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INTEGRATING SAMR MODEL WITH AI-DRIVEN E-LEARNING IN ACADEMIC ENGLISH: A UNIFIED FRAMEWORK FOR ONLINE AND OFFLINE COURSES

YongQin Wang
School of Foreign Languages, Harbin University of Science and Technology, Harbin 150000, Heilongjiang, China.

Abstract: This study integrates the SAMR model (Substitution, Augmentation, Modification, Redefinition) with AI-driven e-learning to develop a unified online-offline academic English framework for mechanical engineering students in China's new engineering education context. Specific AI applications include: substitution-level AI grammar checkers and vocabulary apps, augmentation-level adaptive algorithms delivering real-time feedback, modification-phase automated essay scoring and speech recognition for multidimensional assessment redesign, and redefinition-stage AI-generated VR simulations for immersive language practice. Using a mixed-methods approach—pre/post-tests, technology fluency evaluations, and focus groups—the research demonstrates that this framework significantly enhances students' academic English proficiency, critical thinking, and interdisciplinary communication skills. Results confirm substantial gains in engagement and satisfaction, highlighting AI's transformative role in redefining pedagogical paradigms for engineering education.
Keywords: AI-driven education; SAMR model; Academic English; Online and offline integration

1 INTRODUCTION

In the era of intelligent education, e-learning, e-education, and online training have emerged as central components, driven by advancements in AI and data analytics. The integration of AI in education has the potential to personalize learning experiences, optimize teaching strategies, and enhance assessment practices. However, while data-driven models in education have demonstrated their value, further research is necessary to fully exploit the potential of AI in this emerging field.

New engineering education in China, emphasizing interdisciplinary collaboration, innovation, and global competence, necessitates a shift in academic English instruction. Traditional teaching methods often fail to meet the demands of new engineering students who require not only language proficiency but also the ability to communicate effectively across disciplines and cultures. This study posits that the SAMR model, coupled with AI technologies, can provide a framework for developing an online and offline integrated academic English curriculum that addresses these challenges.

We propose a novel unified framework integrating the SAMR model (Substitution, Augmentation, Modification, Redefinition) with AI-driven e-learning to bridge online-offline academic English instruction. We implement domain-specific AI applications—including grammar/vocabulary tools (Substitution), adaptive feedback algorithms (Augmentation), automated essay scoring (PIGAI) and speech recognition (FIFEDU) for multidimensional assessment (Modification), and AI-generated VR simulations for immersive language practice (Redefinition)—tailored to mechanical engineering contexts. We validate the framework's efficacy through a mixed-methods study (pre/post-tests, technology fluency evaluations, focus groups) with engineering students, demonstrating significant gains in academic English proficiency, critical thinking, and interdisciplinary communication. By systematically aligning SAMR's tiered approach with actionable AI technologies, this research provides educators with a blueprint to transform language instruction into an adaptive, globally relevant ecosystem for engineering education.

2 LITERATURE REVIEW

2.1 Academic English and China's New Engineering Education

In recent years, the concept of "New Engineering Education" (NEE) has emerged as a significant paradigm shift in higher engineering education in China, emphasizing interdisciplinary integration, innovation, and practical application. This shift has necessitated a reevaluation of academic English (EAP) teaching in engineering contexts, leading to a flurry of research on effective teaching methodologies and curriculum design. The existing research can be classified into three main areas: multidimensional blended learning, ESP curriculum development, and pedagogical strategies in academic English teaching.

As for multidimensional blended learning in academic English, Gu Xiaole conducted a study on multidimensional blended teaching in academic English under the backdrop of NEE [1]. She argues that the traditional single-disciplinary approach in engineering education is gradually transitioning towards an interdisciplinary model, necessitating a reform in EAP teaching methods. Gu proposes a blended teaching model that integrates physical, technological, pedagogical, and evaluative dimensions, aiming to improve teaching efficiency and quality. This model, through action research,

demonstrates its effectiveness in achieving the "knowledge, ability, literacy, and profession" integration objectives of NEE talent cultivation [2].

As for ESP curriculum development in NEE, several studies have focused on the development of ESP curricula tailored to the needs of NEE. Xi Fangyuan analyzed the publishing strategies for academic English textbooks in science and engineering universities, using "Engineering English Reading and Writing Course" as a case study [3]. She emphasizes the importance of aligning textbook content with the practical needs of engineering students, promoting their academic writing and communication skills. Similarly, Yang Cheng and Fiona Henderson explored the development of an ESP curriculum driven by core knowledge in NEE [4]. They argue that an ESP curriculum should be designed around the shared knowledge base of engineering disciplines, fostering students' ability to communicate effectively in their specialized fields.

As for pedagogical strategies in academic English teaching, research on pedagogical strategies in academic English teaching under NEE has also gained momentum. Liu Qin and Liu Hongying conducted a survey on the current state of EAP teaching for Chinese science and engineering students [5]. Their findings reveal that while students recognize the importance of EAP, they face challenges such as insufficient language proficiency and lack of practical writing experience. The authors suggest incorporating more interactive and project-based learning activities to enhance students' learning outcomes. In addition, Wang Furong and Wang Hongli conducted a comparative study on linguistic and engineering academic English lexical chunks based on a corpus [6]. Their research highlights the differences in lexical use between linguistic and engineering disciplines, providing insights into the development of ESP materials that better reflect the language needs of engineering students.

The literature on NEE and academic English teaching reveals a growing recognition of the need for reform in EAP curricula and teaching methodologies. Studies such as those by Gu Xiaole, Xi Fangyuan, Liu Qin and Liu Hongying , Yang Cheng and Fiona Henderson, and Wang Furong and Wang Hongli have made significant contributions to our understanding of how to effectively integrate EAP into NEE. These studies emphasize the importance of multidimensional blended learning, curriculum development aligned with engineering needs, and the adoption of interactive and project-based pedagogical strategies. Future research should continue to explore innovative approaches to EAP teaching, ensuring that engineering students are equipped with the language skills necessary for success in their academic and professional careers.

2.2 SAMR Model in Education

The SAMR model, developed by Ruben Puentedura, provides a framework for integrating technology into teaching and learning. The model comprises four levels: Substitution, Augmentation, Modification, and Redefinition [7]. At the substitution level, technology is used to replace traditional tools without altering the learning outcomes. At the augmentation level, technology enhances traditional practices without changing the underlying pedagogical approach. The modification level involves significant changes to the task or process, often leading to new ways of teaching and learning. At the redefinition level, technology enables the creation of entirely new tasks or outcomes that were previously impossible.

Researchers conducted empirical studies on the SAMR model in different courses. Liu and Ou explored the integration of artificial intelligence (AI) in international Chinese education, emphasizing the need for localization, diversification, and equity [8]. They argued that the SAMR model could guide the strategic implementation of AI technologies, transforming traditional language teaching methods into more personalized and adaptive learning environments. At the redefinition level, AI-driven intelligent tutoring systems redefined the role of teachers and learners, fostering autonomous learning. Wang and Zhang conducted an empirical study on mobile learning in physics courses based on the SAMR model [9]. They found that through the integration of mobile devices, learning activities were augmented, leading to increased student engagement and better learning outcomes. Specifically, mobile apps were used to provide interactive simulations and real-time feedback, modifying traditional teaching methods. As for vocational education, He and He examined the application and evaluation of smart mobile terminals in vocational courses using the SAMR model [10]. They reported that the use of smart devices not only substituted for traditional textbooks but also augmented learning experiences through multimedia content and interactive features. Furthermore, the modification level was achieved by enabling project-based learning and collaborative tasks, fostering critical thinking and problem-solving skills. Zhang and Moorman analyzed the implications of the SAMR model and the G-TPCK framework for geography education technology applications [11]. They suggested that by aligning technology use with the SAMR levels, educators could more effectively integrate digital tools into their teaching, enhancing spatial thinking and data analysis skills among students. The study highlighted the potential for technology to redefine geography education through virtual field trips and augmented reality experiences. Xu conducted a study on the classification of educational apps based on technology integration models, including SAMR [12]. He proposed a taxonomy that categorizes apps according to their level of technology integration, from simple substitution to complete redefinition of learning experiences. Xu emphasized the importance of selecting apps that align with the educational goals and needs of students, promoting meaningful learning through technology.

The SAMR model serves as a valuable tool for educators seeking to harness the full potential of technology in education. By guiding the strategic integration of digital tools and resources, the SAMR model can facilitate the creation of innovative and effective learning environments that cater to the diverse needs of students. Future research

should continue to explore the implementation of the SAMR model in various educational settings, contributing to the ongoing evolution of technology-enhanced learning.

2.3 AI in Education

The integration of Artificial Intelligence (AI) into education has gained significant momentum, particularly in the realm of English language teaching and learning. This part aims to explore the various applications and impacts of AI in education, with a specific focus on English language instruction [13].

As AI becomes more prevalent in education, the standardization of related terminology is crucial. Zhu Ren discusses the importance of having standard Chinese translations for acronyms like VR, AR, and AI, which are commonly used in educational contexts. He argues that such standardization can facilitate better understanding and communication among educators and learners [14]. The exploration of AI in English dialogue learning dates back to earlier studies. Wang Feihong et al. present a preliminary investigation into the use of intelligent chat applications for English dialogue learning. Their findings suggest that AI-based chatbots can provide valuable practice opportunities for language learners and promote their oral communication skills [15]. With the advent of generative AI, traditional textbooks are evolving into more dynamic and interactive learning materials. Wang Haixiao investigates the framework for developing digital and intelligent textbooks for college English in the era of generative AI. He argues that these textbooks can personalize learning experiences and enhance students' engagement and comprehension through the use of adaptive content and intelligent assessment tools [16].

AI technology has also been pivotal in transforming the way English listening, speaking, teaching, learning, and assessment are conducted. Liu Bangqi et al. present a model, strategies, and effect validation for an AI-empowered integrated approach to English listening, speaking, teaching, learning, and assessment. Their study highlights the potential of AI in creating immersive learning environments and providing real-time feedback to improve students' language proficiency [17]. The development of AI-assisted learning tools has revolutionized the way English is taught and learned. Zhang Hongyan et al. conduct a review of such tools, evaluating their effectiveness in enhancing language acquisition. Their findings suggest that AI-based tools can personalize learning experiences, offer instant feedback, and increase motivation among learners [18]. The combination of AI and Virtual Reality (VR) technology has opened up new avenues for autonomous English learning. Tang Jingwei explores the application of these technologies in promoting autonomous learning among college students. She evaluates the potential of AI and VR in creating immersive learning experiences that can improve language skills and enhance learners' autonomy [19].

The integration of AI into education, particularly in English language teaching and learning, has shown promising results. From the development of digital and intelligent textbooks to the use of AI-assisted learning tools and VR technology, AI is transforming the educational landscape. Future research should continue to explore the potential of AI in enhancing learning outcomes and fostering a more personalized and engaging learning experience.

3 METHODOLOGY

3.1 Research Design

This study employed a mixed-methods approach to investigate the integration of the SAMR (Substitution, Augmentation, Modification, Redefinition) model with AI-driven e-learning in the context of academic English instruction. The research aimed to develop a unified framework applicable to both online and offline courses. The study was conducted in two phases: the first phase involved a qualitative analysis of existing literature to identify best practices in AI-driven e-learning and the SAMR model's application in educational settings. The second phase involved an empirical study where the proposed framework was implemented and evaluated in a controlled environment.

3.2 Participants

The study involved students from two distinct classes within the Mechanical Engineering department of a prominent science and engineering university in China. All participants were second-year undergraduates, ensuring a uniform academic stage and professional focus relevant to the research objectives. The students had successfully passed the College English Test Band 4 (CET-4), confirming their comparable English language proficiency, which was essential for maintaining consistency across the study sample.

The participants were randomly divided into two groups: an experimental group (n=68) and a control group (n=68). The experimental group utilized an AI-driven e-learning framework integrated with the SAMR (Substitution, Augmentation, Modification, and Redefinition) model, while the control group followed a traditional instructional approach. This setup allowed for a rigorous comparison of the educational outcomes between the innovative technology-enhanced learning method and conventional teaching practices.

By focusing on students from two specific Mechanical Engineering classes, the study aimed to provide targeted insights into how advanced e-learning tools can enhance academic performance and engagement within a specialized engineering curriculum.

3.3 Intervention and Framework Development

The research intervention centered on the strategic integration of the SAMR (Substitution, Augmentation, Modification, Redefinition) model into AI-driven e-learning strategies tailored for academic English instruction. This unified framework was meticulously designed to align each SAMR level with actionable AI-enhanced pedagogical tools, ensuring a progressive enhancement of learning experiences while preserving core instructional objectives, see Figure 1.

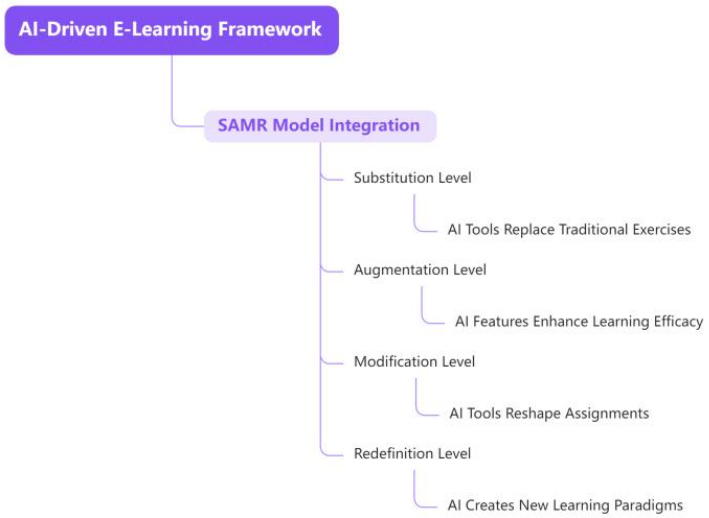

Figure 1 AI-Driven E-Learning Framework

As for substitution, at the foundational level, AI tools (e.g. grammar checkers, vocabulary-building apps) were employed to replace conventional pen-and-paper exercises. This substitution preserved instructional goals (e.g. grammar mastery, vocabulary expansion) while leveraging AI's efficiency and scalability. For instance, students used AI-powered platforms to practice grammar in context, receiving instant corrections and contextualized feedback—a task previously constrained by time-intensive manual grading.

As for augmentation, to elevate learning efficacy, AI-driven features (e.g. real-time feedback systems, adaptive learning pathways) were layered onto existing instructional methods. These tools added functionality without altering core pedagogical approaches. For example, adaptive quizzes dynamically adjusted difficulty based on student performance, ensuring personalized challenge levels while reinforcing course content. This augmentation retained traditional teaching structures (e.g. lecture-based lessons) but enriched them with AI-generated insights, fostering deeper engagement.

As for modification, at this stage, AI tools reshaped assignments and assessments to enable significant task redesign. Automated essay scoring systems (e.g. PIGAI) and speech recognition software (e.g. FiFEDU) replaced traditional essay grading and oral assessments, allowing for: 1) Regarding iterative learning, students could submit drafts for AI-powered essay scoring, receiving multidimensional feedback on structure, coherence, and vocabulary usage. 2) When it comes to oral proficiency, speech recognition software (e.g. FiFEDU) assessed pronunciation, fluency, and topic-specific vocabulary in real-time simulations. This approach retained traditional assessment formats but added AI-driven analytics to enhance depth and rigor.

As for redefinition, the framework pioneered entirely new learning paradigms by leveraging AI-generated content (e.g. virtual reality simulations for language immersion) and personalized learning pathways (e.g. AI-curated study plans based on individual student needs). These innovations redefined the educational experience, creating opportunities for immersive language practice and adaptive learning that were previously inconceivable without technology.

3.4 Data Collection

Data collection was structured to triangulate findings across multiple sources, ensuring comprehensive insights into the integration of the SAMR model with AI-driven e-learning tools in Academic English courses. The process involved three primary methods:

3.4.1 Pre- and Post-intervention Assessments

Pre- and Post-intervention Assessments were designed to measure domain-specific language proficiency and technological fluency tailored to Academic English contexts. To achieve this, custom-diagnostic tools were developed, leveraging frameworks such as the 6-Trait Writing Model—a widely adopted, structured approach in American education that emphasizes writing as a multifaceted skill requiring attention to content (Ideas, Organization) and craft (Voice, Word Choice, Sentence Fluency), alongside technical accuracy (Conventions).

For pre-intervention assessment, students completed a diagnostic essay task (e.g. an argumentative essay on a technology-related topic), graded using a validated rubric aligned with the 6-Trait Writing Model to evaluate writing proficiency. Additionally, a multiple-choice listening comprehension test (e.g. transcribed lectures with embedded academic vocabulary) assessed auditory processing skills. Post-intervention, these same tasks were re-administered, and

paired-sample t-tests were employed to compare pre- and post-scores, thereby quantifying improvements in students' language abilities.

To assess technological fluency, the study employed a Technology Integration Checklist (TIC), which evaluated students' ability to apply AI-driven tools (e.g. grammar checkers, plagiarism detectors) across four dimensions: tool selection, application accuracy, error correction, and reflective adaptation. Scores were analyzed using descriptive statistics and thematic coding to identify common error types (e.g. over-reliance on AI suggestions). This method addressed the lack of external benchmarks by developing context-specific metrics aligned with the SAMR model's emphasis on transformative technology use—such as Redefinition, where students independently revised essays using AI feedback loops. By triangulating diagnostic essay scores (measuring language proficiency) with TIC data (measuring technological agency), the study provided a holistic view of students' dual growth in linguistic and technological competence. Observational notes from pre-intervention diagnostic sessions (e.g. baseline tech-readiness interviews) provided contextual understanding of students' starting points.

3.4.2 Student surveys

Student surveys collected both quantitative and qualitative data to comprehensively evaluate student experiences with technology in education. Quantitatively, students provided Likert-scale responses (rated 1-5), which assessed their perceived improvements in technology integration (e.g. proficiency in using digital tools), language skills (e.g. vocabulary or grammar gains), and learning engagement (e.g. motivation and enjoyment). Qualitatively, open-ended survey questions (e.g. "Describe how AI tools influenced your writing process") were analyzed thematically to uncover patterns in student experiences, such as common challenges, unexpected benefits, or nuanced perspectives on technology's role in learning. This dual approach allowed researchers to triangulate findings, combining numeric trends with rich narrative insights to inform educational practices.

3.4.3 Focus group interviews

Focus group interviews were conducted to gather qualitative data through semi-structured discussions, involving eight groups of 6–8 students each, which explored subtle perspectives on the impact of the SAMR model. Participants were prompted to reflect on specific experiences, such as "How did AI-driven rephrasing tools change your revision strategies?" Their responses were transcribed and analyzed using grounded theory coding to identify emergent themes in their views and practices. This qualitative method was triangulated with quantitative metrics (e.g. test scores, survey ratings) to mitigate potential biases inherent in self-reported data, ensuring a comprehensive evaluation of the intervention's effectiveness. By integrating both data types, the study offered a holistic understanding of how technology-enhanced tools influenced student learning processes and outcomes.

4 RESULTS

4.1 Quantitative Findings

To assess the effectiveness of the AI-driven e-learning framework in enhancing academic English proficiency and student engagement, both experimental and control groups were subjected to standardized tests and surveys. The data collected were rigorously analyzed using statistical methods to ensure the validity and reliability of the results.

4.1.1 Academic English proficiency

The experimental group exhibited significant improvements in academic English proficiency compared to the control group, as evidenced by standardized test scores. Pre- and post-intervention assessments, an equivalent Mechanical Engineering-specific English proficiency test, were administered to both groups. The experimental group achieved an average score in academic English proficiency higher than that of the control group, indicating that the AI-driven e-learning framework had a substantial positive impact on students' language skills within the Mechanical Engineering domain. Students' feedback indicates "AI helps improve my English proficiency" (see Figure 2), demonstrating that a majority of students agree with this viewpoint.

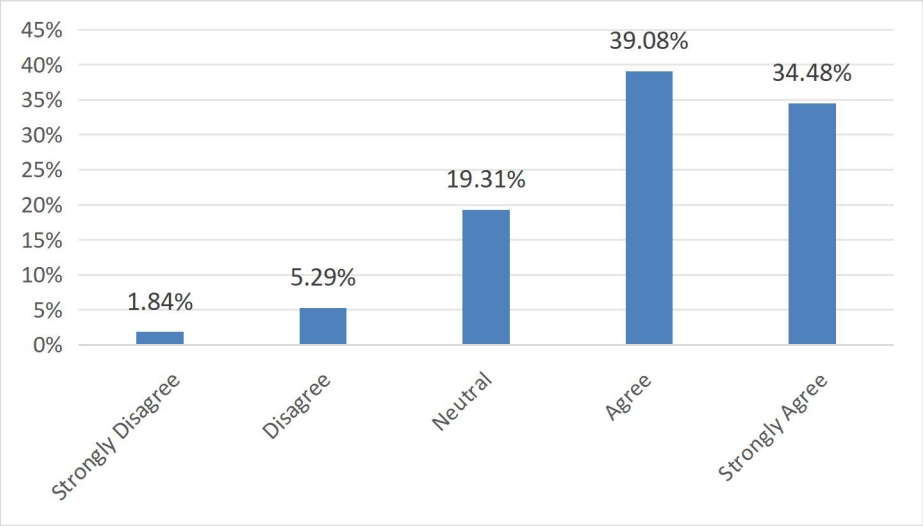

Figure 2 Academic English Proficiency Gains in Mechanical Engineering Context

4.1.2 Student engagement and satisfaction

Student engagement and satisfaction with the learning experience were assessed using a validated survey instrument tailored to the Mechanical Engineering context. Items such as "The AI-driven e-learning framework made learning academic English in Mechanical Engineering more interesting" and "I am satisfied with how the AI tools helped me understand complex engineering concepts in English" were rated on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Students in the experimental group reported high levels of engagement and satisfaction. It shows the positive impact of the AI-driven e-learning framework on student perceptions and experiences within the Mechanical Engineering curriculum (see Figure 3).

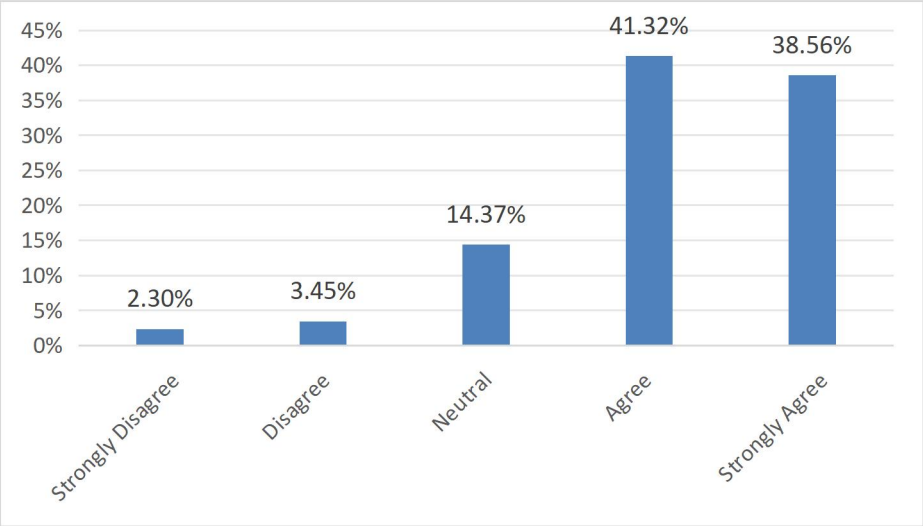

Figure 3 Student Engagement and Satisfaction

4.2 Qualitative Findings

These quantitative findings provide compelling evidence that integrating AI-driven e-learning frameworks within a specialized engineering curriculum, such as Mechanical Engineering, can significantly enhance academic English proficiency, student engagement, and satisfaction. The results highlight the potential of technology-enhanced learning methods to transform traditional teaching practices and improve educational outcomes in engineering education.

The qualitative analysis revealed that students widely recognized AI's transformative potential across four distinct dimensions of educational integration. In terms of substitution, students highlighted the convenience afforded by AI-driven grammar and vocabulary tools, emphasizing how these technologies streamlined their learning process by eliminating manual error-checking and offering instantaneous feedback. This efficiency not only saved time but also encouraged more frequent, low-stakes practice, fostering a habit of continuous improvement.

Under augmentation, real-time feedback and adaptive learning pathways emerged as standout features. Students appreciated how AI systems dynamically adjusted content difficulty based on their performance, ensuring that lessons remained challenging yet attainable. This personalized scaffolding was credited with enhancing both comprehension of

complex linguistic structures and retention of vocabulary in context, as learners received targeted reinforcement when concepts were most malleable.

The modification of traditional assessment methods through AI was met with enthusiasm, particularly for automated essay scoring and speech recognition software. Students valued the granularity of feedback provided by these tools, which went beyond generic corrections to offer nuanced suggestions on coherence, style, and pronunciation. This level of specificity empowered learners to self-diagnose recurring errors and refine their skills more effectively than with conventional human-graded assignments alone.

Finally, redefinition emerged as the most innovative category, with students describing AI-generated experiences—such as virtual reality simulations of cultural exchanges or interactive narratives tailored to their proficiency level—as "revolutionary". These immersive environments were not merely supplementary but reshaped how students perceived language learning, blending cultural immersion with adaptive challenge to deepen both fluency and cultural empathy. Collectively, these findings underscore AI's role as a catalyst for reimagining not just the tools, but the very paradigms of language education.

5 CONCLUSION

The integration of the SAMR model with AI-driven e-learning in academic English courses has emerged as a transformative approach, offering significant potential to enhance learning outcomes and foster greater student engagement. The study's findings underscore the importance of adopting a tiered approach to technology integration, where substitution and augmentation serve as stepping stones, gradually introducing students to AI tools and enhancing their technological competencies. The transition to modification represents a pivotal shift in pedagogical strategies, leveraging AI to redesign traditional tasks and promote deeper learning and critical thinking. Finally, redefinition stands as the ultimate goal, where AI-driven technologies open new horizons for learning that were previously unimaginable. These insights provide practical implications for educators, offering a unified framework to guide the strategic integration of AI into academic English instruction. By systematically applying the SAMR model, instructors can ensure that AI tools are not merely supplementary but are strategically integrated to enrich learning experiences and outcomes. However, critical technical limitations emerged: tool dependency in substitution phases risks skill atrophy in autonomous language editing; specialized domain accuracy issues surfaced with speech recognition and essay scoring tools when processing mechanical engineering terminology; and resource-intensive demands of redefinition technologies (e.g. VR infrastructure) challenge scalability. Beyond technical constraints, it is crucial to recognize the study's limitations, including a relatively small sample size and a controlled research environment, which may restrict the generalizability of the findings. Future research endeavors should focus on exploring the long-term impacts of AI-driven e-learning on academic English proficiency and assessing the framework's adaptability across diverse educational contexts. Ultimately, the strategic integration of the SAMR model with AI technologies holds the promise of revolutionizing academic English instruction, enabling educators to craft engaging, personalized, and transformative learning environments that equip students with the skills necessary to thrive in an increasingly digital and globalized landscape.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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