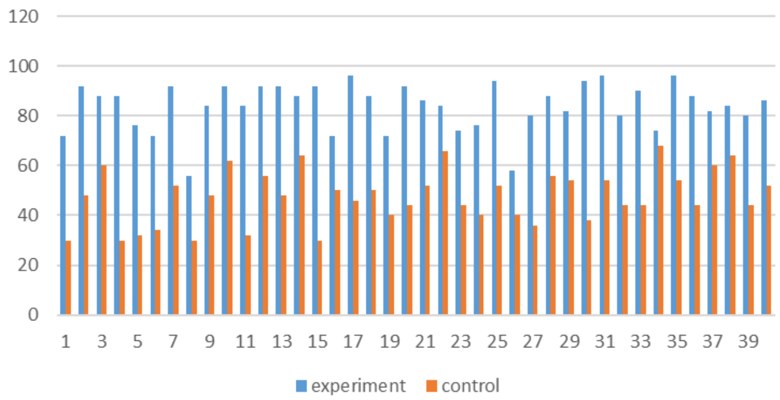

Fig 4 Test Result

The implementation of ATAR media had an impact on increasing basic knowledge of EFI material in light vehicle techniques (TKR) classes. Students who used ATAR experienced an increase in EFI material knowledge, as shown in Figure 4. This increase in knowledge was made possible due to the ease of use and flexibility of ATAR.

IV. Discussion

The research results showing that AREFI is effective in significantly improving student learning outcomes are in line with various other research findings on the use of technology in education. The success of AREFI can be discussed in a broader context by comparing it with similar studies. The use of AREFI showed an increase in students' average scores from 44.73 to 70.92, with ANOVA results showing $F = 90.217$ and $p < 0.05$, as shown in Table 2. These findings are consistent with research by Akbar and which showed that AR improves understanding of abstract chemistry concepts [8]. AREFI had an impact on basic knowledge of EFI material, as shown in Figure 4. Students in the experimental class obtained better scores than those in the control class. Similarly, the application of VULK-AR in geography learning by [9] successfully improved understanding of volcanism significantly. In the field of ICT, emphasized that 3D AR is effective in improving students' critical thinking skills [10].

The use of AR in physics education also showed improvements in conceptual understanding and learning motivation [11]. Overall, the results of AREFI can be considered theoretically and empirically relevant to existing literature, reinforcing AR's position as an effective pedagogical approach. More broadly, the implementation of Augmented Reality (AR) in vocational education has proven to have a transformative impact across disciplines, as seen in simulations of automotive engine components [12] and TV studio equipment [13], where marker-based tracking features facilitate practical training without physical tools. This consistency reinforces AREFI's position as part of a solution-oriented trend in technical education.

AREFI's success lies not only in its technology but also in the interactivity it offers, aligning with AR's effectiveness in other contexts such as Sundanese script learning (93.6%) ease of use [14] and optional prayers [15]. This principle of interactivity is supported by research [16] showing 97% positive responses from teachers toward AR-integrated LKPD, as well as a study on the perceptions of Indonesian-Malaysian students [17] confirming readiness for AR implementation in abstract material (≥50% agreed).

A. Consistency with Augmented Reality-Based Media and Android

The effectiveness of AREFI in visualizing abstract objects and improving understanding is consistent with research by[18], [19]. Their study demonstrates that the implementation of Augmented Reality (AR) in science lessons at elementary schools results in significant differences in learning outcomes, with classes using AR achieving a higher average score (85.2) compared to classes using conventional media (77.6). This reinforces the argument that AR's ability to project virtual objects into the real world is a key advantage that facilitates understanding.

Additionally, the selection of the Android platform as the basis for AREFI has proven to be an appropriate choice. Research by Nasution [20]on the development of Android-based learning media for Engine Management System (EMS) material for vocational high school students also showed significant differences in learning outcomes between the experimental and control groups, with a t-test significance level of $0.000 < 0.05$. Similar findings were reported by, who stated that Android-based media on direct current electrical circuit material is highly suitable for use and effective in improving learning outcomes with an N-Gain of 0.62 (moderate category) [21]. Both of these studies, which are also in the technical and vocational fields, reinforce that the Android platform is highly effective for presenting complex and procedural material.

B. The Role of Interactivity and Student Engagement

The success of AREFI is not only due to its technology but also the interactivity it offers. This principle is supported by research Bashri [16] on the use of interactive WORDWALL media. The study concluded that there is a significant effect of using WORDWALL on student learning outcomes in Islamic Education, with a significance value of 0.000 < 0.05. Similarly, research by Pratiwi [22] that developed a monopoly-based application showed that this media is very valid and practical for increasing student engagement. These findings indicate that media that can actively engage students, either through gamification or direct interaction as in AREFI, tends to produce better learning outcomes.

C. The Influence of Visual Media and Learning Motivation

In general, the use of learning media, especially visual-based media, has been proven to have a positive influence on learning outcomes. Research by Safitri [23] found that learning media in general has a positive and significant influence on learning outcomes in Basic Electricity and Electronics, contributing 26.9%. Furthermore, Govindarajan [24] found that video media and learning motivation together have a significant effect on student learning outcomes. This is relevant to AREFI, which not only presents 3D visualizations but also has the potential to increase student learning motivation by presenting difficult material in a new and engaging way.

Thus, the success of the AREFI application is not an anomaly. The findings of this study are firmly grounded in empirical evidence from various studies showing that interactive, visual, and modern technology-based learning media such as Augmented Reality and Android applications consistently improve student learning outcomes across various subjects and educational levels.

The infrastructure challenges faced by AREFI (such as the need for large storage space) are also universal obstacles in AR implementation, as identified in cross-contextual [17]. However, institutional support in the form of strategic planning such as the five-year AR development framework at Senior High School (SMA) Assa'adah [16] is key to sustaining AR-based solutions like AREFI.

D. Analyze the Potential and Challenges of AREFI

On the other hand, AR has challenges that are not easy to overcome, requiring teachers who are proficient in technology, high media development costs, freedom levels, misuse that needs to be controlled, data security issues, ethical issues, and unequal access, which are crucial focuses in implementing technology in education [25], [26], [27]. Therefore, interdisciplinary collaboration and joint efforts between educators, researchers, and technology developers are essential to ensure that technological innovations can be implemented appropriately and sustainably, thereby maximizing positive impacts for society at large. By focusing on foundational approaches, this will help manage user privacy when entering the virtual reality world [28], [29].

V. Conclusion

The development of AREFI media based on Augmented Reality has proven to be significantly effective in improving the learning outcomes of vocational high school students in Electronic Fuel Injection material. This success is demonstrated by a surge in average scores from 44.73 to 70.92, which is statistically significant ($F=90.217$; $p<0.05$). The effectiveness of AREFI stems from its ability to visualize abstract concepts into interactive 3D objects, consistent with findings from other studies on the advantages of AR. This media successfully enhances student engagement and facilitates a deeper understanding of the components and functioning of the complex EFI system, thereby serving as a relevant solution to enhance graduate competencies.

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