REVIEW ARTICLE

Artificial intelligence in aviation English testing

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Abstract
In the field of aviation, English language proficiency is essential for ensuring clear communication and safe flight operations. Effective assessment of pilots' and air traffic controllers' aviation English (AE) proficiency is, therefore, crucial. Conventional AE proficiency assessments, while effective, face limitations in scalability, objectivity, and feedback mechanisms. This article reviews the advancements and effectiveness of AI-driven assessment tools for AE proficiency testing, highlighting their potential to overcome these limitations. The review encompasses AI technologies such as automated speech recognition (ASR), natural language processing (NLP), and intelligent tutoring systems (ITS) in the light of the language proficiency requirements stated by the International Civil Aviation Organization (ICAO). Overall, the present review concludes that AI-driven tools provide accurate, reliable, and immediate feedback, significantly improving learners' AE proficiency. Despite challenges such as speech recognition errors and ethical concerns, these tools offer scalable and accessible solutions for large aviation training programs. The review concludes with recommendations for future research, emphasizing the need for continued innovation to address technological limitations and enhance adaptive learning environments. This review offers valuable insights for English for Specific Purposes (ESP) practitioners and stakeholders in the aviation industry.

https://doi.org/10.47216/literacytrek.1556603

Keywords
AI-driven assessment, Artificial intelligence, Aviation English, Generative AI, Language proficiency testing

Submission date
26.09.2024
Acceptance date
25.12.2024

Introduction

The proficiency in Aviation English (AE) is paramount to ensure precise and effective communication among aviation professionals, which includes, but not limited to, pilots and air traffic controllers (ATCOs). In the ever-growing aviation industry, each flight operation must be flawless, which is pivotal for global connectivity and trade. Considering this nature of aviation, there is an indispensable need for clear and effective communication both in the air and on the ground, which is not just for operational convenience but as a matter of safety and prevention of potential calamities. Although safety in the aviation industry has significantly improved over the decades, human

factors remain a persistent challenge (Dobson, 2017). Diminishing the number of incidents and accidents resulting from human factors is, therefore, an unremitting battle for aviation authorities. Even the slightest communication error between pilots and ATCOs can mean the difference between a safe departure and a disaster, which was noted in the infamous Tenerife Disaster. Unsurprisingly, miscommunication between pilots and ATCOs makes up a substantial portion of human errors. The research into miscommunication in aviation is, therefore, getting more attention among scholars. The study conducted by Ishihara and Prado (2021), for instance, revealed a clear link between inaccurate communication and life-threatening situations, as well as significant consequences for misunderstanding in radiotelephony. These instances of miscommunication can vary depending on its nature. These include factors like the language barrier, accent, dialect, ambiguous instruction by the ATCOs, and even technical issues with the radiotelephony devices in the cockpit or with the radio signals. The expected outcome of this communication problem is mostly uniform.

Having taken a lesson from the past, policy makers in aviation realized the need to establish a shared language for effective interactions. The International Civil Aviation Organization (ICAO) mandates that aviation professionals demonstrate Operational Level (Level 4) proficiency in AE, ensuring safety and efficiency in global air traffic operations. The AE language proficiency requirements encompass pronunciation, fluency, vocabulary, comprehension, structure, and interactions. These language proficiency assessment criteria are crucial for mitigating misunderstandings that could lead to safety incidents. Therefore, AE can be argued to serve as tool for a standardized mode of communication. It can also ensure that the exchange of critical information between pilots and ATCOs is intelligible which, in turn, represents a commitment to safety and operational efficiency.

In addition, the proficiency in AE can further bolster safety in aviation since the interlocutors in radio communication, namely pilots and ATCOs, are mandated to comply with the radiotelephony communication regulations defined in the Manual of Radiotelephony (ICAO, 2007). These require pilots and ATCOs to mutually ratify the acknowledgement of the message passed by either interlocutor. This safety procedure is known as *readback*. It refers to the process in which a pilot repeats or acknowledges a

received message or instruction from ATCO. This practice is a critical component of effective communication, ensuring that both the pilot and the controller have a shared understanding of instructions, clearances, or information exchanged during flight operations. When an ATCO issues an instruction to a pilot, such as a takeoff clearance, an altitude change, or a vectoring, the pilot is required to read back the information to confirm its accuracy. This readback procedure serves as a verification step, allowing the ATCO to confirm that the pilot correctly received and understood the given instructions.

The standard format for a readback typically involves the pilot restating the relevant elements of the communication, including the aircraft's call sign, the instruction or clearance received, and any specified details. For example, a readback might include the assigned altitude, heading, or other parameters outlined by the ATCO. Despite technological advancements, radio communication is vulnerable to background noise, impeding the clarity of radiotelephony communications (Dinçer & Demirdöken, 2023). The readback process is, therefore, crucial for preventing misunderstandings and minimizing the risk of errors in air traffic control instructions. It helps maintain a high level of safety in aviation operations by promoting a shared situational awareness between pilots and controllers which, in turn, contributes to the overall efficiency and reliability of air traffic management. Considering the unique and indispensable component of safety in aviation, improving the readback performance of pilots is crucial. The study conducted by Demirdöken and Atay (2024) was designed to serve this purpose. They designed and developed a simulation-based AE course and assigned readback tasks to student pilots who completed various simulated flights by communicating with the ATCO, exchanging flight information with the ATCO, and practicing the readback procedure in every phase of their simulated flight sessions. The results showed that student pilots significantly improved their readback performance by the end of the course.

As a result, the AE practitioners should adopt the latest technology to improve the job-specific English language skills of ESP learners. In the case of AE, developing a better understanding of the components of AE language proficiency, designing and developing effective AE trainings to pilots and air traffic controllers, and assessing the AE proficiency effectively emerge as a significant pursuit for English for Specific Purposes (ESP) researchers and practitioners.

AE Training: From the traditional to the innovational

AE trainings have traditionally relied on in-person classroom teaching and language textbooks. While effective to some extent, these methods often fail to address the dynamic and rapidly evolving nature of aviation operations. The absence of dynamic educational resources and real-world context may hinder the development of essential English language communication skills and situational awareness. To effectively address the limitations of traditional AE instruction, it is essential to adopt a fundamental change in approach. That is, contemporary technology should be leveraged to enhance educational practices. At the forefront of this paradigm shift is the incorporation of Artificial Intelligence (AI), particularly generative AI (Gen-AI), which has the potential to transcend conventional language acquisition barriers. Gen-AI, dedicated to creating novel and contextually appropriate content, has made significant strides in recent years. This technology has transformative potential across various fields, including creative arts, healthcare, and education. In the context of AE language learning, generative AI can revolutionize the process, offering learners' novel opportunities to engage with and achieve proficiency in languages in ways previously inconceivable.

AI technologies provide a range of tools to transform language acquisition, such as Automatic Speech Recognition (ASR) for refining pronunciation and Natural Language Processing (NLP) for enhancing contextual comprehension. These tools provide learners with an immersive experience in genuine aviation situations, allowing them to engage in real-time conversations with AI-generated companions. Intelligent Tutoring Systems (ITS) subsequently tailor individualized learning trajectories, adapting to the unique proficiencies and deficiencies of each learner, while virtual reality (VR) generates immersive settings for practicing communication skills within realistic aircraft scenarios.

The integration of Gen-AI with AE is not just a technical combination, but rather a strategic enhancement of teaching methods. Through the utilization of Gen-AI, instructors may create prompts that simulate authentic aviation communication, merging conventional language instruction with the intricacies of operational flying. Students are immersed in dynamic situations, which promote cognitive flexibility, resilience, and a thorough comprehension of aviation protocols. Moreover, AI-

generated material exemplifies a mutually beneficial collaboration between technology and human skill. Teachers can utilize AI-generated scenarios to customize learning experiences and offer immediate feedback, while students traverse linguistic subtleties and cultural variations in cross-functional aviation settings. The outcome is a comprehensive and proficient command of aviation English that goes beyond only language skills to include operational proficiency and situational awareness. AIEd is commonly categorized into three domains: learning, teaching, and assessment (Luckin, 2017). In addition to its role in student-focused AIEd, AI has the potential to be applied in education administration (system-focused AIEd) and teacher assistance (teacher-focused AIEd) and may even inspire new pedagogical and andragogical methods. Currently, educational data produced by e-learning systems, such as AIEd, are being analyzed by the rapidly expanding fields of educational data mining and learning analytics. This analysis is becoming crucial for policy-making and practical implementation (Hakimi et al., 2021)

To conclude, integration of Gen-AI into AE learning environments represents a significant advancement in the field of ESP. AI-driven tools offer promising solutions to the limitations of traditional methods and compensate for the relatively less efficient traditional AE trainings. In addition, these tools provide student pilots with scalable, objective, and immersive learning experiences. The rapid advancement of AI will undoubtedly offer new possibilities for enhancing AE learning outcomes. Embracing this technological shift will be a crucial upgrade for the design and development of more effective AE courses hence the attainment of English language proficiency among student pilots.

The AI era in education

The AI did not emerge overnight; rather, it came into view after a series advancement in technology. According to Zhai and his colleagues (2021), it was directly associated with the advent of big data, cloud computing, artificial neural networks, and machine learning. They argued that these developments empowered engineers to develop a computer capable of emulating human intelligence. This history can be traced back to the mid-20th century when the foundations of AI were first established. With the advent of machine learning in the early 2000s, AI in education began to leverage more sophisticated algorithms that could learn from data. This era marked a shift from rule-

based systems to data-driven models. Intelligent tutoring systems became more adaptive and capable of providing real-time feedback. For instance, the ASSISTments platform, developed at Worcester Polytechnic Institute, used machine learning to provide immediate feedback and hints to students working on math problems, thus enhancing their learning outcomes.

The 2010s witnessed a significant proliferation of AI-powered educational technologies. Several contemporary AI systems designed for education, commonly referred to as Intelligent Tutoring Systems (ITS), primarily deliver automated, adaptive, and personalized instruction. Natural Language Processing (NLP) and speech recognition technologies enabled the development of AI-driven language learning apps like Duolingo, which provided personalized language instruction to millions of users worldwide. Additionally, AI-based platforms such as Coursera and Khan Academy utilized algorithms to recommend courses, track progress, and personalize learning experiences for students. AI also began to play a role in administrative tasks, helping educators manage grading, attendance, and student engagement. Automated essay scoring systems like the ETS' e-rater could evaluate written responses, providing immediate feedback to students and reducing the workload for teachers.

AI existed for a long time, yet its integration into educational contexts has become pervasive and sophisticated in the 2020s. Currently, it is more widely used due to its proved potential to transform the way educators teach, and students learn. AI-driven adaptive learning platforms like Knewton and Smart Sparrow, for instance, proved that it was possible to personalize content delivery based on individual learning styles and progress. In addition, it was used in predictive analytics to identify students at risk of falling behind, enabling timely interventions. Moreover, the COVID-19 pandemic accelerated the adoption of AI in remote and hybrid learning environments. Virtual classrooms, AI-powered proctoring systems, and interactive AI tutors became essential tools in maintaining educational continuity.

Looking forward, the future of AI in education promises even greater advancements. Emerging technologies such as augmented reality (AR), virtual reality (VR), and the Internet of Things (IoT) are expected to integrate with AI to create immersive and interactive learning experiences. In conclusion, the history of AI in

education is marked by continuous innovation and improvement. From early rule-based systems to sophisticated adaptive learning platforms, AI has transformed education, making it more personalized, efficient, and accessible. As technology continues to evolve, AI's role in education will undoubtedly expand, offering new possibilities for enhancing teaching and learning outcomes.

AI and aviation English

In the rapidly evolving field of aviation, proficiency in Aviation English (AE) is of paramount importance to ensure clear and effective communication between pilots and air traffic controllers. Given the critical nature of this communication, the assessment of AE proficiency emerges as a crucial component of AE training programs. The International Civil Aviation Organization (ICAO) mandates that all pilots and air traffic controllers demonstrate Operational Level (Level 4) proficiency in AE to ensure safety and efficiency in global air traffic operations (ICAO, 2008). Regarding these requirements, proficiency in AE can be argued to encompass several components, including pronunciation, fluency, vocabulary, and comprehension, all of which are crucial for mitigating misunderstandings that could lead to safety incidents (Farris, 2016). Accordingly, the assessment of English language proficiency is a challenging task for ICAO raters. Besides, ensuring the reliability in these raters' scoring appears as an even more difficult task to handle. Considering these challenges and combining them with the traditional methods of assessment make it significantly more complicated for aviation professionals to correctly determine the English language proficiency of pilots. The assessment of AE proficiency through traditional methods, while effective, have limitations in terms of scalability, objectivity, and feedback mechanisms. Typically, the traditional AE proficiency assessments involve standardized tests such as the Test of English for Aviation (TEA) and the ICAO English Language Proficiency Tests (ELPT). These assessments often require human raters to evaluate spoken and written responses, which can introduce subjectivity and inconsistencies (Kim & Elder, 2009). Additionally, the manual nature of these assessments can limit the frequency and comprehensiveness of feedback provided to learners. The integration of AI into AE language proficiency assessment processes offers promising advancements in addressing these limitations. It is, therefore, one of the main concerns of this paper to review the current state of AI-

driven assessment tools for AE proficiency testing, exploring their methodologies, effectiveness, and potential implications for the future of aviation training.

AI-driven assessment tools can significantly improve the overall AE language proficiency assessment in many ways. To illustrate, AI tools utilize machine learning algorithms and natural language processing (NLP) techniques to evaluate language proficiency. These tools offer several advantages, including real-time feedback, scalability, and the ability to provide consistent and objective assessments. The incorporation of AI as a tool to streamline or potentially supplant human labor is becoming more widespread, with applications including several fields such as healthcare, computer sciences, and education. AI is currently being utilized in the field of education alongside other rising trends like Smart Classrooms, Personal Learning Environments, and Learning Analytics. These technologies facilitate the use of data-driven methods to evaluate and forecast the effectiveness of new procedures, aiding in the decision-making process. In addition, AI functions as an educational tool for teaching subjects like music and mathematics, as well as for creating tutoring and adaptive systems. In addition, there are intriguing applications of AI in contexts other than aviation, and these applications are connected to feedback (González-Calatayud, 2021). Studies have shown that AI-driven tools can effectively evaluate pronunciation, fluency, and other linguistic features with a high degree of accuracy (Chen et al., 2020; Yoon et al., 2021). However, the application of AI in AE proficiency testing is a relatively new area of research. AI tools such as automated speech recognition (ASR) and intelligent tutoring systems (ITS) have, for instance, shown promise in providing robust assessments and personalized learning experiences (Zhang et al., 2019). These tools can simulate real-world aviation scenarios, offering a practical and immersive approach to language learning and assessment. Having reviewed the potential contributions of AI in AE assessment, the following title offers an in-depth analysis of AI use for the assessment of pilots' English language proficiency based on ICAO regulations.

AI-based assessment in aviation English

The integration of Gen-AI into AE assessment represents a substantial era of transformation, elevating language proficiency and communication accuracy to unprecedented levels. This review showcases the substantial impact of AI on AE proficiency assessment by incorporating innovative AI-driven approaches and strategies. The assessment, therefore, is not limited to the AE proficiency assessment, rather it extends to the assessment of the quality of instruction.

AI technologies offer a variety of methods that have the potential to enhance the quality of the assessment of pilots' and air traffic controllers' AE proficiency. These technologies, for instance, encompass Automatic Speech Recognition (ASR), which can be employed to analyze pronunciation, and Natural Language Processing (NLP), which facilitates contextual understanding. Apart from the contribution of Gen-AI for ICAO raters, there are significant advantages for AE learners. These technologies offer learners an immersive experience in authentic aviation circumstances, enabling them to participate in real-time conversations with artificially intelligent created companions. In addition, Intelligent Tutoring Systems (ITS) thereafter customize personalized learning paths based on the distinct abilities and constraints of each student. Simultaneously, virtual reality (VR) technology creates realistic environments to improve communication abilities in simulated flying situations. This immersed experience can, in turn, help AE learners self-assess their performance, identify their learning gaps, and focus on the development of key skills that they are missing.

The incorporation of Gen-AI into AE is not just a practical combination, but rather a purposeful improvement of teaching methods through systematic assessment of the teaching content. By using Gen-AI, teachers may create prompts that imitate real aviation conversation, thus blurring the line between traditional language learning and the complexities of operational aviation. Students are placed in challenging environments that promote the growth of cognitive flexibility, resilience, and a thorough understanding of aviation protocols. Furthermore, the creation of AI-generated content serves as a prime example of a symbiotic partnership between technical progress and human expertise. Teachers employ AI-generated scenarios to tailor learning experiences and provide instant feedback, while students navigate the complexities of language and cultural differences in cross-functional aviation environments. The outcome is a

thorough mastery of AE that goes beyond just linguistic ability and includes operational expertise and situational awareness.

In the modern aviation industry, the ICAO's Language Proficiency Requirements (LPRs) underscore the necessity for aviation professionals to achieve and maintain Operational Level (Level 4) proficiency to mitigate risks associated with miscommunication. Given the high stakes, robust and reliable assessment of AE proficiency is essential. Traditional methods of AE proficiency assessment, such as the Test of English for Aviation (TEA) and ICAO English Language Proficiency Tests (ELPT), have served the industry well. These methods typically involve standardized testing and human raters to evaluate spoken and written responses. While effective, these traditional approaches present significant limitations, including subjectivity, inconsistencies in rating, and logistical challenges related to scalability and timely feedback. The labor-intensive nature of these assessments also constrains their frequency, potentially impacting the ongoing proficiency maintenance required by aviation professionals.

Overall, in response to these challenges, the integration of Artificial Intelligence (AI) in language assessment has emerged as a promising solution. AI technologies, particularly those leveraging machine learning algorithms and natural language processing (NLP) techniques, offer the potential to revolutionize AE assessment. These advanced tools can provide real-time feedback, ensure consistency and objectivity, and scale efficiently to meet the demands of the global aviation industry. AI-driven assessment tools, such as automated speech recognition (ASR) and intelligent tutoring systems (ITS), have demonstrated significant accuracy in evaluating linguistic features critical to AE, including pronunciation, fluency, and comprehension. The upcoming heading, therefore, further reviews the current state of AI-driven assessment tools for AE proficiency testing, exploring their methodologies, effectiveness, and potential challenges for the future of AE training.

AI-driven assessment tools for aviation English contexts

Automated speech recognition (ASR)

Automated Speech Recognition (ASR) technology has emerged as a pivotal tool in the assessment of AE proficiency. ASR systems convert spoken language into text, enabling the evaluation of various aspects of spoken communication. In the context of AE, where precise and clear communication is critical for safety and operational efficiency, ASR technology offers a robust solution for assessing language proficiency. This discussion explores the applications, benefits, challenges, and prospects of ASR in aviation English assessment.

ASR technology can be integrated into several aspects of AE assessment, enhancing the evaluation process through automation and accuracy. First, ASR systems can be utilized for pronunciation assessment. They can analyze phonetic accuracy, identifying mispronunciations and providing immediate feedback to learners. This is crucial in AE, where mispronunciations can lead to misunderstandings and potential safety risks. Second, they can be used for fluency evaluation since they can effectively measure speech rate, rhythm, and intonation, providing insights into a speaker's fluency. By assessing these parameters, ASR systems help ensure that communication in aviation contexts is smooth and coherent. The third area of ASR application is comprehension checks. ASR technology can be used to evaluate responses to comprehension questions, ensuring that learners not only speak correctly but also understand the spoken content accurately. The fourth example of ASR application for AE assessment is the readback accuracy. As highlighted before, readback is a critical practice in aviation. ASR systems can evaluate the accuracy and completeness of readback responses, ensuring that critical information is communicated correctly. Simulated interactions are the fifth and last example of ASR systems. They enable the creation of interactive simulations where learners can engage in realistic aviation communication scenarios. These simulations provide a practical assessment environment that mirrors real-world operations.

The integration of ASR technology in AE assessment offers numerous advantages. To illustrate, it ensures consistency and objectivity. Unlike human raters, ASR systems apply consistent criteria for evaluation, eliminating subjective biases and ensuring fair assessments across all learners. Also, it is scalable since it can handle large volumes of assessments efficiently, making it possible to conduct frequent and

widespread testing without the logistical constraints of human-administered tests. Another advantage of ASR technology in AE assessment is the real-time feedback. ASR systems provide immediate feedback, enabling learners to identify and correct errors promptly. This real-time interaction accelerates the learning process and reinforces correct language use. The use of ASR in interactive simulations can also create an immersive learning environment that closely mimics real-world communication scenarios. This practical exposure is invaluable for learners in developing their AE skills. Finally, the cost-effective nature of ASR technology appears as a significant advantage of AI technologies in AE assessment. Over time, the automation of assessments reduces the need for extensive human resources, leading to cost savings for training programs.

Despite its advantages, the implementation of ASR technology in AE assessment faces several challenges. The most significant challenge is related to the accents and dialects. ASR systems may struggle with accurately recognizing diverse accents and dialects, potentially affecting the fairness of assessments for non-native speakers. Considering the number of aviation professionals whose first language is not English, the AI-driven ASR technology needs to be approached carefully before utilizing for assessment purposes. Similarly, ASR may not fully grasp the context or nuances of aviation-specific language despite transcribing the speech accurately, which may lead to potential misunderstandings in assessment. Another issue to be considered regarding ASR is the technological limitations. As such, background noise and poor audio quality can affect the performance of ASR systems, leading to inaccurate transcriptions and assessments. Also, the data privacy, as always, is an important concern. The use of ASR technology involves the collection and processing of speech data, raising concerns about data privacy and security. Finally, the successful integration of ASR technology into existing training programs requires significant investment in infrastructure and the training of educators and learners to use the technology effectively.

The future of ASR in AE assessment looks promising with ongoing advancements in AI and machine learning. Future developments may include, for instance, improved accuracy. Enhanced algorithms will improve the accuracy of ASR systems in recognizing diverse accents and understanding contextual nuances. Adaptive

learning systems will also provide personalized learning experiences, adapting to the specific needs and progress of each learner. Multilingual capabilities of advanced ASR systems can be the most significant improvement in the future by facilitating training and assessment for a global aviation workforce. Finally, enhanced security measures can be expected in the future use of ASR technologies. That is, improved data encryption and privacy protocols will address concerns related to data security and compliance with regulatory standards.

To conclude, ASR technology holds significant potential for revolutionizing the assessment of Aviation English proficiency. By providing consistent, scalable, and real-time evaluations, ASR enhances the effectiveness of training programs and ensures that aviation professionals possess the necessary communication skills for safe and efficient operations. However, addressing the challenges associated with accents, contextual understanding, and data privacy is crucial for the successful implementation of ASR in AE assessment. As technology continues to evolve, the integration of advanced ASR systems will play a pivotal role in shaping the future of aviation language training and assessment.

Natural language processing (NLP)

NLP techniques are used to analyze and interpret the meaning of spoken and written language. In AE assessments, NLP can evaluate the semantic and syntactic accuracy of responses. Research indicates that NLP-based tools can provide detailed feedback on vocabulary use, grammatical structures, and overall language proficiency (Chen et al., 2020).

Among many areas of application, NLP can be, for instance, applied for AE assessment to understand and analyze communication between pilots and air traffic controllers. This may ensure clarity and adherence to aviation standards. By processing spoken or written English, NLP tools can identify key phrases by detecting and categorizing critical aviation phrases or terminology to ensure they are used correctly. Also, the NLP tools can assess grammar and syntax by evaluating the grammatical structure and syntax of communication to check if it adheres to established aviation protocols. Another contribution of NLP tools to AE assessment is the evaluation of proficiency. That is, they can help raters in assessing a pilot's or controller's proficiency in Aviation English. This may include speech recognition and language modeling.

While the former includes converting spoken language into text to assess pronunciation, fluency, and adherence to aviation-specific language use, the latter includes creating models that simulate how aviation professionals should speak or write, allowing for comparative analysis against actual performance.

Apart from the aforementioned contributions, NLP tools can assist in developing automated scoring systems for AE tests. These systems can analyze written responses by evaluating the coherence, appropriateness, and correctness of written responses in English proficiency tests and they can assess oral communication by using voice recognition and analysis to score spoken responses, focusing on factors like clarity, accuracy, and use of standard aviation phraseology. Besides, NLP can create simulations and scenarios for training purposes. For instance, it can generate realistic aviation communication scenarios for training exercises as well as develop interactive systems that simulate conversations between pilots and air traffic controllers to practice and improve communication skills. Finally, NLP tools can effectively detect errors in communication and provide feedback accordingly. This appears as a unique contribution to assessing the AE proficiency of pilots and air traffic controllers according to ICAO Language Proficiency Requirements (LPRs). In this sense, mispronunciations, incorrect phraseology, or deviations from standard communication practices can be detected. Also, learners and test-takers can be provided constructive feedback to help them improve their language skills and adherence to aviation standards. However, the following issues should be considered when applying NLP tools in the AE context. Context sensitivity, for instance, is a critical issue in AE assessment because aviation communication often involves context-specific jargon and phrases. NLP systems, therefore, need to be highly context-aware to interpret and assess communication accurately. Also, variability in accents and pronunciations can pose challenges for NLP systems in accurately assessing spoken language.

In summary, NLP holds significant potential in enhancing Aviation English assessment by providing tools for more accurate evaluation, training, and feedback. However, careful attention to the nuances of aviation communication and ongoing development of NLP technologies are necessary to fully realize these benefits.

Intelligent tutoring systems (ITS)

Intelligent Tutoring Systems (ITS) are advanced educational technologies that use artificial intelligence to provide personalized instruction and feedback. These systems can adapt to the individual needs of learners, providing tailored feedback and guidance. ITS have been shown to enhance learning outcomes by offering real-time corrections and suggestions, thereby improving learners' proficiency over time (Zhang et al., 2019). In the context of Aviation English assessment, ITS can significantly enhance the training and evaluation process.

Personalized learning, for instance, can be argued as a significant advantage of ITS. As part of the personalization of the learning process, ITS offers customized content. The system can adapt the difficulty and focus of learning materials based on the learner's current proficiency level. For example, if a pilot struggles with certain aviation terminology, the ITS can provide additional practice and resources on those specific terms. Also, adaptive learning paths are offered based on performance and progress. That is, the ITS can create personalized learning paths, guiding learners through a sequence of lessons that build on their strengths and address their weaknesses.

Effective feedback is crucial in language learning, and ITS can provide real-time, targeted feedback for AE learners on both written and spoken communication. To exemplify, the ITS can identify errors in grammar, pronunciation, or usage of aviation terminology and provide immediate corrections. Besides, detailed analytics on performance can help learners understand their progress and areas needing improvement, such as frequent mispronunciations or common grammatical mistakes.

Similarly, ITS can be utilized to provide relevant context for learners since it can simulate real-world aviation scenarios to provide practical experience. As such, the system can create realistic communication scenarios, such as emergency situations or routine air traffic control conversations, allowing learners to practice and refine their skills in a controlled environment. In addition, learners can engage in simulated conversations with virtual air traffic controllers or other pilots, receiving feedback on their language use, clarity, and adherence to standard aviation phraseology, and it can continuously monitor the learners' performance allowing for ongoing assessment of their language skills and improvement over time. Finally, the personalized instruction and interactive features of ITS can boost learner engagement and motivation by

incorporating game-like elements, such as scoring, levels, and rewards, to make learning more engaging and motivating and by offering interactive exercises, quizzes, and simulations. Despite its potential to improve the quality of AE assessment, the ITS has some potential drawbacks. Among these, contextual understanding is a significant issue. Effective aviation communication involves understanding context and nuance. ITS must, therefore, be sophisticated enough to handle the specific context of aviation communication accurately. Besides, it should ensure the privacy and security of learners' personal data. Finally, ITS must be regularly updated to reflect current standards and practices so that it will comply with aviation regulations.

In summary, ITS can complement traditional training methods by providing additional practice and support outside of formal classroom settings. For example, while classroom instruction focuses on foundational knowledge and skills, ITS can offer personalized reinforcement and practice. It also has the potential to significantly enhance Aviation English assessment by offering personalized, adaptive learning experiences, real-time feedback, and engaging simulations. As technology continues to evolve, ITS can play a key role in improving the effectiveness and efficiency of language training for aviation professionals, which are explored more in the following sections.

Effectiveness of AI-driven assessment tools

The integration of AI in AE assessment processes represents a significant advancement in the field of language proficiency testing. This advancement, for instance, includes a more accurate and reliable assessment compared to conventional AE testing. Also, providing real-time feedback in an adaptive learning environment stands out as a significant improvement for AE learners and test-takers. Finally, the flexibility to apply AI tools in AE learning settings with varying numbers of learners is a huge advantage in the AI era.

Accuracy and reliability

One of the primary advantages of AI-driven assessment tools is their ability to deliver accurate and consistent evaluations. Traditional assessments, often reliant on human raters, are susceptible to variability due to subjective interpretations and fatigue. The findings of the study conducted by Assassi and Ghodbane (2023), for instance,

indicate challenges stemming from an emotional dimension, including stress and anxiety resulting from inadequate preparation and unfamiliarity with examination tasks. Also, they reported that assessors have identified a distinct interpretation of ICAO descriptions utilizing the rating scale as additional concern. Furthermore, technical difficulties with the computer-based listening assessment and the non-compliance of test content with the characteristics of the target language use context are reported as primary concerns identified by both examinees and evaluators. AI technologies, particularly those utilizing machine learning algorithms and natural language processing (NLP), can minimize these inconsistencies. Besides, it was found that AI-driven tools can assess pronunciation, fluency, and comprehension with a high degree of precision. For instance, it was reported that subtle differences in pronunciation and fluency that might be overlooked by human raters could be detected by means of automated speech recognition (ASR) systems (Chen et al., 2020). The consistent application of scoring criteria by AI tools can, therefore, ensure fairness and reliability across assessments by eliminating the challenges originating from human factors.

Real-time feedback and adaptive learning

Another significant advantage of AI-driven assessment tools is providing real-time feedback, which is an essential feature for effective AE language learning. These tools allow learners to understand their mistakes and correct them promptly, facilitating a more dynamic and responsive learning environment. Corrective feedback is crucial for the success of English language teaching and learning at all levels due to its fundamental role in enhancing learners' English proficiency. It is, therefore, crucial to address this need of English language learners for improved learning outcomes. The study conducted by Nhac (2021) explored the role of corrective feedback and found that the outcomes of explicit corrective feedback surpassed those of the control group getting implicit feedback on the enhancement of learners' appropriate application of grammar, vocabulary, and pronunciation. The results, therefore, underscored the significance of teachers' remedial feedback in enhancing students' English proficiency. Similarly, Lynch and Maclean (2003), in an earlier study, had concluded that the ESP students' judgments of the significance and impact of feedback corresponded with tangible enhancements in their spoken performance. Despite its clear support to English language learning processes, giving timely feedback also requires competent AE

instructors. Considering the number of aviation professionals needed in the rapidly expanding aviation industry, it is not very probable to provide high-quality and timely feedback for AE learners as well as AE proficiency test-takers. Intelligent tutoring systems (ITS) and adaptive learning platforms can, therefore, be the solution for the aviation professionals and AE instructors since these systems can both tailor the feedback and the learning activities to the individual needs of each student pilot and create personalized learning experiences. This adaptability ensures that learners receive the most relevant and effective support, enhancing their proficiency in AE (Zhang et al., 2019). Overall, AE teaching will likely benefit more from these conveniences AI tools provide for learners and AE instructors.

Scalability and efficiency

The scalability of AI-driven assessment tools addresses one of the significant limitations of conventional assessment methods. Manual assessments are resource-intensive, often requiring substantial time and a handful of ICAO raters, which can limit their frequency and accessibility. Moreover, there is a constant need for physical infrastructure, effective scheduling, and qualified ICAO raters. AI-driven tools mitigate these constraints by enabling assessments to be conducted remotely, reducing the need for physical presence and allowing trainees to participate from any location. In addition, AI tools can process large volumes of data swiftly and efficiently as well as evaluate oral communication, simulate various flight scenarios, and analyze pilot responses in real-time. The assessment cycle is, therefore, shortened, enabling more frequent evaluations and continuous learning. As regards scalability, ICAO raters can also be influenced by subjective biases and inconsistencies. AI-driven tools, however, apply standardized criteria uniformly across all assessments, ensuring fair and objective evaluations. This also ensures that every learner is assessed against the same criteria. Overall, the future of AI-driven assessment tools in aviation training looks promising, with ongoing advancements in AI and machine learning technologies. However, it should be noted that there are certain challenges and considerations regarding the AI-based AE language proficiency assessment.

Challenges and considerations

AI-driven assessment tools represent a significant advancement in the field of AE proficiency testing. These tools offer numerous benefits, including enhanced accuracy, real-time feedback, and scalability. While there are challenges to be addressed, the potential of AI to transform language assessment and training is immense. This review underscores the importance of continued research and innovation in this area to ensure that aviation professionals are equipped with the necessary language skills to maintain safety and efficiency in global air traffic operations.

Despite their advantages, AI-driven assessment tools are not without limitations. Technological challenges such as speech recognition errors, especially in non-native accents, and the need for extensive data to train AI models can affect the performance of these tools. Continuous advancements in AI technology are necessary to address these limitations (Zhang et al., 2019). The use of AI in language assessment raises ethical and privacy concerns. The collection and storage of learners' data must comply with privacy regulations, and there should be transparency in how AI algorithms make decisions. Ensuring the ethical use of AI in educational settings is crucial to gaining the trust of learners and educators (Chen et al., 2020).

The integration of AI in AE proficiency testing is an ongoing process with significant potential for future developments. Future research should focus on enhancing the accuracy of AI tools, particularly in recognizing diverse accents and dialects. Additionally, exploring the use of AI in developing adaptive learning environments that respond to the evolving needs of learners can further enhance the effectiveness of AE training programs (Yoon et al., 2021). All things considered, AI-based AE language proficiency assessment tools need to be integrated into AE testing considering the existing and future challenges and ethical issues.

Conclusion

As the chapters reveal the capabilities of AI in aviation English teaching, it becomes clear that AI-driven solutions provide a clear direction for the future. The combination of AI-generated information and human instruction provides aviation professionals with abilities that go beyond language barriers, allowing them to flourish in the fast-paced

and safety-critical aviation business. This innovative approach enables learners to effectively communicate in many aviation situations, promoting a culture of high standards, precision, and teamwork in aviation communication.

The integration of Generative AI (Gen-AI) into Aviation English (AE) assessment represents a pivotal advancement, reshaping the landscape of language proficiency evaluation within the aviation industry. By leveraging AI-driven tools such as Automatic Speech Recognition (ASR), Natural Language Processing (NLP), and Intelligent Tutoring Systems (ITS), AE assessments can now achieve unprecedented levels of accuracy, consistency, and scalability. These technologies not only enhance the evaluation of AE proficiency but also provide immersive, real-time learning experiences that allow learners to engage in authentic aviation scenarios. The symbiotic relationship between AI and human expertise fosters a comprehensive mastery of AE, extending beyond linguistic capabilities to include operational proficiency and situational awareness. As the aviation industry continues to evolve, the adoption of AI in AE assessment ensures that professionals meet the stringent communication standards set by the ICAO, ultimately contributing to safer and more effective global aviation operations.

When it comes to education, combining knowledge-based and data-driven techniques shows great potential for progress. Data-driven artificial intelligence (AI) is highly proficient at analyzing fundamental data, such as identifying patterns, whereas traditional education primarily emphasizes the gradual acquisition of specialized theoretical knowledge in certain fields (Tuomi, 2022). Several recent advancements in data-driven artificial intelligence, such as the ability to identify a cat in an image or differentiate words in a spoken sentence, are skills that human children often acquire well before starting formal education. Therefore, the future progress of AI in education can be better understood as a cooperative advancement of human and artificial thinking.

From a technical perspective, the upcoming alteration in the fundamental structure of the internet will result in substantial modifications in our society. Over the next ten years, there will be a change in data storage from centralized clouds to locations that are closer to users. This shift will coincide with the widespread adoption of virtual and augmented reality technology. Additionally, there will be a growing integration of

the physical environment with the digital world in real-time. Technological advancements that connect cloud computing to edge devices, and machine learning, in addition to artificial intelligence (AI), are expected to have significant roles in this transition. Sensors will establish connectivity between various items and the upcoming version of the Internet, encompassing AI-powered vehicles, household appliances, factory production lines, public services, wearable gadgets, and potentially even mobile phones, if they continue to exist.

Overall, this review offers readers valuable insights to navigate the uncertainties surrounding the future of education. Our perceptions of the future are fundamentally influenced by our comprehension and analysis of the past. It presents a classification of AI systems in education, along with examples of the most advanced ones now available. Additionally, the article discusses the obstacles that need to be overcome to further advance the area. In light of the swift evolution of the technological landscape, it is imperative to contemplate the significance of education in this dynamic world. Although technological innovation is commonly associated with progress, it is crucial to carefully evaluate the timing and manner in which these changes correspond to significant and well-received advancements in education.

Ultimately, the transition from conventional language learning to AI-enhanced aviation English instruction is a noteworthy achievement. As we consider the future, the combination of AI and aviation English shows potential not only for achieving language proficiency but also for enhancing operational safety, fostering international cooperation, and promoting the joint pursuit of excellence in aviation communication. This voyage marks the beginning of a new era filled with endless possibilities, as technology and education come together to propel aviation professionals towards a more promising and interconnected future.

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