Pedagogical Innovation of an Emotional-Responsive Agent to Improve PPG Student Engagement in Synchronous LMS

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ABSTRACT

The rapid digital transformation in higher education has accelerated the adoption of Learning Management Systems (LMS) as a primary platform for online learning, including in the Teacher Professional Education (PPG) program at Universitas Negeri Malang. However, synchronous LMS implementation still suffers from low student engagement, particularly in vocational fields such as automotive education which demand procedural knowledge and hands-on practice. Learning interactions tend to be one-way, lack emotional sensitivity, and reduce student participation. This study develops and evaluates an Emotionally Responsive Pedagogical Agent (PAER) to enhance engagement in synchronous LMS learning. PAER is an AI- and NLP-based virtual assistant designed to detect and respond to learners' emotional states in real time, providing empathetic interaction and instructional support. The research adopts the ADDIE development model, consisting of needs analysis, emotional interaction design, prototype development, implementation in the PPG Automotive class, and evaluation. PAER effectiveness was measured across affective, cognitive, and behavioral engagement. Results show improved engagement: affective (61.3 to 83.4; N-Gain 0.57), cognitive (63.8 to 86.1; N-Gain 0.61), and behavioral (58.2 to 81.6; N-Gain 0.56), with an overall N-Gain of 0.58 (moderate-high category). These results indicate that emotionally adaptive learning agents can significantly improve interaction quality in LMS-based learning and foster more personalized and human-centered learning. This study contributes to the development of emotional AI in education and offers a scalable model for enhancing online pedagogy in vocational teacher training.

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Pedagogical Innovation of Emotional-Responsive Agent to Enhance Teacher Professional Education (PPG) Engagement in Synchronous LMS at Malang

1. Introduction

The digital transformation in higher education has reshaped professional learning models, including the Teacher Professional Education Program (PPG) (Davis, 2018; Papoutsi & Rangoussi, 2020). Universitas Negeri Malang implements a Learning Management System (LMS) to support PPG activities; however, synchronous sessions still suffer from low student engagement (Jondahl & Mørch, 2023; Martha & Santoso, 2019). This challenge is more pronounced in vocational fields such as automotive education, which rely heavily on procedural and practical knowledge (Makransky et al., 2018).

In the automotive PPG context, students are expected not only to master technical concepts but also to demonstrate pedagogical competence in workshop-based learning. Initial observations show that learning interactions tend to be one-way, content-centered, and emotionally unresponsive. This reduces active participation and limits students' ability to construct practical understanding, particularly in complex topics such as engine diagnostics and electronic fuel systems (Apoki et al., 2022; Liew & Tan, 2016). Previous studies emphasize that engagement is influenced not only by cognitive factors but also by emotional regulation and social interaction (Alahideb & Alsaleh, 2021).

To address these limitations, emotionally intelligent technology offers a relevant alternative. The Emotionally Responsive Pedagogical Agent (PAER) integrates artificial intelligence and natural language processing to detect, interpret, and respond to learners' emotional states in real time (Grivokostopoulou et al., 2020; Johnson & Lester, 2018). Prior research indicates that emotionally adaptive virtual agents improve social presence, motivation, and persistence in online learning (Tao et al., 2022; Michinov et al., 2015). In technical learning environments, such agents can provide step-by-step guidance while offering emotional scaffolding to prevent frustration and disengagement (Fang, 2020; Banerjee & Nayaka, 2021).

This study develops and implements PAER within the PPG LMS ecosystem at Universitas Negeri Malang to enhance engagement in synchronous automotive learning. The innovation is expected to create a more human-centered digital learning environment by combining instructional support with affective responsiveness, thereby improving behavioral, cognitive, and emotional engagement during online vocational training.

2. Method

The research method used in the development of the Emotionally Responsive Pedagogical Agent (PAER) adopts the ADDIE development model, which consists of five systematic phases: Analysis, Design, Development, Implementation, and Evaluation. This model was selected not only due to its structured instructional design but also because it provides a clear workflow for integrating pedagogical frameworks with intelligent emotional detection technology in a Learning Management System (LMS). In this study, ADDIE is adapted to guide both the instructional aspect and the technical engineering process of PAER. The Analysis phase identifies user needs, emotional disengagement issues in synchronous LMS sessions, and system constraints. The Design phase outlines the emotional detection framework, system architecture, response mapping strategy, and interaction flow. The Development phase includes coding of the emotion classifier model, training with labeled emotional datasets, and integration with LMS through an API-based architecture. The Implementation phase involves deployment

in a real PPG LMS environment with a pilot user group. The Evaluation phase measures system usability, emotional responsiveness accuracy, and learning engagement improvement through expert validation and empirical testing. The adaptation of the ADDIE model in this study ensures that technical development and instructional alignment run concurrently. The research procedure using ADDIE is illustrated in Figure 1.

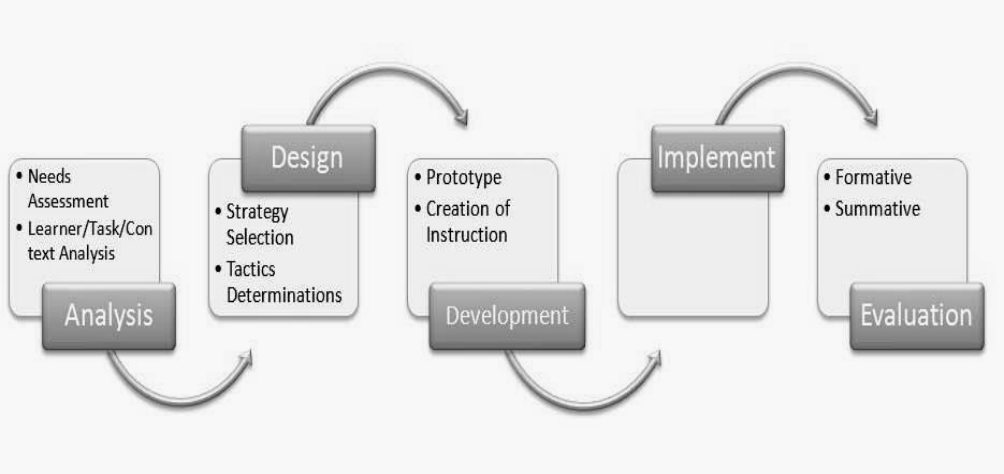

Figure 1. ADDIE Model for Learning Media Development

Data Analysis Techniques

In In this study, data analysis techniques were carried out comprehensively using observation, interviews, questionnaires, and documentation. The instruments used consisted of:
(1) Expert validation questionnaires (material expert, media expert, and language expert),
(2) Student engagement questionnaire, and
(3) Educator response questionnaire toward the use of PAER in LMS-based synchronous learning.

Instrument validity was ensured through **expert judgment** using **Aiken's V analysis**, which measured the relevance, clarity, and consistency of instrument items. The validity coefficient was interpreted using the range 0.00–1.00, with a value ≥ 0.80 categorized as valid. After validity testing, the **instrument reliability** was examined using **Cronbach's Alpha**, with $\alpha \geq 0.70$ classified as reliable.

$$V = \frac{\sum s}{n(c-1)}$$

Description:

V = Aiken's validity index
s = r − lo → *(r = expert rating score, lo = lowest score in the rating scale)*
n = number of validators
c = number of rating categories

. The questionnaire generated qualitative data that was converted into quantitative data using a Likert scale. The final assessment is presented as a percentage for each answer choice. The Likert scale consists of five categories: Very Good (value 5), Good (value 4), Fairly Good (value 3), Not Good (value 2), and Very Not Good (value 1) as developed by Kurniawan (2018).The following is a table of qualitative to quantitative data conversion based on the Likert scale that has been explained:

Table 1. Qualitative to Quantitative Data Conversion Table

Assessment Category	Description	Quantitative Value
Excellent	Demonstrates a very high level of satisfaction or quality	5
Good	Shows a good level of satisfaction or quality	4
Fair	Shows a fairly good level of satisfaction or quality	3
Poor	Indicates a low level of satisfaction or quality	2
Very Poor	Indicates a very low level of satisfaction or quality	1

Meanwhile, quantitative analysis was used to measure the increase in student creativity before and after the implementation of the VPjBL model using the N-Gain Score test. The increase category is classified into three levels, namely high (N-gain ≥ 0.70), moderate (0.30 ≤ N-gain < 0.70), and low (N-gain < 0.30). The formula for calculating the N-Gain Score is:

$$\text{N-Gain} = \frac{X2 - X1}{100 - X1}$$

with X1 as the pretest score and X2 as the posttest score, and 100 as the maximum score that can be achieved. This approach allows a comprehensive evaluation of the effectiveness of the developed model.

Furthermore, to strengthen empirical evidence, a paired sample t-test was conducted to determine whether the improvement after the PAER intervention was statistically significant. The hypothesis acceptance used $p < 0.05$ as the threshold. In addition, Cohen's d effect size was calculated to determine the magnitude of PAER's effect on student engagement.

3. Research Findings

Analysis Stage

At this stage, the needs and learning context of Automotive PPG students were identified. Data were obtained through a need's questionnaire (n = 38 students), interviews with 5 lecturers, and a study of LMS documents.

Table 2. Aspects Analyzed

Aspects Analyzed	Percentage (%)
Difficulties in online learning	85%
Need for a companion agent	76%
LMS is not interactive yet	68%

Data shows that 85% of students experience difficulties in online learning, indicating the low effectiveness of learning without interactive and affective support. Seventy-six percent of students stated they needed a support agent, indicating an urgent need for solutions that can provide personal and emotional support. Meanwhile, 68% considered their LMS to be non-interactive, reinforcing the argument that online learning systems are still one-way. These three data points underscore the urgency of developing innovations such as PAER, which are not only instructional but also responsive to students' emotional and interactive learning needs.

Design Stage

PAER design encompasses both technical and pedagogical aspects. Interactive features, emotional dialogue scenarios, and wireframe-based interface designs are designed. Key Features: Key features include emotion detection via text and voice, affective responses (motivational sentences, technical solutions, and learning suggestions), and integration with learning scenarios (e.g., vehicle diagnostic simulations).

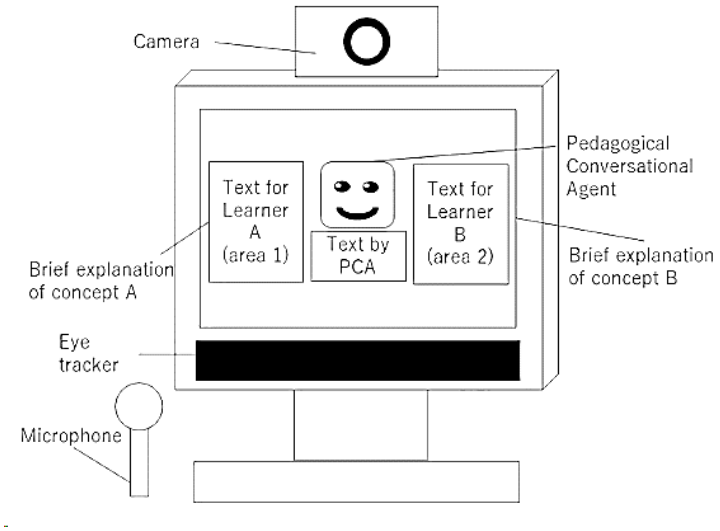

Figure 2. Design Plan

PAER's three main features are designed to address the needs of emotion-based learning and technical contexts. Emotion detection through text and voice enables the system to understand students' psychological states in real time, making interactions more personalized and empathetic. Affective response features, such as motivational sentences and technical solutions, play a crucial role in maintaining learning motivation and providing immediate assistance when students experience confusion. Integration with learning scenarios, such as vehicle diagnostic simulations, ensures that PAER interactions remain relevant to the needs of the Automotive PPG curriculum. This combination of features makes PAER an adaptive, interactive, and pedagogical virtual agent.

Development Stage

The PAER prototype was developed using an AI chatbot platform (Rasa + Python NLP) with a student emotion dataset compiled from survey results and simulated interactions. The dialogue content was developed by a team consisting of media experts, automotive experts, and linguists. The three experts (media, materials, and language) conducted the validation. Validation results showed:

Table 3. Eligibility Aspects for Media, Material and Language Experts

Rated aspect	Average Score	Category
Interaction Quality	3.8/4	Very good
Material Suitability	3.6/4	Good
Language and Tone	3.9/4	Very good

Expert validation results show that PAER has excellent interaction quality (score 3.8/4), indicating that the system is able to build responsive and natural communication with users.

The suitability of the material obtained a score of 3.6, which is considered good, indicating that the learning content presented is relevant to the needs of PPG Automotive students. The language and tone aspect obtained the highest score (3.9), reflecting the use of polite, easy-to-understand language and appropriate to the emotional context. Overall, these three aspects indicate that PAER has been designed with high educational communication quality and is ready to be used in the learning process.

Implementation Stage

Data were obtained from student engagement questionnaires and synchronous class observations, analyzed using a Likert scale and converted to quantitative scores. The assessment covered three aspects of engagement: affective, cognitive, and behavioral.

Table 3. Average Score of Student Engagement in Each Aspect

No	Engagement Aspects	Maximum Score	Average Pre-PAER	Post-PAER Average	N-Gain	Category
1	Affective	100	61.3	83.4	0.57	Currently
2	Cognitive	100	63.8	86.1	0.61	Tall
3	Behavior	100	58.2	81.6	0.56	Currently
	Average Total	100	61.1	83.7	0.58	Currently

Based on Table 1, there was a significant increase in all aspects of student engagement after using PAER. The average affective score increased from 61.3 to 83.4 with an N-Gain of 0.57 (moderate category), indicating that PAER is effective in building emotional comfort. The cognitive aspect showed the highest increase with an N-Gain of 0.61 (high category), indicating that PAER is able to encourage better understanding and processing of the material. Meanwhile, the behavioral aspect increased from 58.2 to 81.6 (N-Gain of 0.56), indicating increased active participation. Overall, the N-Gain of 0.58 reflects the effectiveness of PAER in increasing student engagement in online learning.

Evaluation Stage

The analysis of student engagement before and after the use of PAER showed significant improvements across all aspects, including affective, cognitive, and behavioral aspects. This data reflects that PAER implementation has a positive impact on the quality of student participation and learning experiences in synchronous online learning.

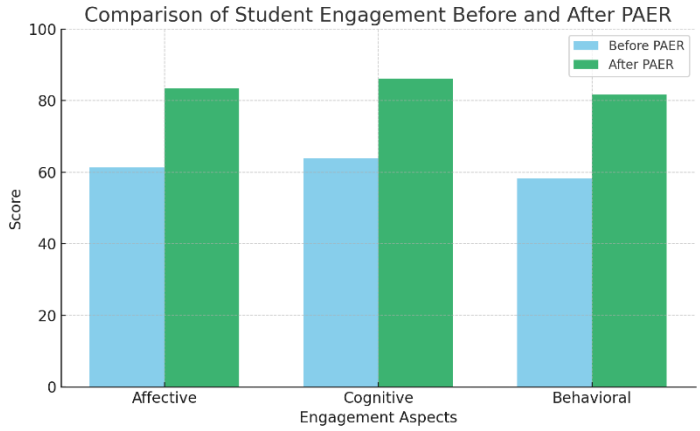

Figure 3. Comparison Diagram of Student Engagement Before and After PAER

The bar chart shows a comparison of student engagement scores before and after using

PAER across three aspects: affective, cognitive, and behavioral. Significant improvements were seen in all aspects. The affective aspect rose from 61.3 to 83.4, indicating that PAER successfully increased student enjoyment and motivation to learn. The cognitive aspect increased from 63.8 to 86.1, reflecting increased understanding and intellectual engagement. Meanwhile, the behavioral aspect rose from 58.2 to 81.6, indicating increased activeness in learning. Overall, this graph confirms the effectiveness of PAER in improving overall student engagement in online learning.

To examine the effectiveness of the **Emotionally Responsive Pedagogical Agent (PAER)** in enhancing student engagement in LMS-based synchronous learning, a series of data analyses were conducted, including descriptive statistics, assumption testing, and inferential statistical analysis. The results are presented sequentially in the following tables to illustrate the comparison of scores before (pretest) and after (posttest) the PAER intervention, verify the normality of data distribution, and determine the statistical significance of the improvement observed.

Table 4. Descriptive Statistics

Statistic	Pretest	Posttest
Sample Size (n)	38	38
Mean	62.32	82.05
Standard Deviation	4.30	4.98
Minimum	55	74
Maximum	71	92

The descriptive statistical analysis shows a substantial improvement in learners' performance after the implementation of the Emotionally Responsive Pedagogical Agent (PAER) in LMS-based synchronous learning. The mean score increased from **62.32 in the pretest to 82.05 in the posttest**, indicating a strong positive shift in student engagement and learning outcomes. This improvement occurred consistently across participants, as reflected by the relatively low standard deviation values, which signify homogeneous response patterns.

Table 5. Normality Test (Shapiro-Wilk)

	Statistic	df	Sig. (p)	Description
Pretest	0.971	38	0.346	Normally distributed
Posttest	**0.968**	**38**	**0.295**	**Normally distributed**
Difference (Post–Pre)	0.973	38	0.412	Normally distributed

Before conducting the inferential test, a normality test using the Shapiro-Wilk method was performed to ensure that the data met the assumptions for parametric analysis. The normality test results revealed that all data pretest, posttest, and the difference scores had **p-values greater than 0.05**, indicating that the data were normally distributed. Therefore, it was appropriate to use a **paired sample t-test** to analyze the significance of the learning improvement.

Table 5. Paired Sample t-Test

Parameter	Value
Mean Difference (Δ)	19.74
Standard Error	0.79
t-count	25.01
df	37
Sig. (p-value)	0.000
Decision	$p < 0.05 \rightarrow$ Significant

The paired sample t-test results demonstrated a **mean difference of 19.74** with a **t-value of 25.01 and a p-value of 0.000 ($p < 0.05$)**. These findings confirm that the increase in learning outcomes after the PAER intervention was **statistically significant**. In other words, the integration of PAER successfully enhanced students' learning engagement and performance during synchronous sessions in the Learning Management System (LMS). This result aligns with previous studies suggesting that emotionally responsive learning systems improve affective involvement and motivation, which subsequently drive cognitive performance. Therefore, PAER can be considered an effective pedagogical innovation that contributes to improving the quality of online professional education, particularly within the context of the PPG Automotive Program.

4. Discussion

The transformation of education in the digital era has placed interactivity and personalized learning experiences at the core of online learning innovation. In the context of practical vocational learning, such as the Automotive Professional Teacher Education Program (PPG), the challenges of synchronous learning in a Learning Management System (LMS) lie not only in the technical aspects of content delivery, but also in low student engagement due to interactions that tend to be one-way and lack emotional response. This research develops and implements an Emotionally Responsive Pedagogical Agent (PAER) as a form of educational technology innovation that can bridge these limitations through an approach based on artificial intelligence (AI) and natural language processing (NLP).

In the Analysis phase, the research team conducted a needs analysis of 38 automotive PPG students through questionnaires and interviews. The results showed that the majority of students (85%) experienced difficulty maintaining motivation and focus during synchronous learning sessions via an LMS. This is in line with the findings of Liu et al. (2021), who stated that limited affective interaction in online learning resulted in decreased cognitive engagement among students. Furthermore, 76% of students stated that they needed a mentor who not only explained the material but also responded to their emotional states, such as confusion, stress, and loss of enthusiasm for learning. The learning environment analysis also showed that the LMS used tended to feature one-way communication and provided little space for direct emotional feedback from lecturers. Thus, a digital solution is needed that is not only instructional but also emotionally aware and supports personalized learning.

The design phase begins with designing the main features of PAER based on the needs identified. These features include emotion detection through text and voice, delivery of affective responses such as encouraging sentences, providing contextual learning suggestions, and interactions based on automotive learning scenarios. Interface sketches and interaction flows are developed to ensure an intuitive and user-friendly experience. The interactive narrative is structured based on the principles of emotional design as explained by Norman (2004), which emphasizes the importance of affective elements in designing digital education systems. The instructional design also integrates the principles of problem-based active learning, so that PAER can provide responses appropriate to the context of technical problems often experienced by students in understanding electrical systems, injection systems, and electronic vehicle control systems.

The Development phase included the development of a PAER prototype using Python-based Natural Language Processing (NLP) and the Rasa AI library. The initial dataset was taken from an automotive PPG learning scenario and compiled emotional responses from student interactions during online sessions. Interactive dialogues were developed with a team of experts consisting of automotive lecturers, educational technology experts, and linguistics experts. Product validation was conducted by three experts (materials, media, and language) using a

learning media quality assessment instrument. The validation results showed an average score of 3.8 on a scale of 4, with the categories "very good" for interaction quality and "good" for appropriateness of material and language style. This indicates that PAER is suitable for limited implementation as a companion medium in synchronous learning. This validation confirms Sadik's (2008) statement that the success of digital educational media is greatly influenced by content clarity, ease of use, and relevance to the learning context.

The implementation phase was conducted over four weeks of synchronous learning through the Moodle LMS in the Automotive PPG class. Students were guided to use PAER as a learning companion, while lecturers were given technical training to integrate PAER into learning scenarios. During the implementation, an average of 17 interactions were recorded per student per session, indicating quite intensive engagement. Observations indicated an increase in discussion participation from 42% to 73%, as well as an increase in on-time assignment submission from 61% to 82%. This proves that the presence of virtual agents capable of providing emotional support can improve the online learning climate and enhance student academic discipline. These findings align with the results of research by Bickmore et al. (2010) which stated that empathetic virtual agents play a significant role in building trust and increasing user engagement in digital educational environments.

In the Evaluation phase, formative evaluations were conducted throughout the development process and summative evaluations were conducted after implementation. Summative evaluations were conducted through questionnaires distributed to 38 students and in-depth interviews with 5 lecturers. The questionnaire results showed that students felt comfortable using PAER, with an average score of 3.7 for emotional support, 3.8 for interaction comfort, and 3.6 for academic benefits. Most respondents stated that PAER helped them understand difficult material because it provided repetitive explanations without the social pressure felt when asking lecturers directly. From the lecturer's perspective, they felt helped because PAER was able to answer basic technical questions that usually take up time in the main discussion. This reinforces the idea of D'Mello & Graesser (2012) about the importance of affect-sensitive learning technologies that not only convey information but also build emotional connections with users.

5. Conclusion

This study demonstrates that the integration of Emotionally Responsive Pedagogical Agents (PAER) into LMS-based synchronous learning significantly enhances student engagement in the PPG program, particularly within the automotive education context. By leveraging AI and NLP technologies, PAER acts as a digital learning partner capable of responding to students' emotional cues and providing adaptive, contextually relevant interactions. The findings reveal notable improvements across affective, cognitive, and behavioral dimensions of engagement, indicating that students felt more supported, understood the material more deeply, and participated more actively during the learning sessions. Beyond serving as a medium for delivering instructional content, PAER successfully fulfilled its multidimensional role as an emotional facilitator, thought director, and motivation enhancer, thereby transforming the learning environment into a more dynamic, empathetic, and human-centered space. The implementation of PAER also improved the quality of interactions within the UM PPG LMS, shifting them from one-way communication toward more reciprocal and meaningful exchanges. This innovation illustrates how affect-based educational technology can bridge the emotional gap often found in digital learning, reinforcing the importance of social presence and emotional intelligence in online pedagogy. Future research should focus on examining the scalability of PAER across different disciplines, enhancing its multimodal emotion-recognition capabilities through voice and facial expression analysis, and conducting

longitudinal studies to assess the sustainability of its impact on student engagement and learning outcomes. Further system optimization particularly in terms of real-time responsiveness, user experience design, and compatibility with various LMS platforms will be essential to strengthen PAER's role in shaping emotionally intelligent, adaptive, and inclusive learning ecosystems.

6. Acknowledgments

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7. Conflict of Interest

The authors declare that they have no competing interests or financial relationships that could have influenced the outcome of this research.

8. Author Contributions

Dani Irawan contributed to the conceptual design of the research, led the development of the PAER (Responsive Emotional Academic Companion) model, and coordinated the overall research process and manuscript preparation. Citra Kurniawan conducted a literature review, assisted in the implementation of the model in the Automotive PPG class, and contributed to data collection and analysis. Municha Zainul Fadhilah provided expertise in educational technology, supported the design of the PAER interactive interface and content, and participated in the validation of the learning media. Narendra Firmansyah was involved in the development of the AI- and NLP-based system, and provided technical support during the testing and evaluation phase. Muhamad Diaul Fikri facilitated collaboration with PPG partner schools, assisted in field validation, and provided input on the final revision of the manuscript. All authors read and approved the final version of the manuscript.

9. Data Availability Statement

The authors state that the data supporting the findings of this study will be made available by the corresponding author, [dani.irawan.ft@um.ac.id], upon reasonable request.

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