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AI and Recognition Technologies to Facilitate English as Foreign Language Writing for Supporting Personalization and Contextualization in Authentic Contexts

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Abstract

English as Foreign Language (EFL) writing is challenging for students due to the lack of related lexical resources to inspire them for meaningful writing besides grammar feedback. Moreover, it is crucial to design personalized feedback based on students' original writings in helping to improve their writing abilities. Therefore, we developed Smart RoamLingo app to help writing meaningful content in authentic contexts with sample sentences based on texts generated by recognition technologies named as AI-Sample Sentences (AI-SS) and writing qualities with revision suggestions based on

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personal original writings named as AI-Writing Feedback (AI-WF). 104 undergraduate students were assigned into an experimental group (EG) and two control groups. EG significantly outperformed the other groups in the post-test. In EG, AI-SS can help the contextualization to produce comprehensive content actively while AI-WF can help the personalization to improve the writing quality through several revisions. Hence, the cohesion and consistency of their writing can be enhanced. Further, the total number of revisions in practices and the assignment score can significantly predict the post-test. Moreover, EG students revealed that Smart RoamLingo was useful for EFL writing. Therefore, it is strongly suggested to use Smart RoamLingo with AI-SS and AI-WF for EFL writing in authentic contexts.

Keywords
EFL writing, recognition technologies, smart feedback, AI, authentic contexts

Introduction

The English language is essential for university students to prepare for entering the working environment. Commonly, English writing is the method to communicate and collaborate, that is, writing the technical documentation or reports, with the international community (Tatzl et al., 2012). Nonetheless, EFL writing is quite challenging besides speaking for non-native English university students (Hughes, 2011). In EFL writing, besides remembering the vocabulary, university students need to consider not only improving the local level like the grammar but also consider the global level like the content or logical connection in each sentence when writing (Liu et al., 2021).

Most studies of EFL writing usually used common mechanisms such as grammar checking to help writing by checking spelling and grammatical errors (Loncar et al., 2021). This is not enough, especially for students, and it will be more meaningful and helpful to connect with authentic contexts surrounding them to support writing resources like vocabulary and phrases, which is called contextualization. By doing contextualization, the students could get inspiration and have more ideas from their surroundings to improve their writing content (Nguyen et al., 2020). Moreover, if personal writing can be traced and analyzed, individual suggestions based on their original writing can help improve writing quality (Wang, 2020), which is called personalization.

Not many studies addressed the EFL writing related to authentic contexts (Loncar et al., 2021). The possible reason is that it is challenging to conduct EFL writing in authentic contexts with mobile devices (Nguyen et al., 2020) and it is not easy to design learning activities with suitable supports when students are in very diversified contexts. The studies were conducted to help EFL speaking in authentic contexts by implementing recognition technologies with mobile devices, such as Speech-to-Texts

Recognition (STR) and Image-to-Text Recognition (ITR) (Shadiev et al., 2018; Shadiev, Wu, et al., 2020). STR is to recognize their voice for practicing English speaking (Shadiev et al., 2018). ITR is to recognize the photos from their surroundings and then retrieve related vocabulary (Shadiev, Zhang, et al., 2020). Therefore, it offers a great opportunity to bring the advantages of recognition-to-texts technologies not only for EFL speaking but also for EFL writing since it can connect authentic contexts well to support the contextualization.

Recently, with the fast development of artificial intelligence (AI), particularly Natural Language Processing (NLP), smart mechanisms with NLP have been adopted to facilitate learning (Chen et al., 2020; Du et al., 2021; Yang et al., 2022). For example, Gayed et al. (2022) who used NLP in EFL writing showed that generative-AI algorithms could predict new words based on the previous content. In an online learning community, Du et al. (2021) showed that generative-AI such as the GPT-2 model can help students to interact with the community by providing them with text generation. Besides, NLP can also be used to organize forum post by classifying relevant and irrelevant posts to seek students' participation patterns (Yang et al., 2022). In addition, the generative-AI not only can enhance the grammar like a common grammar checker but also have potentials to help reorganize and rewrite the sentences by giving suggestions (Rees, 2022).

Therefore, recognition-to-text technologies and generative-AI can be integrated together to provide smart mechanisms for facilitating EFL writing in the aspects of personalization and contextualization. For instance, the smart mechanism, writing feedback can be implemented by evaluating students' writing and giving personalized suggestions to improve writing quality (AI-WF); and, another smart mechanism using AI can be implemented by providing sample sentences based on the texts generated by recognition technologies in authentic contexts (AI-SS).

The covid-19 pandemic situation shaped students' learning ways (Tsao, 2021). Sometimes they cannot learn at school, they usually learn online or do practices or assignments at their home (Reynolds et al., 2020). This situation gives an opportunity for students to explore and learn from authentic contexts surrounding them at home and nearby, which could connect EFL knowledge and inspire them to apply writing to their daily life (Nguyen et al., 2020). Furthermore, it is quite promising to integrate the recognition technologies in authentic contexts with AI, thereby improving writing contents and qualities by offering sample sentences related to contexts and personalized feedback. Hence, in this study, we developed an innovative app called "Smart RoamLingo" to facilitate the EFL writing with recognition-to-texts technologies like ITR and STR, and smart mechanisms in authentic contexts. The ITR, STR, and the smart mechanisms could inspire students with generated sample sentences to connect the authentic contexts. The smart mechanisms could also provide the students with personalized writing feedback that is different from grammar checking. In addition, the STR could make them write easily with their speech. Two learning activities, practice and assignment activities, were designed to help EFL writing in authentic contexts

using the developed app. Based on the aforementioned, the research questions in this study are as follows:

1. What are the differences in the learning achievement among the three groups, the experimental group (EG) with two recognition technologies (i.e., ITR and STR) and AI support (i.e., AI-SS and AI-WF), the control group one (CG1) with two recognition technologies (i.e., ITR and STR), and the control group two (CG2) with one recognition technology only (i.e., STR)?
2. What are the correlations of the learning behaviors in the practice and assignment activities with the learning achievement of EG and the influence of learning behaviors in both practice and assignment activities on learning achievement?
3. What are the affordances of AI and its limitations in EFL writing?
4. What are the students' perceptions towards the proposed RoamLingo?

Literature Review

EFL Writing for University Students in Authentic Contexts

The university students could learn EFL writing well in authentic contexts (Nguyen et al., 2020). For example, they can clearly write a descriptive or narrative English essay about the scenario that they would like to introduce when they immerse themselves in authentic contexts. Hence, it is an opportunity to facilitate the non-native English speakers, particularly university students, to learn EFL writing when they explore authentic contexts by themselves (Liu et al., 2021). However, the students usually faced difficulty to write in authentic contexts if they did not have enough lexical resources like vocabulary or phrases related to authentic contexts (Hwang et al., 2014; Nguyen et al., 2020). Moreover, the studies suggested utilizing the scaffolding to help EFL writing content and organization of university students because they usually had difficulty to write meaningful content and organize their writing without any support (Cheng & Zhang, 2021; Xu & Xia, 2021). Therefore, the university students needed more support like related lexical resources and individual feedback to enhance their EFL writing in authentic contexts (Nguyen et al., 2020). Nguyen et al. (2020) used recognition technology to recognize their surroundings and provide the lexical resources to help students to write meaningful content. The study in EFL writing that used AI algorithms can predict new words based on students' original and previous writing and provide them with feedback suggestions for their next writing (Gayed et al., 2022). The university students can improve writing through practice writing and revising the writing from the automated feedback suggestions (Coyle et al., 2020). Therefore, it is promising to use the recognition technologies and AI together to help EFL writing for university students in authentic contexts.

Regarding the criteria to evaluate the writing quality, several studies have been done to measure the writing quality of university students (Lin et al., 2020; Nguyen et al., 2020).

They used similar dimensions to evaluate the writing quality such as the content, organization, grammar and vocabulary, and cohesion and consistency. The content refers to the detailed writing and it addresses the topic effectively. The organization refers to the organization of the sentences based on the section. Grammar and vocabulary refers to the accumulation of corrected grammar and displays the variety of use of the appropriate word or idiomatic. Lastly, cohesion and consistency refers to displaying unity and coherence with clear connections in each sentence.

Recognition Technology-Supported EFL Writing

The previous studies reviewed that several recognition technologies can be applied to assist EFL learning and identify students' behaviors (Hwang et al., 2022; Shadiev, Wu, et al., 2020). One example of technology to assist EFL speaking is STR that can transcribe texts from students' speech input (Shadiev et al., 2018). It can also be used to help evaluate students' pronunciation (Dai & Wu, 2021). In addition, STR can enhance the learning performance of EFL learners during English lectures (Hwang et al., 2022; Shadiev et al., 2017). The other is ITR, which can also be used to facilitate EFL learning. A study showed that students who used ITR in EFL learning felt motivated because they can easily remember and understand English vocabulary related to their surroundings (Nguyen et al., 2020). The use of recognition technologies enhanced not only students' learning achievement but also students' learning motivation in EFL learning (Hwang et al., 2022; Nguyen et al., 2020; Shadiev et al., 2017). However, most of the studies focused on the implementation of these recognition technologies for EFL listening and speaking and only few focused on for EFL writing using these recognition technologies (Hwang et al., 2022).

Cloud services provides recognition technologies and becomes more mature, accurate, and easy to integrate with mobile phones, such as ITR services from Microsoft Azure (Nguyen et al., 2020) or STR from Google Cloud (Liu et al., 2021). Therefore, it is worth bringing two recognition technologies, ITR and STR, into the mobile devices with cloud services to assist not only EFL speaking but also EFL writing (Hwang et al., 2022).

Smart EFL Learning in Authentic Contexts

The smart learning environment proposed by Kim et al. (2013) mentioned that the learning environment could be SMART, an acronym for self-directed, motivated, adaptive, resource-enriched, and technology embedded. Thus, the smart learning environment could connect with the authentic contexts to enrich the lexical resources and motivate students' imagination to help learning, which refers to contextualization (Nguyen et al., 2020). In addition, it accommodates self-directed and adaptive learning that makes learning more effective when personalized guidance and feedback can be provided based on individual learning status, which refers to personalization

(Wang, 2020). In traditional EFL learning environment, students usually learn English from the textbook without any related authentic contextual support (Zhang et al., 2019).

The authentic context is important for EFL writing because students can get inspiration from the context (Liu et al., 2021; Zhang et al., 2019). They can go anywhere to find suitable authentic contexts related to the topics of EFL writing and then use recognition technology, that is, ITR to retrieve vocabulary related to the authentic contexts to help their writing. However, the advantages of ITR only provide students with texts (e.g., vocabulary and phrases) without any further support like a sentence making based on ITR generated texts (Shadiev, Zhang, et al., 2020). Based on the ITR texts generated from the taken photos from the real world, generating sample sentences can be realized using generative-AI. It is very useful for EFL writing individually. This is because ITR generated texts are based on individual photo taking and its generated sample sentences could match individual needs, which are usually very different from the common sample sentences given by teachers for all students in traditional teaching. Therefore, sample sentences based on ITR generated texts from individual photos can help EFL writing in contextualization.

Furthermore, several studies had accommodated learning needs with AI support to fulfill personalization (Hwang et al., 2020; Lin et al., 2020; Zhang & Aslan, 2021). For example, Loncar et al. (2021) used grammar checking as personalized feedback to help EFL writing. However, it can only correct the local level, such as grammar and spelling. In contrast, university students need more advanced feedback to evaluate the global level, such as providing suggestions regarding the content and cohesion of EFL writing (Liu et al., 2021). The advanced personalized writing feedback can be achieved by utilizing the generative-AI to analyze students' writing and then help to improve the writing content (Rees, 2022). Hence, the students received the writing suggestions from the AI based on their original writing. Afterwards, they can repeatedly revise their writing based on personalized feedback and their writing quality can be enhanced (Liu et al., 2017).

Smart RoamLingo and Its Implementation in EFL Writing

Smart Mechanisms in Contextualization and Personalization

This study proposed a Smart EFL writing environment with AI and recognition technologies to support contextualization and personalization in authentic contexts, as shown in Figure 1. In the beginning, the students take photos related to writing topics in their surroundings and use ITR to get the texts like vocabulary or phrases. Afterward, they can also edit the ITR generated texts to ensure they are useful for their writing or use STR to generate more other texts for their writing. Furthermore, the ITR generated texts are further used as prompt input to generative-AI for generating AI-SS. As a result, the lexical resources by ITR and the content of AI-SS can be strongly connected with the authentic contexts surrounding students and inspire them to write more comprehensive contents related to the topics. Moreover, the students can also contextualize

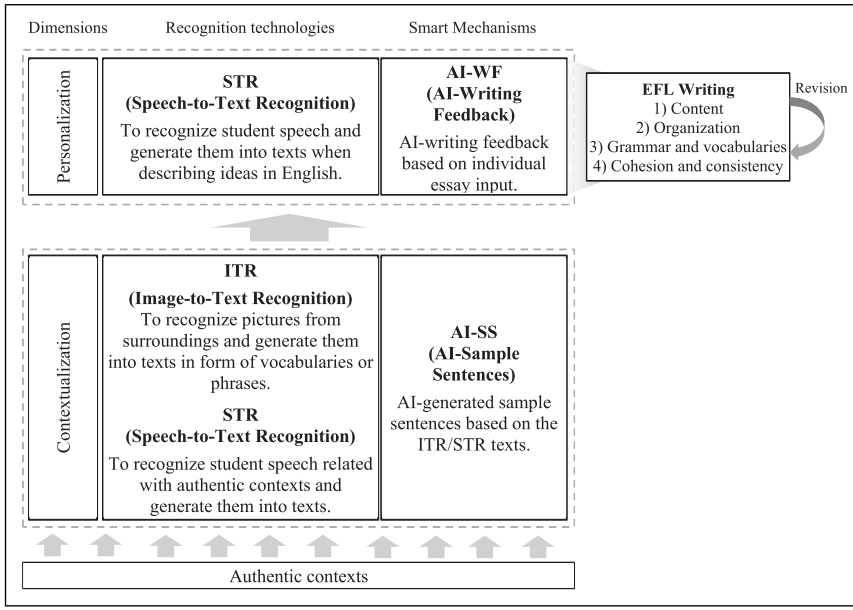


Figure 1. Smart EFL writing environment.

their essays to connect with the authentic contexts through smart contextualization mechanisms provided by ITR and AI-SS.

Thereafter, students can write their first draft by following the writing scaffolding with hand typing or with STR to input. The personalized feedback from AI-WF will be given to the students after their first draft is completed and submitted. The students can submit their writing to AI-WF several times as they want after several revisions and then get different feedback from AI-WF to help them to improve their writing quality. Thus, students can repeatedly revise their writing through smart personalization mechanisms with AI-WF as they need and improve their writing qualities.

Smart RoamLingo

We used generative-AI with a pre-trained language GPT-3 model from OpenAI (Brown et al., 2020) to provide the next level of generating texts and writing feedback. We proposed generative AI and two recognition technologies (i.e., STR and ITR) for supporting contextualization and personalization and developed a mobile app Smart RoamLingo for EFL writing in authentic contexts.

The learning activities, except questionnaires, required students to write essays. To write an essay, the students need to complete four steps (Figure 2). Firstly, the students explore their surroundings and take the authentic images according to the essay topic. ITR will produce lexical resources such as vocabulary and phrases for them. Then, they

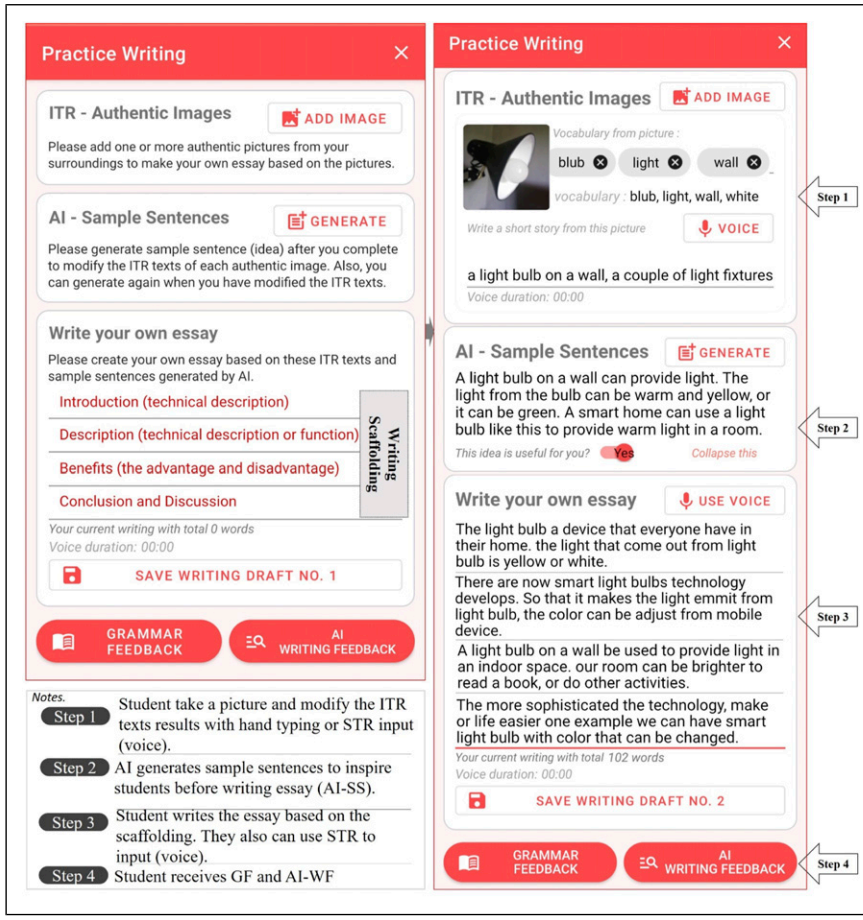


Figure 2. Four steps to write an essay using Smart RoamLingo.

could modify the vocabulary and phrases with hand typing or speech input. Secondly, to inspire them to write the essay drafts, the students can press the generate button in Figure 2 to show the sample sentences that are generated using AI-SS.

Thirdly, the students then write their first draft by following writing scaffoldings (i.e., introduction section for the definition of technology, description section for the detailed function of technology, benefits section for advantage or disadvantage of technology, and conclusion and discussion section). The essay can be written with hand typing keyboard or speech input. Lastly, the students will receive GF and AI-WF. In figure 3, we demonstrate examples of GF and AI-WF to show the powerful feedback provided by AI for personalization. GF is to check a grammatical error on each word without changing the sentence structures (Figure 3(a)). AI-WF will correct the

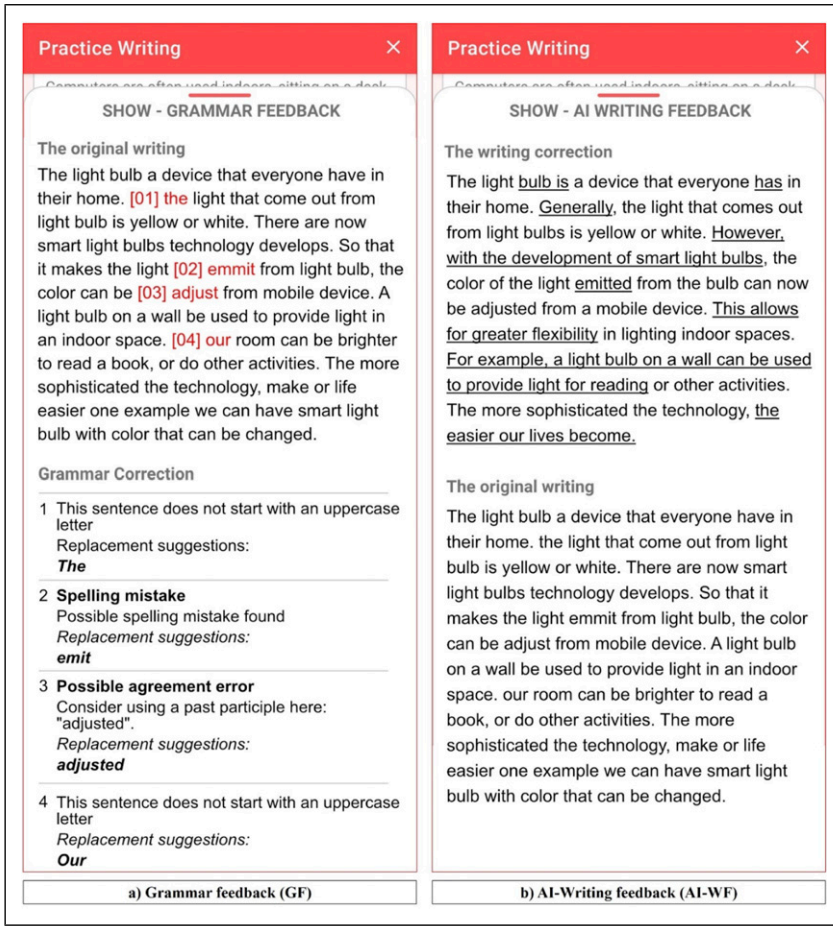


Figure 3. An example of GF and AI-WF.

grammatical errors and add the sentence connections in the essay draft (Figure 3(b)). The students need to follow the four steps in order to guarantee completing their essay based on their taken pictures and generated sample sentences.

Method

Participants

Three classes of the total of 104 second-year Indonesian university students majoring in informatics participated in this quasi-experimental design. They enrolled in the mandatory course, English for Engineering. One class assigned to an experimental

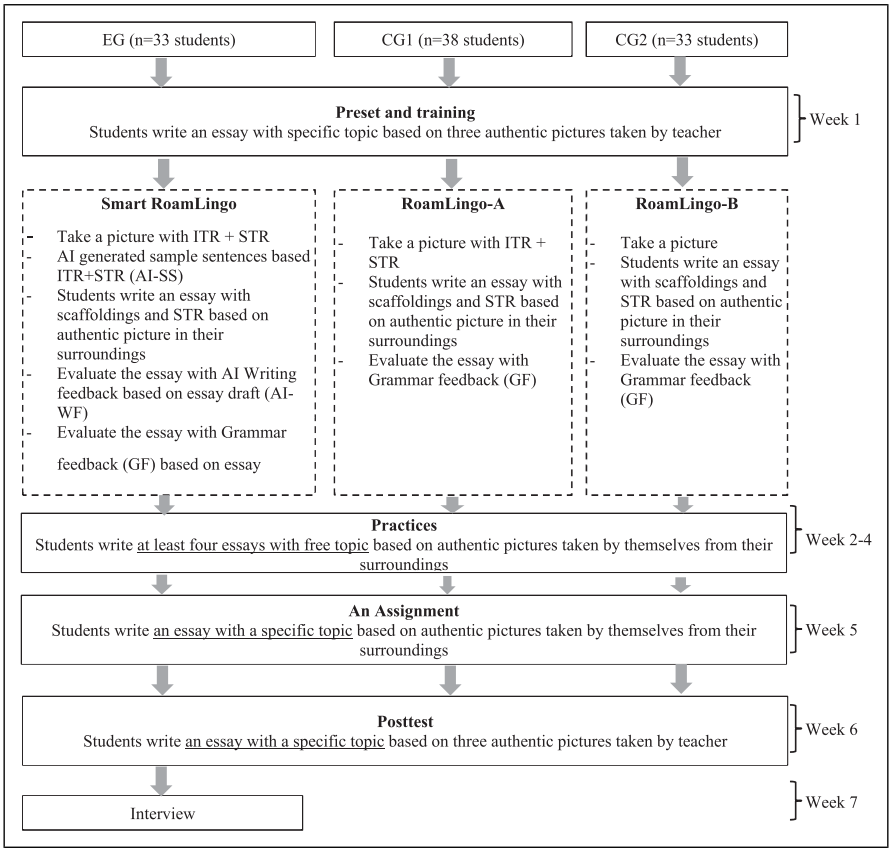


Figure 4. Research procedure.

group (EG) with Smart RoamLingo ($n = 33$), the other two classes assigned to a control group 1(CG1) with RoamLingo-A ($n = 38$), and a control group 2 (CG2) with RoamLingo-B ($n = 33$). Therefore, the three groups of the students used different versions of RoamLingo app with different functions. Smart RoamLingo used by EG was fully equipped with ITR, STR, and AI-support to provide students with AI-SS and AI-WF. RoamLingo-A used by CG1 was equipped with ITR and STR without AI support. Meanwhile, RoamLingo-B used by CG2 was equipped with STR only without AI support. The students were taught by the same English lecturer and had regular online meetings with the lecturer once a week. They were required to write essays to describe the learning topic (i.e., hardware and software objects/specific topic) surrounding them.

Experimental Procedure and Activity Design

This study was conducted online within 7 weeks (Figure 4) due to the covid-19 pandemic situations. In the first week, the students completed a pre-test for an hour.

Afterwards, the lecturer and researchers trained them to use the apps. From the second week to the fourth week, they practiced their essay individually. They had freedom to choose the topic with a minimum of four essays for the submissions. In the fifth week, they then completed the learning assignment with a specific topic by submitting one essay. In the sixth week, the students were asked to finish the post-test for an hour. Finally, the researchers randomly chose 20 students of EG to complete a semi-structured interview.

Research Variables, Instruments, and Data Collections

Two research variables namely, learning achievements and learning behaviors were investigated in this study. The learning achievements were collected based on a pre-test and a post-test. The pre-test and post-test has a similar mechanism to the test instrument of (Nguyen et al., 2020) namely, the teacher will provide the students with four authentic photos that related to the topic and ask them to write an essay by the following rules:

1. Please provide vocabulary that could describe the first photo.
2. Please create a description from the vocabulary that you obtained in the first photo.
3. Please create an essay based on the three last photos.

The learning behaviors included the learning behaviors of students in the practice activity and the learning behaviors of students in the assignment activity. The learning behaviors were collected using the apps. The learning behaviors consist of a total number of used ITR, STR, AI-SS, AI-WF, and GF, a total number of revisions and photos, a total number of practices, and a total score of assignments.

The students' essays in the pre-test, post-test and assignment were evaluated by three experienced raters based on four dimensions including content, organization, grammar and vocabulary, and cohesion and consistency. The essays were scored using a writing scoring rubric adopted from TOEFL independent writing rubric (ETS, 2019) and the rubric has also been confirmed by an EFL teacher with 10 years of teaching experience. Each dimension scored between 1 and 5 points (see Appendix 1). The inter-rater reliability of the pre-test was 0.890, the post-test was 0.873, and the assignment was 0.799, which indicated the two raters reached acceptable levels of agreement. Twenty of EG students were randomly chosen to complete a semi-structured interview that consisted of 10 questions (Appendix 3). The interview lasted 10–20 min using an online way. It was recorded and transcribed for data analysis.

Table 1. The Scheme of Data Analysis.

RQ	Data analysis
RQ1. The differences in the learning achievement among the three groups	1. ANOVA to know the difference of the pre-test among the groups 2. ANCOVA to know the difference of the post-test among the groups with the pre-test score as covariate
RQ2. The correlation of the learning behaviors in the practice and assignment activities with the learning achievement of EG and the influence of learning behaviors in both practice and assignment activities on learning achievement	3. Pearson correlation to know the correlation of the learning behaviors in the practice and assignment activities with the learning achievement of EG. 4. Stepwise multiple linear regression to know the most influential variables of the learning behaviors in both practice and assignment activities on learning achievement
RQ3. The affordances and limitations of writing feedback for EFL writing	5. Embeddings with OpenAI to weight the similarity of the students' writing 6. The elbow method to determine the number of K for K-means clustering 7. K-means clustering based on the similarity of students' writing in four clusters 8. OpenAI to summarize the essay themes of each cluster 9. Measure of textual lexical diversity (MTLD) analysis to measure the writing quality 10. T-unit analysis to measure the syntactic complexity of the writing
RQ4. The students' perceptions towards the proposed RoamLingo	11. Thematic analysis technique to define each theme of the interviews' results

Data Analysis

This study adopted a mix-method analysis. The scheme of data analysis in this study is shown in Table 1. In the quantitative analysis, this study was conducted ANOVA analysis to compare the learning differences among the three groups in the pre-test and ANCOVA analysis to compare the learning differences among the groups in the post-test. The score for the pre-test (Table 2) and the post-test (Table 3) in learning achievement were summed up scores from two professional raters. In addition, Pearson correlation analysis was used to analyze the correlation between the learning behaviors of EG in the practice and assignment activities and the learning achievements.

Furthermore, a stepwise multiple linear regression was used to find out the learning predictor of learning achievements. In the qualitative analysis, the essay similarities of the EG were processed with embedded OpenAI. Then, K-means clustering analysis was further conducted to divide the EG into four clusters based on their essay similarities. The Elbow method was used to determine the optimal number of the clusters

Table 2. The ANOVA Analysis Results of the Pretest Among Groups.

Dimensions	Group	*N*	Mean	*SD*	Std. Error	*F*	*p*
Content	EG	33	3.667	1.652	.265	2.001	.141
	CG1	38	3.789	1.379	.247		
	CG2	33	4.364	1.537	.265		
Organization	EG	33	3.576	1.678	.273	.422	.657
	CG1	38	3.842	1.461	.254		
	CG2	33	3.909	1.568	.273		
Grammar and vocabulary	EG	33	3.606	1.599	.265	1.192	.308
	CG1	38	3.947	1.374	.247		
	CG2	33	4.182	1.609	.265		
Cohesion and consistency	EG	33	3.576	1.620	.281	1.765	.176
	CG1	38	3.632	1.496	.262		
	CG2	33	4.242	1.732	.281		
Total score	EG	33	14.424	6.339	1.044	1.226	.298
	CG1	38	15.210	5.473	.973		
	CG2	33	16.697	6.222	1.044		

for K-means clustering (Dangeti, 2017). Furthermore, an analysis using generative-AI was used to summarize the essay themes of the clusters (OpenAI, 2021). The essay writing quality was analyzed using the Measure of Textual Lexical Diversity (MTLD) analysis (Riazi, 2016) and the syntactic complexity of writing was analyzed using a T-unit analysis (Kyle, 2016; Lu, 2010). Regarding the analysis and coding of the interview content in this study, we used thematic analysis techniques based on the study of (Liu et al., 2022). In this study, we also used INV to define the name of each coding theme from the interview responses of EG.

Result and Discussion

Learning Achievement of EFL Writing among Groups

Table 2 shows no significant differences among the three groups in the pre-test, which indicated that the groups were not significantly different regarding the writing ability in each dimension. The ANCOVA analysis (Table 3) shows significant differences among the groups on each dimension in the post-test. Regarding the post-hoc, the total score of the post-test of EG was significantly superior to that of CG1 and CG2. A plausible reason was that the EG students were provided with AI support to help their essay writing and the other groups did not have AI support. In addition, the content ($\eta^2 = .158$) and the cohesion and consistency ($\eta^2 = .189$) reached the highest Eta Square in the post-test, which indicated that these two dimensions had large effect sizes. Smart-RoamLingo provided EG students not only with GF but also with AI-WF that could improve their writing ability, particularly in cohesion and consistency. The use of AI-WF encouraged students to improve their essay quality by making good

Table 3. The ANCOVA With Post Hoc Analysis Results of the Posttest Among Groups.

Dimensions	Group	*N*	Mean	*SD*	Adj. Mean	Std. Error	*F*	η^2	Post-hoc
Content	EG	33	7.636	2.088	7.792	.335	9.364***	.158	EG > CG1**
	CG1	38	5.894	2.010	5.979	.311			EG > CG2**
	CG2	33	6.363	2.219	6.111	.338			
Organization	EG	33	7.666	2.041	7.796	.370	4.214*	.078	EG > CG2*
	CG1	38	6.631	2.572	6.591	.344			
	CG2	33	6.484	2.320	6.402	.370			
Grammar and vocabulary	EG	33	7.636	1.782	7.838	.343	6.223**	.111	EG > CG1*
	CG1	38	6.447	2.309	6.425	.318			EG > CG2*
	CG2	33	6.484	2.412	6.308	.343			
Cohesion and consistency	EG	33	7.939	1.886	8.083	.351	11.652***	.189	EG > CG1***
	CG1	38	5.947	2.229	6.057	.326			EG > CG2**
	CG2	33	6.272	2.540	6.003	.354			
Total score	EG	33	30.818	7.621	31.504	1.337	8.250***	.142	EG > CG1**
	CG1	38	24.921	8.893	25.072	1.240			EG > CG2**
	CG2	33	25.606	9.249	24.747	1.340			

Notes. *$p < .05$. **$p < .01$. ***$p < .001$.

connections between sentences. Besides, the EG students also used ITR-generated vocabulary and AI-SS which could help them create more writing content with consistent vocabulary in their essays. Hence, the EG students benefited from these smart mechanisms to help them learn EFL writing.

However, the dimension of the organization reached the lowest score of Eta Square (η^2 =.078). Although the writing organization of each group has a significant difference (F = 4.214, $p < .05$), the three groups almost had similar size effects in the post-test. A possible explanation for this might be that the students in the groups used the same writing scaffoldings to organize their essays while writing (Cheng & Zhang, 2021; Xu & Xia, 2021)

The Relationships between the Learning Behaviors and Learning Achievements of Experimental Group

In terms of contextualization, Table 4 shows that there was a significant correlation between the total use of AI-SS in the practice activity and the total post-test score (r = .346, p = .049), particularly regarding to the content (r = .360, p = .039) and organization (r = .346, p = .048) of the essay writing. A similar correlation was also found between the total use of AI-SS in the assignment activity and the total post-test score (r = .373, p = .032), particularly regarding to the content (r = .369, p = .034) and organization (r = .389, p = .025) of the essay writing (Table 5). These findings indicated that AI-SS can inspire students to write their essays. The students can learn from the sample sentences provided by AI-SS to write more detailed content and connect the content with their authentic pictures. By learning the

sample sentences, the students also can learn to organize their sentences in a correct essay structure including introduction, description, benefit, discussion, and conclusion sections.

Furthermore, the total use of ITR in the practice activity significantly correlated with the total post-test score (r = .374, p = .032) and the total use of ITR in the assignment activity significantly correlated with the total post-test score (r = .348, p = .047).

These results seem to be consistent with other research which found that providing vocabulary generated by ITR for students can help them to enrich their writing content (Hwang et al., 2020). Surprisingly, no significant correlation between the total use of STR and the total post-test score were found in both activities. The students rarely used STR input to write their sentences or essays since the STR input was only provided in the English language.

In terms of personalization, the total use of AI-WF in the practice activity was significantly correlated with the total post-test score (r = .365, p = .037) and the total use of AI-WF in the assignment activity was significantly correlated with the total post-test score (r = .358, p = .041). The total use of AI-WF was also significantly correlated with organization and grammar and vocabularies in both activities. Moreover, there was a significant correlation between the total use of AI-WF and the cohesion and consistency (r = .369, p = .035) in the assignment activity. This finding shows that AI-WF provided students not only with the general grammar corrections but also with sentence connections in the assignment. AI-WF is a powerful function because it can help students restructure the connection between the sentences based on students' personal writing draft. By utilizing AI-WF, the students not only can check the grammar but also can personalize their essay by rewriting the sentences or adding the conjunction words (see Appendix 2). Additionally, the total use of GF in the assignment activity was also significantly correlated with the total post-test score (r = .359, p = .040). GF could help students to check their grammatical errors. Both GF and AI-WF encourage students to repeatedly revise their essay and thereby improve the quality of their essay.

A positive correlation was found between the total revisions in the practice (r = .359, p = .040) and assignment (r = .375, p = .032) activities and the total post-test score. These results indicate that the revision process is an important step in the writing. In accordance with the present results, a previous study has demonstrated that revision helped students to improve their writing essay (Liu et al., 2017). The students could get some inspiration from the sample sentences provided by AI-SS when revising their essay and use writing feedback provided by AI-WF to help them rewrite the essay. By doing so, the student can improve the quality of their writing.

The Predictive Variables of Learning Achievement of EG

If we consider which variables affect learning achievement (post-test) significantly, then according to Table 6, the total assignment score was the most important and the first significant predictor. This indicates that the assignment score is influential on the post-test. This result may be explained by the fact that the students worked hard to complete the assignment like a formal test after practicing their writing several times in

Table 4. Pearson Analysis Between Learning Behaviors in the Practice Activity and Learning Achievement.

		Learning behaviors in the practice activity								Learning achievements			
		1	2	3	4	5	6	7	8	9	10	11	12
1	Total photos	1											
2	Total use of ITR	.308	1										
3	Total use of STR	−.183	.195	1									
4	Total use of AI-SS	.273	.172	−.073	1								
5	Total use of AI-WF	.334	.334	−.241	.365*	1							
6	Total use of GF	.375*	.249	−.138	.202	.520**	1						
7	Total revisions	.741**	.400*	−.058	.507**	.370*	.242	1					
8	Total practices	.924**	.359*	−.163	.380*	.404*	.348*	.843**	1				
9	Content	.175	.328	.016	.360*	.393*	.350*	.357*	.186	1			
10	Organization	.148	.395*	.098	.346*	.380*	.352*	.381*	.182	.953**	1		
11	Grammar and vocabulary	.120	.382*	.106	.313	.379*	.379*	.325	.133	.962**	.954**	1	
12	Cohesion and consistency	.090	.389*	.154	.314	.307	.301	.320	.119	.938**	.968**	.941**	1
13	Total posttest score	.138	.374*	.096	.346*	.365*	.342	.359*	.159	.981**	.979**	.980**	.979**

Notes. *$p < .05$. **$p < .01$. Image-to-texts recognition (ITR). Speech-to-text recognition (STR). Sample sentences by AI (AI-SS). Writing feedback by AI (AI-WF). Grammar feedback (GF).

Table 5. The Pearson Analysis Between Learning Behaviors in the Assignment Activity and Learning Achievement.

		Learning behaviors in the assignment activity								Learning achievements			
		1	2	3	4	5	6	7	8	9	10	11	12
1	Total photos	1											
2	Total use of ITR	.172	1										
3	Total use of STR	.012	−.010	1									
4	Total use of AI-SS	−.009	.511*	−.004	1								
5	Total use of AI-WF	−.083	−.127	.390*	.308	1							
6	Total use of GF	.217	.111	.071	.478**	.769**	1						
7	Total revisions	.381*	.207	.210	.512**	.378*	.347*	1					
8	Assignment score	−.064	.367*	.173	.509**	.361*	.248	.422*	1				
9	Content	.213	.350*	−.141	.369*	.311	.342	.328	.378*	1			
10	Organization	.186	.342	−.059	.389*	.381*	.378*	.367*	.407*	.953**	1		
11	Grammar and vocabulary	.249*	.352*	−.064	.370*	.354*	.351*	.445*	.399*	.962**	.954**	1	
12	Cohesion and consistency	.175	.309	−.006	.321	.369*	.338	.344*	.414*	.938**	.968**	.941**	1
13	Total posttest score	.209	.348*	−.066	.373*	.358*	.359*	.375*	.402*	.981**	.986**	.980**	.979**

Notes. *$p < .05$. **$p < .01$. Image-to-texts recognition (ITR). Speech-to-text recognition (STR). Sample sentences by AI (AI-SS). Writing feedback by AI (AI-WF). Grammar feedback (GF).

Table 6. The Predictors of Learning Achievement.

Model	Predictor	R^2	Adjusted R^2	F	B	β	t
1	Total assignment score	.162	.135	5.975	.593	.402	2.444*
2	Total assignment score	.275	.227	5.688	.566	.383	2.461*
	Total revisions on practices				.285	.337	2.166*

Notes. *$p < .05$. Dependent variable: total posttest.

the practice activity. In addition, since the scoring rubric of the assignment and the post-test were the same, the students tended to make the assignment activity as a preliminary test. Therefore, they paid more attention to finishing the assignment as well as possible. According to Table 6, the total revision of the practice activity was the second most important predictor for post-test. It shows that revision plays an important role in writing (Liu et al., 2017). What is surprising is that AI-SS and AI-WF did not appear as predictors of learning achievements. However, AI-SS and AI-WF encouraged EG students to make more revisions in practice and assignment activities as shown in Table 3 and Table 4 and thereby enhancing their post-test.

The Affordances of AI and Its Limitations

The EG was clustered using K-Means Clustering into four clusters based on their content similarity in their essay. Then generative-AI analyzed the theme of each cluster as shown in Table 7. The mean value of words in the essay for C4 was 189.00, which was the highest score compared to the other clusters (C1–C3). It shows that C4 wrote more meaningful words that were used to describe not only the definition/function of the objects but also the importance of the objects. Hence, the words in the essay of C4 were more complex (M = 3.001) and more varied (M = 59.747).

Surprisingly, in terms of the total use of AI-SS and AI-WF, AI-SS and AI-WF was more beneficial to describe the function or definition of the specific objects such in C1 and C2. The lexical diversity and syntactic complexity of C1 and C2 were lower than the other two clusters, which indicated that C1 and C2 tended to use the same words repeatedly to describe a specific object/theme in their essay. These findings could imply the limitation of AI which is not powerful enough to describe an object meaningfully. The possible reason may be that AI lacks sufficient information to address the specific topic (Murati, 2022). Furthermore, besides giving the general prompts, we need to provide more specific prompts with several examples to AI like the benefits or advantages of each device to help learners, thereby generating more meaningful sample sentences (AI-SS). It is because the output from AI can imitate the writing style by learning from content of the prompt to provide more meaningful AI-SS and AI-WF (Hutson, 2021; Rees, 2022). Thus, the AI-SS can generate comprehensive sentences not only describe the objects generally but also describe their importance or help to human life in depth and AI-WF

Table 7. Analysis of Writing Quality of EG

K-means clustering results	Essay theme results	Average of essay words	Average of writing quality		Average of total use	
			Lexical Diversity (MTLD)	Syntactic Complexity (clauses/t-unit)	AI-SS	AI-WF
C1	Hardware devices are used for inputting data into a computer	111.111	53.177	2.504	11.222	64.333
C2	The tools for the sound system	142.500	49.179	2.185	12.375	66.500
C3	The use of technology to improve productivity	152.250	59.233	2.368	10.125	50.000
C4	The writing essays discuss the importance of computers or smartphones in modern society	189.000	59.747	3.001	10.875	62.750

can provide more meaningful personalized writing feedback. Hence, the students will receive AI-SS and AI-WF meaningfully to inspire writing essays more.

Students' Perceptions towards Roamlingo in EG

The interview responses of EG were coded into 11 items as shown in Table 8. The results showed that Smart RoamLingo was useful for EFL writing since the students could learn and practice repeatedly with their mobile phones (INV-5) at any time anywhere. Most of them also felt healthy because they did more walks to find the objects in their surroundings (INV-8). Although they were still in the covid-19 pandemic situations at the time of the experiment, they had strong motivations to explore their surroundings to complete their essays (INV-10) because of Smart RoamLingo features and activity designs. Interestingly, the students also revealed that they need sample sentences (AI-SS) and vocabulary to inspire them to write their essays (INV-1b; INV-3). They were driven to write more creative descriptions in their essay using the vocabulary that was taken from their surroundings (INV-6). Furthermore, the students mentioned that AI-WF helped them to improve their writing quality (INV-2). AI-WF not only checked students' grammatical errors but also provided the students with sentence connections to make their essay more readable. Moreover, the students were allowed to revise their essays without limit through Smart Roamlingo. By doing so, they can deeply improve their writing before producing a final draft of their essays (INV-9).

Table 8. Interview Results of EG.

Code	Themes	Freq (n = 20) N	%
INV-1a	The difficulty when writing English is in the grammar	12	60
INV-1b	I Need to have inspiration (AI-SS) and vocabulary before writing (ITR)	18	90
INV-2	The technology can help me to improve my writing quality by the smart writing feedback (AI-WF) immediately	16	80
INV-3	RoamLingo can inspire me before writing (AI-SS), help me to correct essay writing with the feedback when writing (AI-WF), and the writing can be saved for revision later	15	75
INV-4	RoamLingo is easy to use for EFL writing because the user interface is clear, and the tutorial is easy to understand	14	70
INV-5	RoamLingo is useful for EFL writing because it can be used to practice writing on mobile devices before writing tests	20	100
INV-6	I Can learn new vocabulary from the surroundings (ITR) and it makes me more creative to describe	13	65
INV-7	I Will continue to use RoamLingo to learn and practice EFL writing by myself because I can improve my writing skills	16	80
INV-8	I Feel like exercising because I have to move around looking at surroundings that make me healthy	18	90
INV-9	I Practiced writing based on the minimum requirements assigned by the teacher, but I revised many times to make sure that the writing quality was good before submitting it	15	75
INV-10	I Can still practice writing by exploring the surroundings because the covid-19 pandemic does not affect my learning	13	65

Based on the findings of this study, we summarize that recognition technologies such as STR and ITR can help generate vocabulary and phrases related to authentic contexts surrounding learners and open AI can help make meaningful sentences to guide students how to describe their taken pictures. Furthermore, open AI can provide students with more meaningful writing feedback based on their original writing to improve the writing quality including writing fluency with suggested conjunction words and giving more related description sentences. The integration of these recognition technologies and AI can work very well to support EFL writing.

Conclusion

Regarding the first research question, this study confirmed that the use of AI and recognition technologies such as ITR and STR significantly enhanced students' EFL writing in authentic contexts, particularly when it came to contextualization and

personalization aspects. In terms of contextualization, Smart RoamLingo provides sample sentences (AI-SS) for students to help them write more essay content actively during the learning activity. While in terms of personalization aspect, Smart RoamLingo provides writing feedback (AI-WF) to help students improve their writing quality, particularly concerning the cohesion and consistency (Liu et al., 2021). Hence, students' writing skills including content, organization, grammar and vocabulary, and cohesion and consistency improved significantly.

In terms of the second research question, this study also confirmed that total revision was one of the important predictors to affect the learning achievement of students in the post-test. Providing students with more opportunities to revise their essay using writing feedback can sharpen their writing skills and thereby, improve their learning achievements (Liu et al., 2017).

In the third research question, this study showed that AI can support students to write meaningful essays with AI-SS and improve the writing quality with AI-WF. However, AI still lacks to describe an object meaningfully as their limitations (Murati, 2022). Further, AI needs to have sufficient good examples of essays as an input to generate more meaningfully AI-SS and AI-WF in depth to inspire students to write essays more (Rees, 2022).

Regarding the fourth research question, the students' felt that RoamLingo was useful to help them to learn EFL writing anytime and anywhere using mobile phones with AI and recognition technologies. The students have strong motivation to complete their essay by exploring their surroundings even in covid-19 pandemic situations (Hwang & Hariyanti, 2020). It is because they got inspiration from the contexts in their surroundings with AI-SS. In addition, the students received personalized writing feedback with AI-WF to encourage them to improve their writing quality.

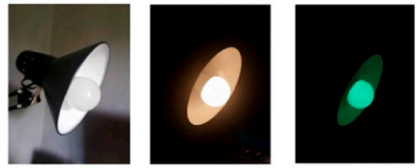
We found several constraints in this study. The learning activities were designed for individual tasks and completed at home. The study collected and analyzed the learning behaviors of EG only. These may influence the current findings. Thus, future study may consider varied learning activities such as individual and collaborative activities to deeply investigate the effects of Smart RoamLingo in EFL writing. In addition, there might be hidden correlations between the learning behaviors and learning achievements of EG since the EG students must sequentially follow the four steps to complete the practice and assignment activities. The future studies should consider a comprehensive analysis such as Lag sequential analysis to deeply study the correlations between learning behaviors and learning achievements of all groups. Furthermore, the use of AI in this study was not mature enough yet to provide meaningful themes for students. Therefore, future study should consider using a specific prompt in the generative-AI. By doing so, more insightful AI-WF could be provided for students.

Appendices

Appendix 1 Essay Scoring Rubric on Each Dimension.

Dimension	Score	Detail
Content	1	Little or no detail or irrelevant specifics, or questionable responsiveness to the task
	2	Limited development in response to the topic and task
	3	Addresses the topic and task using somewhat developed explanations, exemplifications, and/or details
	4	Addresses the topic and task well, though some points may not be fully elaborated
	5	Effectively addresses the topic and task
Organization	1	Serious disorganization or underdevelopment
	2	Inadequate organization or connection of ideas
	3	May demonstrate inconsistent facility in sentence formation and word choice that may result in lack of clarity and occasionally obscure meaning
	4	Is generally well organized and well developed, using appropriate and sufficient explanations, exemplifications, and/or details
	5	Is well organized and well developed, using clearly appropriate explanations, exemplifications, and/or details
Grammar and vocabulary	1	An accumulation of errors in sentence structure and/or usage
	2	A noticeably inappropriate choice of words or word forms
	3	May display an accurate but limited range of syntactic structures and vocabulary
	4	Displays facility in the use of language, demonstrating syntactic variety and range of vocabulary, though it will probably have occasional noticeable minor errors in structure, the word form, or use of idiomatic language that do not interfere with meaning
	5	Displays consistent facility in the use of language, demonstrating syntactic variety, appropriate word choice, and idiomaticity, though it may have minor lexical or grammatical errors
Cohesion and consistency	1	Serious and frequent errors in sentence structure or usage
	2	Inappropriate or insufficient exemplifications, explanations, or details to support or illustrate generalizations in response to the task
	3	Displays of unity, progression, and coherence, through the connection of ideas, maybe occasionally obscured
	4	Displays unity, progression, and coherence, though it may contain occasional redundancy, digression, or unclear connections
	5	Displays unity, progression, and coherence

Appendix 2 An Example of Student Essay.

Session practice	2242afe3-6b1c-46d0-9ecc-9a90b5fafe3b	
Authentic photos		
ITR-generated	*Original from the recognition results*	*Edited by students*
- vocabulary	wall, indoor, black, light, light, logo	wall, indoor, black, light, bulb, light, smart home, warm, yellow, bulb, green, smart home
- short description	a light bulb on a wall, a couple of light fixtures, logo	a light bulb on a wall, a warm yellow light bulb, light bulb with green light
AI-SS	*The last AI generation results* A light bulb on a wall can provide light. The light from the bulb can be warm and yellow, or it can be green. A smart home can use a light bulb like this to provide warm light in a room.	
Essay	*The introduction section* The light bulb a device that everyone have in their home. the light that come out from light bulb is yellow or white. *The description section* There are now smart light bulbs technology develops. So that it makes the light emmit from light bulb, the color can be adjust from mobile device. *The benefits section* A light bulb on a wall be used to provide light in an indoor space. our room can be brighter to read a book, or do other activities. *The conclusions section* The more sophisticated the technology, make or life easier one example we can have smart light bulb with color that can be changed.	
AI-WF	The light bulb is a device that everyone has in their home. Generally, the light that comes out from light bulbs is yellow or white. However, with the development of smart light bulbs, the color of the light emitted from the bulb can now be adjusted from a mobile device. This allows for greater flexibility in lighting indoor spaces. For example, a light bulb on a wall can be used to provide light for reading or other activities. The more sophisticated the technology, the easier our lives become.	
Metadata	Total words: 102 words Total photos: 3 photos Total revision: 5 times Total used of ITR: 21 inserted	Total used of AI-SS: 3 inserted Total used of STR: 0 inserted Total used of GF: 4 inserted Total used of AI-WF: 9 inserted

Appendix 3 Semi-Structured Interview Questions.

1. What are the hardest things when you want to write in English?
2. What is your opinion regarding the technology that can support EFL learning?
3. What is your opinion regarding the RoamLingo for EFL writing?
4. Is it easy to use RoamLingo for EFL Writing? In what aspect?
5. Do you think the RoamLingo is useful for EFL writing compared with the conventional methods like pen and paper?
6. What is the impact of learning EFL writing by exploring and observing your surroundings?
7. Do you want to continue to use RoamLingo to improve your EFL writing?
8. Do you think learning by exploring can make you healthy or unhealthy? Why?
9. Will you do the practice writing based on the minimum requirements assigned by the teacher or will you do it more than the minimum requirements?
10. Does the Covid-19 pandemic affect you when you practice writing by exploring the surroundings?

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