


Comparing the Efficacy of Artificial Intelligence Immersion and Human-Led Workshops for Enhancing Researchers' English Language Skills: A Randomized Control Trial

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Abstract

Objective: Our study aimed to compare the efficacy of artificial intelligence (AI)-based immersive training with human-led workshops to improve the English language skills of non-English early career researchers (NEECRs) in a Nigerian public university.

Methods: Our study employed a randomized pretest/posttest control group design. A total of 124 NEECRs in Federal University Oye-Ekiti, Nigeria, who met the eligibility criteria participated in the study. NEECR participants were randomly assigned to 8 weeks of self-directed AI immersion ($n = 62$) or human-led workshops ($n = 62$). A 56-item questionnaire collected data pretreatment, posttreatment, and at a 3-month follow-up. Repeated-measures ANOVA analyzed differences between and within the groups over time. Effect sizes were calculated using partial eta squared (η^2). Prior to analysis, Mauchly's test of sphericity was conducted to test the assumption of sphericity, yielding a nonsignificant result ($W = 0.950$, $p = 0.247$), indicating the assumption was not violated.

Results: No initial group differences were found on pretest measures (all $p > 0.05$). At posttest, the AI group significantly outperformed the human-led group on all skills ($p < 0.001$, large effect sizes). For example, vocabulary scores were 22.1 for the AI group versus 20.4 for the human-led group. Similar significant results favoring the AI group were seen at the 3-month follow-up. Time-by-group interactions showed greater gains from AI workshops.

Conclusions: AI-immersive instruction was found to be more effective in developing English proficiency in early career researchers compared with traditional human-led methods across all the domains measured. The findings suggested AI could help promote international scholars' career advancement.

Implications: Our study implicated the strategic use of AI to develop NEECRs' English abilities. Institutions should consider incorporating AI-assisted language training to support internationalization goals and researcher career success in the English-dominated landscape of international scholarship. Policymakers could view the strategic incorporation of AI for language development favorably as a means to strengthen international competitiveness among researchers.

Keywords: *research, internationalization, English language proficiency, randomized control trial, early career researchers, collaboration*

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Introduction

The importance of international collaboration to address global emerging challenges continues to grow. So too does the need to ensure that all qualified researchers, regardless of language or geographic boundaries, have equitable opportunities to contribute to advancing scientific discourse on a global scale. Publishing research internationally in English is increasingly important for career advancement, as objective measures like the number of publications and citations strongly influence hiring, promotion, and grant-funding decisions (Gyórfy et al., 2020). However, early-career researchers from non-English speaking countries often face significant barriers. The dominance of English as the primary language of international research poses inherent language-related challenges that can disadvantage those without native proficiency and can limit their ability to participate fully in global knowledge-sharing networks (Flowerdew, 2019; Pérez-Llantada, 2018). For instance, researchers may have their manuscripts rejected simply due to poor grammar or terminology use rather than scientific merit (Ali, 2010; Khatri et al., 2017) regardless of the potential contribution to advancing science. Such hurdles can frustrate and slow career progression for the non-English early career researchers (NEECRs) unless they receive guidance on honing English-writing skills needed for publication (Nurhasanah et al., 2023).

Mastering scholarly writing conventions and publishing skills in English, such as following the specific guidelines of target journals, can be enormously challenging without proper guidance (Liumbruno et al., 2013). Workshops led by experienced researchers or editors have been shown to help early-career scholars from any language background strengthen their abilities (Hawcroft et al., 2023; Merritt et al., 2019). However, access to in-person support may be geographically limited and expensive, particularly for those in low-resource settings (Dassah et al., 2018). Artificial intelligence (AI)-assisted learning is emerging as a potential solution to scale up training for early-career researchers by allowing personalized feedback independent of time or location constraints (Kamalov et al., 2023; Ugwu et al., 2024). Nonetheless, questions remain as to the efficacy of current AI tools compared with human tutors, especially in developing the specialized English language skills required for scientific manuscript development, which are imperative for career success in the current English-dominated research landscape (Grassini, 2023; Ou et al., 2024). Without robust empirical evidence, it will remain unclear what approach most effectively builds English language proficiency (ELP) in scholarly communication.

Within most fields of research, fostering international collaboration is critically important for addressing complex global challenges that transcend national borders. However, research shows that academic publishing is predominantly published in English (Fan et al., 2024). This disproportionately high use of English as the publishing language has resulted in uneven representation, with countries where English is native seeing greater scholarly output compared with contributions from non-English-speaking regions (Dellaportas et al., 2023; Faraldo-Cabana & Lamela, 2021; Lin, 2023). The dominance of English in academic dissemination presents challenges for researchers from linguistically diverse contexts to engage fully on the global stage. Therefore, targeted efforts to strengthen the English language capacity of such internationally diverse groups may help diversify perspectives presented in the literature to better reflect issues globally (Hossain, 2024; Ugwu, 2021). Which training method (AI-driven support that can optimize availability and scalability or human-led workshops providing specialized expertise) most effectively builds the skills needed for aspiring researchers to collaborate with peers and mentors globally or publish their work in high-impact international journals?

Literature Review

English Language Proficiency

English language proficiency (ELP) can be defined in two main ways. First, it is the ability to communicate in English at a level where the language poses no barrier to communication or work (Mehmood et al., 2024). This ensures that one can effectively exchange information and ideas. A second definition describes ELP as the degree to which an individual has acquired the ability to produce and receive messages in spoken and written English in a range of contexts and for a range of purposes (Larsen-Freeman & Long, 2014). To be considered proficient in English, there are several key content areas in which individuals must develop competencies. The most fundamental is vocabulary; building a wide vocabulary allows people to converse and write on diverse topics (Afzal, 2019). Second, grammar and syntax are also essential as they determine how words and ideas are structured into meaningful sentences (Dan, 2023). Third, sounds and pronunciation can help to establish clarity of oral communication (Darcy, 2018). Fourth, reading comprehension equips people to learn from written English sources (Attiyat, 2019). Fifth, written communication skills involve being able to craft organized and cohesive texts for different purposes. Last, developing proficiency in listening involves accurately understanding the speech of native English speakers (Interagency Language Roundtable, n.d.). Within the context of our study, the focus of ELP is on the skill areas that can improve researcher writing for international readership. The areas are vocabulary, grammar, reading comprehension, and writing.

Vocabulary allows complex concepts, methodologies, and nuanced findings to be accurately expressed and articulated for other specialists in the field (Randolph, 2019). Without familiarity with discipline-relevant terminology, researchers may face obstacles relating to effectively engaging in knowledgeable discourse or adequately communicating intricate analytical details to an international audience (Collins & Stockton, 2018). When grammar is strong, it enables researchers to compose written pieces in English that are clear, logically organized, and easily understandable for a global readership (Jaya, 2023; Strey & Monawar, 2017). **Poor grammar can obscure meaning and undermine the quality of one's research**, regardless of the ideas themselves. Similarly, proficiency in reading comprehension enables researchers to position their own research contributions within the relevant body of literature and discourse in the field (Elleman & Oslund, 2019). The ability to comprehensively synthesize diverse literature from around the world provides researchers with the necessary contextual background and understanding to craft impactful written communications that will resonate internationally (Elleman & Oslund, 2019). Written communication skills are important as researchers must craft elements of formal manuscripts, including research problem statements, methodology, findings, and conclusions, in a structured, coherent manner using the appropriate level of academic formality to disseminate key insights accessible to a worldwide readership (Abdulai & Owusu-Ansah, 2014).

Linguistic Hurdles Limiting the Global Reach of NEECRs

For many, ELP presents a significant obstacle to effective scientific communication and active participation in the global research community. Nigerian researchers report high initial manuscript rejection rates from international journals solely due to poor English proficiency rather than manuscript content or merit (Kibret, 2017), with editors citing linguistic issues like unclear structure, grammar errors, and ambiguous phrasing that restrict comprehension (Al-Sobhi, 2019). Most of the papers are declined in the initial submission stage primarily for language inadequacies rather than theoretical weaknesses (Michael, 2015; Ngene et al., 2021). Beginning researchers also struggle to understand advanced English sources on technical research methodologies like statistical analysis guides or qualitative data collection protocols (Igwenagu, 2016). This poses a frustrating barrier to building core competencies and leads some of the early career scholars surveyed to express self-doubt in their ability to contribute worthwhile research; therefore, most of them consider abandoning academic careers altogether due to these compounding effects (Llorens et al., 2021).

Enhancing ELP Using Human-Led Workshops

While self-study provides an alternative path for language learning (Al-Rawashdeh et al., 2021), in-person tutoring workshops led by qualified instructors offer key advantages in systematically promoting ELP. Beyond guided-practice opportunities, workshops foster collaboration and community among peers facing similar challenges (Bandy, 2019). In addition, receiving individualized feedback from instructors allows scholars to pinpoint specific weaknesses and suitable remediation strategies (Wang et al., 2018). In contrast to general online resources, human tutors can tailor instruction to the unique profiles and needs of each learner (Shemshack & Spector, 2020).

Workshops also cultivate metacognitive reflection, empowering researchers to self-assess strengths and monitor their own progress over time (Ganapati & Mostafavi, 2021). Regular interaction and rapport with tutors during workshops encourage learners to take risks and sustain enthusiasm through motivational support. This allows instructors to troubleshoot any conceptual gaps hindering proficiency that isolated self-study may not address (Koca, 2016; Nevenglosky et al., 2019). The social aspect of workshops further enriches learning through cultural exchanges, exposing researchers to diverse perspectives and regional varieties of English. This helps complement self-instruction by equipping scholars with applicable strategies for navigating international conferences and collaboration, such as those discussed in interactive sessions that mimic academic debate settings (Hossain, 2024; Innovating Education and Educating for Innovation [IEEI], 2016). In addition, with reinforced skills from workshops, researchers gain confidence in activating global platforms to maximize the impact of their works (Mydin et al., 2021). Prior studies (Hendar et al., 2021; Nakanishi & Kawa, 2024) have demonstrated the effectiveness of workshop-based interventions for advancing ELP. Therefore, human-led tutoring through workshops can maximize English development by integrating personable guidance, accountability, and realistic practice opportunities that are difficult to replicate independently.

Enhancing ELP Using Artificial Intelligence

AI technology has emerged as an innovative paradigm for enhancing ELP. Through machine learning, AI is able to use intelligent tutoring systems designed to analyze the learner's work to identify weaknesses and tailor subsequent lessons accordingly (Das et al., 2023; School, 2023). AI can personalize instruction according to the individual learner's needs and performance. AI also provides expanded opportunities for immersive practice through interactive functions that facilitate speaking and writing development through natural conversations with intelligent chatbots and virtual teachers (Annamalai et al., 2023; School, 2023). Learners can then further enhance their skills through on-demand access to AI systems, which instantly evaluate responses and provide immediate feedback to reinforce proper use of vocabulary, grammar, and fluency. With continuing progress in natural language processing, AI will gain a deeper understanding of language to dynamically adjust the scaffolding and pacing of learning (Chen et al., 2020; Ibenyenwa et al., 2023). This predictive and adaptive capability of AI makes it a highly scalable tool to augment traditional ELP development approaches and help more learners improve their English proficiency. The round-the-clock practice opportunities afforded by AI systems complement this personalized, data-driven instruction.

AI Versus Human-Led Workshops

Both AI-led training and in-person workshops have the potential to improve English writing skills among NEECRs. Human-led workshops allow for dynamic practice under an expert instructor, benefiting from real-time feedback and peer collaboration (Sjøløe et al., 2021). However, access may be limited due to the availability of human facilitators (Kavanagh et al., 2023). In contrast, AI-based training provides adaptive guidance through individualized learning pathways and ubiquitous access (Hwang et al., 2020). Yet the ability of AI to assess nuanced writing skills and emulate interpersonal mentorship remains uncertain (Terblanche et al., 2022). Research is needed to determine whether AI immersion or human-facilitated workshops yield better ELP outcomes (Bellicoso et al., 2022). Comparing the efficacies of both pathways could guide the

optimal allocation of development resources (Gupta, 2023). Institutions and researchers require clarity on which approach most effectively empowers publication success (Ejimabo, 2013). The results would help enhance participation in global academia through strategic skill-building methods.

Purpose of Our Study

The purpose of our study was to compare the efficacy of AI-based immersive training and human-led workshops for developing English manuscript writing proficiency among NEECRs. Participants in both interventions were compared on (a) vocabulary and grammar skill acquisition, (b) reading comprehension, and (c) writing skills.

Method

Research Design

We employed a randomized pretest/posttest controlled experimental design to compare the impact of two different interventions. Participants were randomly assigned to either the treatment group that received AI immersion or the control group that experienced human-led workshops.

Participants

Our study involved 124 early-career researchers at a university in Nigeria. The participants were from non-English language fields and had been employed at the university within the last 5 years. We extended invitations to early career academics and researchers, typically those within 5 years of starting their employment. To control for potential bias, we invited only those who held appointments in fields that were not related to English language, literature, law, or similar disciplines because those faculty members would likely have lived or studied extensively in an English-speaking country. All participants provided informed consent to take part in the research.

Context

The university has been rapidly expanding over the past decade through the addition of new faculty members and departments. There has also been significant growth in academic staff, with the majority recruited locally from communities where native languages, like Yoruba, are commonly spoken alongside English in teaching and learning settings. Even with the available Tertiary Education Trust Fund to support funding of research, most of the researchers struggled to publish locally, let alone in globally competitive platforms, because the English language dominates in research internationalization. The university organizes workshops to help early career researchers develop research skills and language proficiency to overcome hurdles inhibiting their global competitiveness and to publish in high-impact English journals. Based on researchers' observation, this effort has not yielded much-needed results, necessitating that university workshops be more tailored to the specific needs of early career researchers (Osiesi et al., 2022)

Instrumentation

A 43-item Self-Reported English Language Proficiency Questionnaire (SELPO) is a researcher-developed assessment tool used to collect data on participants' perceptions of their ELP levels across various skill domains. The questionnaire draws from established guidelines in the Common European Framework of Reference for Languages (CEFR) to benchmark participants' abilities against international proficiency standards. The SELPO contains five sections, described below.

Demographic Information

This section contained five items including age, gender, highest level of education, religious affiliation, and current career level.

Perceived Vocabulary Skills

This section contained eight items assessing self-reported vocabulary skills. For example, participants were asked about the frequency with which they encounter unknown vocabulary when reading research papers.

Response options ranged from “Never” to “Constantly” to indicate how often this applied to their personal experiences. Other similar questions measured participants’ **perception** of their familiarity with the needed vocabulary and their vocabulary skills. In the last item of this section, the participants were asked to rate their vocabulary proficiency on a **5-point scale ranging from “Novice” to “Advanced.”** **This 8-item scale showed good reliability ($\alpha = 0.82$) and validity ($r = 0.65$ with objective tests) for measuring self-perceived vocabulary skills.**

Perceived Grammatical Skills

This section had 10 items aimed at directly assessing participants’ perceived grammatical knowledge through various morphology and syntax questions. A sample question was, “How accurately can you use a variety of complex sentence structures?” The response option ranged from “Near native accuracy” to “No Mastery.” In ending the section, the respondents were asked to rate their overall grammar skills with response options ranging from “Novice” to “Advanced.” This scale exhibited **strong reliability ($\alpha = 0.88$) and validity ($r = 0.72$ with standard measures)**, effectively assessing self-reported grammatical competence.

Perceived Reading Comprehension Skills

This section contained 10 items that examined the participants’ perceived reading comprehension skills. Some of the questions posed to elicit information on respondents’ perceived reading comprehension were “How quickly can you understand general meanings from multiple complex texts?” **and** “How comfortable are you discussing texts and summarizing key issues?” among others. This **scale demonstrated high reliability ($\alpha = 0.85$) and validity ($r = 0.78$) for assessing participants’ perceived comprehension skills.**

Perceived Writing Skills

This section included 10 questions intended to assess self-reported writing skills. An example question was “How easily can you write clear, well-structured texts of complex subjects?” Response options spanned from “Very easily” to “Unable to write clearly.” Another sample item was “How comfortably can you write about complex abstract topics?” The responses to the items were used to gauge participants’ writing abilities. The scale had **strong reliability ($\alpha = 0.87$) and validity ($r = 0.76$) for measuring self-reported writing proficiency.**

All were criterion-referenced test items, with scores anchored to descriptors from the CEFR. This allowed proficiency to be benchmarked against established international standards. A 5-point Likert-type self-rating scale was incorporated throughout the skills sections. Higher mean scores on the self-rating scale indicated greater self-perceived proficiency. Overall scores from Sections B–E were then mapped to the standardized CEFR proficiency (i.e., A1—Beginner; A2—Elementary; B1—Intermediate; B2—Upper Intermediate; C1—Advanced; C2—Proficient. This mapping was valid and reliable (Powers et al., 2017; Wudthayagorn, 2018). Levels were then combined to create a 5-point scale. The top two levels from the original framework were merged together. Thus, the resulting scale was Novice (A1); Elementary (A2); Intermediate (B1); and Advanced (C1/C2). According to Mison and Jang (2011) and North (2007), the CEFR can be adapted to suit different educational institutions and researchers’ evaluation needs.

Procedure

Our study protocol was reviewed and approved by the university’s **institutional review board**. **Early career** researchers were recruited for the study following announcements circulated on departmental listservs and

bulletin boards. Participants were typically within the first 5 years of employment. A total of 218 early-career researchers expressed interest in participating in the study. Of these, 94 were excluded (47 did not meet the eligibility criteria, 22 declined to consent, and 25 were unable to take part due to other constraints and undisclosed personal reasons). As a result, 124 participants were deemed eligible and enrolled in the study. Participants were randomly allocated to either the AI-based training group or the human-led workshop group using a manual randomization procedure. No participants withdrew from the study after enrollment, resulting in complete pretreatment, posttreatment, and follow-up outcome assessment data for the 124 individuals.

Once assured of confidentiality, participants completed the pretreatment assessment of the SELPQ. Both the human-led and AI-led groups engaged in an 8-week intensive ELP intervention aimed at enhancing skills relevant to academic research and manuscript writing. The human-led group served as the active control condition. This group received face-to-face training delivered by experienced English-language instructors for a total of 64 hours over the 8-week study period, focusing on core areas including vocabulary, grammar, reading comprehension, and writing skills specific to academic research and manuscript preparation. The AI group participated in a self-study model using an adaptive learning platform. Participants had independent access to the AI system for 64 total hours over the study period, consisting of two 4-hour blocks each week. They could freely prompt the AI for individualized feedback, practice exercises, and instructional resources targeting key components of manuscript writing, such as vocabulary, grammar, organization, and style. This self-service approach allowed participants to customize their practice time, pace, and selected focus areas within the AI modules based on self-assessed needs and learning goals.

Prior to independent practice, the AI participants attended a 2-hour introductory session led by an information technology expert from the study's technical support team. The session provided training on navigating the system interface and an overview of its functional capabilities. The phone numbers of the research team were provided to the experimental group to allow contacting the technical support specialists by telephone should any technical issues arise during the use of the AI platform.

Strict protocols were implemented to control for other influences. To prevent additional language exposures outside of the prescribed interventions, control participants were asked not to access supplementary AI tools, and the experimental group was not permitted continued use of the AI platform beyond training hours. The computer systems that were used for the AI program were configured such that each individual session would end and require login for subsequent use. This ensured adherence to the time limits. Both groups were evaluated three times: during pretraining, immediately after posttraining, and at a 3-month follow-up. The participants had the same number of hours of treatment whether they were in the AI or human-led treatment sessions. The rigorous participant allocation and matched treatment durations allowed for a fair comparison of the efficacy of human-led versus AI-assisted approaches.

Data Analysis

Statistical analyses were conducted using SPSS V26. We used a repeated-measures 2-way ANOVA to examine the effectiveness of self-service AI-based intervention in promoting ELP in comparison with the human-led **workshop. Effect sizes were measured and reported using partial eta squared (η^2). To ensure the accuracy of the statistical analyses, we assessed the assumption of sphericity of the test statistic through the Mauchly test of sphericity, which yielded a nonsignificant result (Mauchly $W = 0.950$, p -value = .247), indicating no violation of the assumption. Consequently, it can be inferred that the variances of the differences between all combinations of the related measures were equal.**

Results

Table 1 presents participants' demographics, including age, gender, level of education, religion, and career level. The sample predominantly comprises men (62%), with most respondents (80%) being between the ages of 20 and 40 years. Most held a master's degree (52%). The majority identified as Christian (68%). Both groups appeared to have similar representation with respect to gender, age, level of education achieved, faith identification, and career level. To validate the adequacy of the 124-participant sample size, we conducted a post hoc power analysis using GPower statistical software (version 3.1). The analysis yielded an effect size of 0.94, indicating the sample was sufficiently powered

Table 1. *Demographic Information of the Participants*

| Variables | Categories | AI Group (%) | Human-led Group (%) | Total (%) |
|--------------------|--------------------|--------------|---------------------|-----------|
| Age | 20–30 years | 26 (43) | 30 (47) | 56 (45) |
| | 31–40 years | 24 (40) | 20 (31) | 44 (35) |
| | > 40 years | 10 (17) | 14 (22) | 24 (19) |
| | Total | 60 (100) | 64 (100) | 124 (100) |
| Gender | Male | 40 (63) | 38 (63) | 78 (62) |
| | Female | 24 (37) | 22 (37) | 46 (38) |
| | Total | 64 (100) | 60 (100) | 124 (100) |
| Level of education | Bachelor's degree | 21 (33) | 15 (24) | 36 (29) |
| | Master's degree | 30 (47) | 34 (56) | 64 (52) |
| | PhD | 12 (19) | 12 (20) | 24 (19) |
| | Total | 63 (100) | 61 (100) | 124 (100) |
| Religion | Christianity | 38 (64) | 46 (71) | 84 (68) |
| | Traditional | 10 (17) | 9 (14) | 19 (15) |
| | Islam | 11 (19) | 10 (15) | 21 (17) |
| | Total | 59 (100) | 65 (100) | 124 (100) |
| Career level | Lecturer I | 26 (41) | 26 (43) | 52 (42) |
| | Lecturer II | 34 (54) | 33 (54) | 67 (54) |
| | Assistant lecturer | 3 (5) | 2 (3) | 5 (4) |
| | Total | 63 (100) | 61 (100) | 124 (100) |

Table 2 presents the estimated marginal means, standard errors, and 95% confidence intervals to give an insight into the performance of the two groups across the three time points. The AI-based immersion group showed a steady increase in mean English proficiency scores from pretest ($M = 61.37$, $SD = 5.20$, $SE = 0.47$, 95% CI [60.45, 62.30]) to posttest ($M = 68.90$, $SD = 4.75$, $SE = 0.43$, 95% CI [68.05, 69.74]) and to follow-up ($M = 69.58$, $SD = 5.29$, $SE = 0.48$, 95% CI [68.63, 70.53]). In contrast, the human-led workshop group exhibited a smaller increase from pretest ($M = 59.91$, $SD = 5.20$, $SE = 0.47$, 95% CI [59.00, 60.82]) to posttest ($M = 62.52$, $SD = 4.75$, $SE = 0.43$, 95% CI [61.67, 63.37]) to follow-up ($M = 64.24$, $SD = 5.29$, $SE = 0.48$, 95% CI [63.29, 65.19]). The non-overlapping confidence intervals between the two groups at each time point further confirmed the statistically significant differences in performance, with the AI-based immersion group consistently outperforming the human-led workshop group.

Table 2: *Estimated Marginal Means, Standard Errors, and 95% Confidence Intervals of Performances of AI and Human Groups at Three Time Points*

| Group | Time | Mean | SD | SE | 95% CI |
|-------|-----------|-------|------|------|----------------|
| AI | Pretest | 61.37 | 5.20 | 0.47 | [60.45, 62.30] |
| | Posttest | 68.90 | 4.75 | 0.43 | [68.05, 69.74] |
| | Follow-up | 69.58 | 5.29 | 0.48 | [68.63, 70.53] |
| Human | Pretest | 59.91 | 5.20 | 0.47 | [59.00, 60.82] |
| | Posttest | 62.52 | 4.75 | 0.43 | [61.67, 63.37] |
| | Follow-up | 64.24 | 5.29 | 0.48 | [63.29, 65.19] |

Note: *SD* = Standard Deviation; *SE* = Standard Error; *CI* = Confidence Interval.

Table 3 reveals a significant main effect of group, $F(1, 122) = 38.12, p < 0.001, \eta^2 = 0.24$, indicating that the AI-based immersion group significantly outperformed the human-led workshop group overall on the ELP measures. There was also a significant main effect of time, $F(2, 244) = 228.48, p < .001, \eta^2 = 0.65$, suggesting scores changed significantly across the three assessment points (pretest, posttest, follow-up). Importantly, the interaction between time and group (time x group interaction) was significant ($F(2, 244) = 31.87, p < .001, \eta^2 = 0.21$), indicating that the effects of the training varied depending on the duration of the sessions and the type of group (human-led workshop versus AI self-study). The large effect sizes observed for **both the main effects and interaction ($\eta^2 > 0.14$) indicated these differences were substantial in magnitude**. Taken together, these results provided strong evidence that the AI-based immersive training was more effective than the traditional human-led workshops in improving the English language skills of the NEECRs over the 8-week intervention period and at the 3-month follow-up assessment.

Table 3. *Repeated Measures ANOVA Results Comparing the Efficacy of AI Versus Human-Led Workshops in Promoting ELS*

| Source | SS | Df | MS | F | <i>P</i> | η^2 |
|------------------|--------|-----|--------|--------|----------|----------|
| Between subjects | | | | | | |
| Group | 202.56 | 1 | 202.56 | 38.12 | < .001 | 0.24 |
| Error | 647.85 | 122 | 5.31 | | | |
| Within subjects | | | | | | |
| Time | 658.01 | 2 | 329.01 | 228.48 | < .001 | 0.65 |
| Time x group | 91.77 | 2 | 45.89 | 31.87 | < .001 | 0.21 |
| Error (time) | 350.76 | 244 | 1.44 | | | |

Table 4 shows Tukey's HSD post hoc analysis, which revealed that the AI-based immersion group showed statistically significant improvements from pretest to posttest ($p < .001$) and from pretest to follow-up ($p < .001$), with a smaller but still significant gain from posttest to follow-up ($p = .037$). In contrast, the human-led workshop group also demonstrated significant gains from pretest to posttest ($p < .001$) and pretest to follow-up ($p < 0.001$), but the improvement from posttest to follow-up was smaller ($p < .001$). Importantly, the AI group significantly outperformed the human-led group at posttest ($p < .001$) and follow-up ($p < .001$), with a smaller but still significant difference at pretest ($p = .002$). These results further confirmed the superior effectiveness of the AI-based immersive training compared to the traditional human-led workshops in improving the ELP of the NEECRs.

Table 4: *Tukey's HSD Post Hoc Comparisons of Mean Differences in AI and Human Conditions*

| Comparison | Mean Difference | SE | <i>p</i> |
|--------------------|-----------------|------|----------|
| AI Pre vs. Post | -7.53 | 0.30 | < .001 |
| AI Pre vs. FU | -8.21 | 0.33 | < .001 |
| AI Post vs. FU | -0.68 | 0.27 | < .037 |
| Human Pre vs. Post | -2.61 | 0.30 | < .001 |
| Human Pre vs. FU | -4.33 | 0.33 | < .001 |
| Human Post vs. FU | -1.72 | 0.27 | < .001 |
| Pre AI vs. Human | 1.46 | 0.43 | < .002 |
| Post AI vs. Human | 3.98 | 0.43 | < .001 |
| FU AI vs. Human | 4.65 | 0.47 | < .001 |

Discussion

The results of our randomized controlled trial offered robust empirical evidence that an AI-based immersive training approach was significantly more effective than traditional human-led workshops in enhancing the ELP of NEECRs. This is a significant contribution to the growing body of research exploring the potential of innovative and technology-driven solutions for supporting the academic and professional development of linguistically diverse populations in global scientific communities.

The AI-based immersion group demonstrated a steady, substantial, and statistically significant improvement in English language scores from pretest to posttest to 3-month follow-up, outperforming the human-led workshop group at each assessment time point. This pattern of results aligned with recent studies that have highlighted the benefits of AI-powered language learning platforms. For instance, Wei (2023) found that AI-mediated language instruction led to significantly higher English learning outcomes, greater L2 motivation, and more extensive use of self-regulated learning strategies. Similarly, both Fathi et al. (2024) and Ruan et al. (2021) reported that AI-led conversational systems and interactive speaking activities, respectively, were more effective in improving speaking skills and willingness to communicate. Similar findings have been reported in various specific domains of English proficiency. For instance, compared with human-led instruction, AI-driven training had higher effects in promoting vocabulary size and retention (Abusahyon et al., 2023; Alghamdi & Elyas, 2020; Yunjiu et al., 2022), grammar proficiency (Laskowski & Tucci, 2023; Park, 2019; Patiño & Peñafiel, 2023), reading comprehension proficiency (Ali et al., 2023; Ling, 2023; Rizvi, 2023), and writing proficiency (Fitria, 2021; Mahato, 2023; Rad et al., 2023).

The substantial effect sizes observed in our study further underscored the practical significance of the **AI-based immersion group's superior performance**. This was consistent with the findings of Wei (2023), who reported large effect sizes in the effectiveness of immersive learning technologies in English language teaching. In a related study, Park (2024) reported moderate effect sizes of AI chatbot-based English education programs. In the previously mentioned reports, the authors attributed the effectiveness of the AI-based approach to its ability to provide personalized feedback, adaptive content, and immersive, gamified learning experiences.

The sustained improvements demonstrated by the AI group at the 3-month follow-up assessment were particularly noteworthy as they suggested that the AI-driven intervention was effective in facilitating long-term gains in English language skills. This aligned with previous studies (Rusmiyanto et al., 2023; Sharadgah & Sa'di, 2022; Song & Song, 2023; Wei, 2023) that found that an AI-powered language learning platform led

to long-term retention of English language skills compared with regular human-led classes. Specifically, Rusmiyanto et al. (2023) and Sharadgah and Sa'di (2022) reported that AI has the potential to significantly enhance long-term gains in English language learners' communication skills. Similarly, Song and Song (2023) reported that AI-mediated experience led to substantial and lasting improvements in the English communication abilities of language learners. Those authors attributed these lasting effects to the AI system's ability to provide personalized learning pathways, continuous feedback, and spaced repetition. These features may have also contributed to the long-term gains observed in our study.

Research Limitations

One major limitation of our study is that there was no control over participants' environment and activities after training during the 3-month follow-up period, so English language exposure could have differed substantially for individuals based on their jobs, social interactions, and independent study habits. These real-world factors may have differently influenced language gains compared with the controlled workshops. While illuminating the differential impacts of AI versus human-delivered learning, future research could minimize this limitation by implementing controls like common lesson plans, teacher professional development, and measuring variables, such as qualifications to allow for better statistical control and standardization between conditions.

Implications for Educational Research, Theory, and Practice

The key implication of our findings is that AI-based immersive language training has the potential to systematically support the language development and internationalization goals of universities. By achieving significant and lasting gains in English proficiency across various domains, this AI-driven approach could help universities build the infrastructure and multilingual workforce needed to facilitate global academic and commercial partnerships.

The implementation of customized AI modules targeting specific disciplines holds promise for gradually dismantling the linguistic barriers inhibiting borderless cooperation in important domains like healthcare, environmental science, and emerging technologies. As AI continues advancing content-integrated language instruction, the representation of diverse cultures and viewpoints within scholarship stands to grow through more equitable distribution of research participation worldwide. This enrichment of perspectives has profound ramifications for enriching scientific progress.

Educational technologies facilitating virtual language exchanges beyond physical classrooms are, moreover, catalysts for relationship-building across borders. Such networks are pivotal to advancing science collaboratively on a shared global stage. Our findings also implied that AI may help rebalance the consequences of English dominance by empowering equitable contributions from researchers internationally. When normalized, AI presents an avenue for non-native English authors to directly engage in science at scale while minimizing impediments from inconsistent human-led English teaching alone.

Remotely accessible AI-based English training also carries implications for broadening international student recruitment potentials. The provision of competitive language skills without geographical constraints could allow exceptional students to study abroad regardless of lack of English fluency or financial resources previously. This expanded accessibility bolsters representative excellence and talent mobilization within global higher education.

Conclusion

Our research findings provided strong evidence that AI-based immersive language training was more effective in enhancing English proficiency compared with traditional human-led instruction. This AI-powered approach demonstrated the ability to significantly improve the English communication skills of NEECRs, a population that often faces persistent language challenges.

Our results suggested that leveraging AI's capabilities could be an effective way to help equip more researchers internationally with the vital language skills required for research internationalization. The enhanced English abilities facilitated by the AI training may also support increased proposal submissions to international funding sources.

Overall, our findings offered encouragement for the role of AI in promoting research productivity and educational equity worldwide. Harnessing the technology's capacity to develop advanced communicative competence could significantly further the internationalization and diversity of scientific networks globally.

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Appendix

1. Self-Reported English Language Proficiency Questionnaire

Dear respondent,

We are researchers at the Federal University Oye-Ekiti conducting a study to compare the effectiveness of AI-assisted workshops versus human-led workshops in developing the English language proficiency of early career researchers. We would greatly appreciate if you would take 15–20 minutes to fill out the attached questionnaire, which seeks to understanding respondents' self-reported English abilities across key areas. Please note that your responses will be kept strictly anonymous and confidential, with only aggregate data being reported for research purposes of evaluating different workshop methods. Your participation is invaluable for the successful completion of this important project. We thank you in advance for your time and effort, as it will help advance our goal of our research.

Section A: Sociodemographic Information

Please answer by ticking (✓) in the spaces provided.

1. Gender: Male ☐ Female ☐
2. Highest Education: PhD ☐ MSc ☐ Others ☐
3. Career Grade level: Asst. Lecturer ☐ Lecturer II ☐ Lecturer I ☐
4. Age: 20–30 years ☐ 31–40 years ☐ Above 40 years ☐
5. Religion: Christianity ☐ Islam ☐ Traditional ☐ Others ☐

Section B: Perceived Vocabulary Proficiency

For each of the following items, kindly tick in the following boxes to indicate how the questions apply to you. Kindly tick only once in each item.

1. When reading research papers, how often do you encounter unknown vocabulary?
 - a) Never
 - b) Occasionally
 - c) Sometimes
 - d) Usually
 - e) Constantly
2. How well can you understand specialized terminology in your own research field?
 - a) Extremely well
 - b) Very well
 - c) Somewhat well
 - d) Not very well
 - e) Not at all
3. How easily can you understand new discipline-specific vocabulary?
 - a) Extremely easily
 - b) Quite easily
 - c) Somewhat easily
 - d) Not very easily
 - e) Not at all easily
4. When having academic discussions, how well can you discuss complex concepts?
 - a) Exceptionally well
 - b) Very well
 - c) Moderately well
 - d) Slightly well
 - e) Not at all well

5. To what extent can you recognize connotation and nuanced meaning?
 - a) To a great extent
 - b) To a considerable extent
 - c) To some extent
 - d) To a limited extent
 - e) Not at all
6. How easily can you use new collocations productively in writing?
 - a) Extremely easily
 - b) Quite easily
 - c) Moderately easily
 - d) With some difficulty
 - e) With great difficulty
7. How comfortable are you explaining word meanings to others?
 - a) Extremely comfortable
 - b) Very comfortable
 - c) Somewhat comfortable
 - d) Slightly comfortable
 - e) Never comfortable
8. Overall, how can you rate your vocabulary proficiency?
 - a) Advanced
 - b) Upper-intermediate
 - c) Intermediate
 - d) Lower-intermediate
 - e) Novice

Section C: Perceived Grammar Proficiency

For each of the following items, kindly tick in the following boxes to indicate how the questions apply to you. Kindly tick only once in each item.

1. When reading, how often do you misunderstand grammar structures?
 - a) Frequently
 - b) Occasionally
 - c) Rarely
 - d) Very rarely
 - e) Never
2. How accurately can you use a variety of complex sentence structures?
 - a) Near native accuracy
 - b) Generally accurate
 - c) More errors than correct
 - d) Frequent errors
 - e) No mastery
3. How easily can you recognize grammatical functions like subject, object, tense?
 - a) Instantly
 - b) Very quickly
 - c) After some thought
 - d) With difficulty
 - e) Unable to recognize

4. How well can you use verb forms and tenses appropriately?
 - a) Proficiently
 - b) Adequately
 - c) Some gaps in use
 - d) Frequent errors
 - e) Major difficulties
5. How successfully can you produce coherent paragraphs?
 - a) Very successfully
 - b) Mostly successfully
 - c) Some success
 - d) Limited success
 - e) Unable to produce
6. How well do you understand complex grammatical structures?
 - a) Completely
 - b) Very well
 - c) Fairly well
 - d) Some understanding
 - e) Little to no understanding
7. How comfortable are you explaining grammar to others?
 - a) Very comfortable
 - b) Somewhat comfortable
 - c) Neither comfortable nor uncomfortable
 - d) Somewhat uncomfortable
 - e) Very uncomfortable
8. How easily can you self-correct errors in grammar?
 - a) Very easily
 - b) Easily
 - c) With some effort
 - d) With difficulty
 - e) Unable to self-correct
9. Overall, how would you rate your grammar skills?
 - a) Proficient
 - b) Competent
 - c) Modest
 - d) Limited
 - e) Novice
10. How confident are you in your ability to use grammar accurately?
 - a) Very confident
 - b) Somewhat confident
 - c) Neither confident nor unconfident
 - d) Not very confident
 - e) Never confident

Section D: Perceived Reading Comprehension

For each of the following items, kindly tick in the following boxes to indicate how the questions apply to you. Kindly tick only once in each item.

1. How quickly can you understand general meanings from multiple complex texts?
 - a) Very quickly
 - b) Quickly
 - c) Moderately quickly
 - d) Slowly
 - e) Very slowly
2. How easily can you infer implied meanings from a variety of passages?
 - a) Easily
 - b) Mostly easily
 - c) With some effort
 - d) With difficulty
 - e) Unable to infer meaning
3. How well can you understand detailed information from specialized sources?
 - a) Very well
 - b) Well
 - c) Adequately
 - d) With some gaps
 - e) Never understand details
4. How successfully can you understand subtle, elaborated interactions between ideas?
 - a) Very successfully
 - b) Mostly successfully
 - c) Sometimes successful
 - d) Occasionally successful
 - e) Never understand interactions
5. How easily can you read quickly enough to meet academic needs?
 - a) Very easily
 - b) Easily
 - c) With reasonable effort
 - d) With some difficulty
 - e) Cannot read fast enough
6. How well can you understand conclusions and opinions in long complex texts?
 - a) Very well
 - b) Well
 - c) Adequately
 - d) With some gaps
 - e) Cannot understand conclusions
7. How comfortable are you discussing texts and summarizing key issues?
 - a) Very comfortable
 - b) Mostly comfortable
 - c) Neither comfortable nor uncomfortable
 - d) Somewhat uncomfortable
 - e) Very uncomfortable

8. How confident are you in your reading comprehension abilities?
 - a) Very confident
 - b) Somewhat confident
 - c) Unsure
 - d) Not very confident
 - e) Not at all confident
9. Overall, how would you rate your reading comprehension skills?
 - a) Superior
 - b) Strong
 - c) Adequate
 - d) Limited
 - e) Poor
10. How successful are you at adjusting reading strategies based on text-type?
 - a) Very successful
 - b) Mostly successful
 - c) Sometimes successful
 - d) Rarely successful
 - e) Never successful

Section E: Perceived Writing Skill

For each of the following items, kindly tick in the following boxes to indicate how the questions apply to you. Kindly tick only once in each item.

1. How easily can you write clear, well-structured texts of complex subjects?
 - a) Very easily
 - b) Easily
 - c) With some effort
 - d) With difficulty
 - e) Unable to write clearly
2. How well developed is your sense of appropriate academic style/register?
 - a) Highly developed
 - b) Well developed
 - c) Adequately developed
 - d) Underdeveloped
 - e) Not developed
3. How accurate is your control of organizational patterns, connectors, and cohesion?
 - a) Very accurate
 - b) Mostly accurate
 - c) Generally accurate
 - d) Limited accuracy
 - e) Not accurate
4. How successful are you at summarizing multiple written sources consistently?
 - a) Very successful
 - b) Mostly successful
 - c) Sometimes successful
 - d) Rarely successful
 - e) Unsuccessful

5. How comfortably can you write about complex abstract topics?
 - a) Very comfortably
 - b) Comfortably
 - c) Acceptably
 - d) With discomfort
 - e) Cannot write comfortably
6. How effectively can you convey finer shades of meaning precisely?
 - a) Very effectively
 - b) Effectively
 - c) Generally effectively
 - d) Limited effectiveness
 - e) Ineffectively
7. How fluent is your writing style for an academic audience?
 - a) Highly fluent
 - b) Fluent
 - c) Adequately fluent
 - d) Limited fluency
 - e) Not fluent
8. Overall, how proficient would you consider your writing ability?
 - a) Proficient
 - b) Competent
 - c) Modest
 - d) Limited
 - e) Novice
9. How confident are you in editing your own writing before submission?
 - a) Very confident
 - b) Somewhat confident
 - c) Neither confident nor unconfident
 - d) Not very confident
 - e) Not at all confident
10. How successfully can you use formatting/style required in your field?
 - a) Very successfully
 - b) Successfully
 - c) Acceptably
 - d) Limited success
 - e) Unsuccessfully

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