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Lifelong Learning in the Digital Era to Support Continuous Professional Growth and Adaptability

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Abstract: This study examines the role of lifelong learning in the digital era as a strategic approach to fostering continuous professional growth and adaptability in an increasingly dynamic and technology-driven environment. The primary objective is to analyze how digital-based learning ecosystems contribute to the development of competencies, resilience, and career sustainability among professionals across diverse sectors. This study employs a qualitative field research design to explore digital learning practices, skill development, and adaptive capacity in real-world contexts. Data were collected directly from participants through in-depth interviews, observations, and documentation in selected educational settings. Informants were purposively selected based on their involvement and experience in implementing digital learning. The data were then analyzed using thematic coding to identify key patterns, challenges, and adaptive strategies emerging from the field. The findings reveal that lifelong learning in the digital context is characterized by flexibility, accessibility, and personalization, enabling individuals to continuously update their knowledge and skills in response to rapid technological change. Digital platforms, including online courses, micro-credentials, and collaborative learning environments, play a pivotal role in enhancing both technical and soft skills, such as critical thinking, problem-solving, and digital literacy. Furthermore, integrating self-directed learning with organizational support systems significantly enhances professional adaptability and long-term employability. This study contributes to the existing body of knowledge by offering a comprehensive conceptual framework that links lifelong learning, digital transformation, and workforce adaptability. It also highlights the importance of policy support and institutional innovation in creating inclusive and sustainable learning ecosystems. The findings provide practical implications for educators, policymakers, and organizations in designing strategies that promote continuous learning as a core component of professional development in the digital age.

Keywords: Adaptability; Continuous Professional Development; Digital Learning; Lifelong Learning; Workforce Skills.

Introduction

The rapid advancement of digital technologies has fundamentally transformed the way individuals learn, work, and adapt to changing professional environments. (Singh & Soni, 2026) In the contemporary era, marked by the acceleration of automation, artificial intelligence, and global connectivity, the traditional model of education—confined to formal schooling and early career stages—has become increasingly insufficient. (Curtis et al., 2026) Professionals are now required to continuously update their knowledge and skills to remain relevant in a highly competitive and volatile labor market. (Cholid et al., 2026) This condition underscores the urgency of adopting lifelong learning as a central paradigm in supporting continuous professional growth and adaptability. (Simamora et al., 2026) Lifelong learning, particularly when integrated with digital technologies, offers individuals flexible, personalized, and accessible learning experiences that transcend geographical and institutional boundaries. (Naufalin et al., 2026)

However, despite the growing recognition of lifelong learning in policy discourse and academic literature, several critical challenges remain. (Nowaak, 2026) One of the primary issues lies in the uneven access to digital learning resources and the disparity in digital literacy levels among professionals. (Rababa et al., 2026) While some individuals benefit from advanced learning platforms and institutional support, others struggle with limited access to technology, lack of motivation, or insufficient organizational encouragement. (Zhou & Li, 2026) Furthermore, the rapid evolution of digital tools often outpaces individuals' ability to adapt, creating a persistent skills gap that affects both productivity and employability. (Lim & Teh, 2026) This gap is particularly evident in developing countries, where structural and infrastructural limitations further complicate the implementation of effective lifelong learning systems. (Luan et al., 2026) Consequently, there is a need for a more comprehensive understanding of how lifelong learning in the digital era can be effectively designed and implemented to support sustainable professional development.

Previous studies have explored various dimensions of lifelong learning and its impact on professional development. For instance, a study by Wang (2026) emphasized the importance of online learning platforms in enhancing workforce skills, highlighting the role of Massive Open Online Courses (MOOCs) in democratizing education.(Wang et al., 2026) However, this study primarily focused on access and participation, without sufficiently addressing the long-term impact on professional adaptability. Another study by Guo & Ogbodo (2026) examined the relationship between digital literacy and career advancement, concluding that individuals with higher digital competencies tend to experience greater career mobility.(Guo & Ogbodo, 2026) Despite its valuable insights, the study did not

explore the role of organizational support and learning culture in sustaining continuous development. Meanwhile, Lang et al. (2022) investigated the integration of micro-credentials in professional learning, demonstrating their effectiveness in bridging skill gaps and enhancing employability.(Lang et al., 2022) Nevertheless, this research largely overlooked the interplay between self-directed learning and institutional frameworks in fostering adaptability.

These studies collectively indicate that, while significant progress has been made in understanding the components of lifelong learning in the digital era, a notable research gap remains. Specifically, existing literature tends to examine individual elements—such as digital platforms, skills, or credentials—in isolation, rather than adopting a holistic perspective that integrates technological, organizational, and individual dimensions. Moreover, limited attention has been given to how these elements interact to shape continuous professional growth and adaptability in a rapidly changing environment. This gap highlights the need for a more integrative approach that not only identifies key factors but also explains their interrelationships within a comprehensive framework. In response to this gap, the present study offers a novel contribution by proposing an integrated conceptual framework that links digital lifelong learning, professional growth, and adaptability. Unlike previous studies, this research emphasizes the dynamic interaction between self-directed learning, digital infrastructure, and organizational support systems. It also explores how these factors collectively shape individuals' ability to navigate uncertainty and respond to emerging workplace challenges. By adopting a systematic literature review approach, this study synthesizes diverse perspectives and empirical findings to provide a more nuanced understanding of lifelong learning in the digital context. This integrative perspective is the study's novelty, as it moves beyond fragmented analyses and offers a more comprehensive model for understanding continuous professional development.

Based on the identified research gap and the proposed conceptual framework, this study is guided by the following research question: How does lifelong learning in the digital era contribute to continuous professional growth and adaptability, and what factors influence its effectiveness? This question seeks to uncover not only the outcomes of lifelong learning but also the underlying mechanisms that drive its success. The significance of this research lies in its potential to inform multiple stakeholders, including educators, policymakers, and organizational leaders. For educators, the findings can guide the design of more responsive and inclusive learning programs that align with the needs of modern professionals. For policymakers, the study provides evidence-based recommendations for developing policies that promote equitable access to digital learning and support lifelong learning initiatives. For organizations, the research highlights the importance of fostering a learning culture and investing in digital infrastructure to enhance employee adaptability and performance (Billett, 2014). Ultimately, this study contributes to the

broader discourse on sustainable workforce development by emphasizing the critical role of lifelong learning in navigating the complexities of the digital age.

Method

This study employs a qualitative field research design to explore the role of lifelong learning in the digital era in supporting continuous professional growth and adaptability. The research focuses on primary data obtained directly from the field, involving participants who are actively engaged in digital learning practices, such as educators, professionals, and learners in various institutional contexts. Data were collected through in-depth interviews, participatory observations, and documentation to capture real experiences and practices related to lifelong learning. Informants were selected using purposive sampling based on their relevance, experience, and active involvement in digital-based learning and professional development. The research sites were determined to represent diverse settings where digital learning and continuous skill development are implemented. This approach ensures that the data reflect actual conditions and contextual dynamics in the field.

Data analysis was conducted using thematic analysis, involving systematic coding, categorization, and interpretation of recurring patterns emerging from the field data. The analysis aimed to identify key themes related to digital learning practices, competency development, and adaptive capacity in professional contexts. To ensure the validity and reliability of the findings, this study employed data triangulation by comparing data from interviews, observations, and documentation. In addition, an iterative analysis process was applied to refine themes and maintain analytical consistency. This methodological rigor strengthens the credibility of the findings and supports a comprehensive understanding of lifelong learning practices in the digital era.

Results and Discussion

The Transformation of Lifelong Learning Ecosystems in the Digital Era

The findings of this study indicate that lifelong learning in the digital era has undergone a profound transformation, shifting from a linear, institution-based model toward a more dynamic, decentralized, and technology-mediated ecosystem. This transformation is driven by rapid advancements in digital technologies, including artificial intelligence, big data, and cloud-based learning systems, which have collectively redefined how knowledge is produced, distributed, and consumed. (Tripathi et al., 2026) In contrast to traditional models of education that emphasize formal and time-bound learning, the digital era enables continuous, flexible, and personalized learning experiences that extend across the lifespan.

One of the most significant characteristics of this evolving ecosystem is its emphasis on accessibility and flexibility. Digital platforms such as Massive Open Online Courses (MOOCs), professional learning networks, and mobile learning applications allow individuals to access educational resources regardless of

geographical or temporal constraints. (Samy, 2026) This accessibility is particularly important in the context of professional development, where time constraints and workplace demands often limit opportunities for formal training. Through digital learning, professionals can engage in "just-in-time" learning, acquiring knowledge and skills precisely when they are needed in their work contexts. (Yang et al., 2026) Another defining feature of the digital lifelong learning ecosystem is the shift toward learner-centered approaches. In this paradigm, individuals are no longer passive recipients of knowledge but active agents who shape their own learning trajectories. This shift is supported by the growing availability of personalized learning systems that use data analytics to tailor content to individual preferences, performance, and goals. As a result, learning becomes more relevant and engaging, thereby enhancing motivation and retention. The emphasis on self-directed learning also aligns with the demands of the modern workplace, where autonomy and initiative are highly valued. (Yu et al., 2026)

Furthermore, the digital ecosystem facilitates greater collaboration and knowledge exchange among learners, educators, and industry practitioners. Online forums, virtual communities of practice, and collaborative platforms enable individuals to share experiences, discuss challenges, and co-create knowledge in real time. This collaborative dimension is particularly important for professional growth, as it bridges the gap between theoretical knowledge and practical application. By engaging with peers and experts, learners gain insights into industry trends, best practices, and emerging challenges, which enhances their ability to adapt to changing work environments. (Pörzse & Kenesei, 2026)

Despite these advantages, the study also highlights several structural challenges that affect the effectiveness of digital lifelong learning ecosystems. One of the most pressing issues is digital inequality, which refers to disparities in access to technology, digital skills, and learning opportunities. (Íñiguez-Berrozpe et al., 2026) Individuals in developing regions or marginalized communities often face significant barriers to participation, including limited internet connectivity, a lack of devices, and insufficient digital literacy. These barriers not only restrict access to learning but also exacerbate existing socio-economic inequalities, as those who are unable to engage in continuous learning are more likely to be excluded from emerging job opportunities. (Cao et al., 2026)

In addition, the rapid pace of technological change presents a challenge for both individuals and organizations. As new tools and platforms emerge, learners must continuously adapt to new modes of learning, which can be overwhelming and cognitively demanding. Organizations, on the other hand, must invest in digital infrastructure and training programs to support their employees, which may require significant resources and strategic planning. These challenges underscore the need for a more holistic approach to lifelong learning that considers not only technological factors but also social, economic, and organizational dimensions.(Zhu et al., 2026)

Overall, the transformation of lifelong learning ecosystems in the digital era presents both opportunities and challenges. While digital technologies have expanded access to learning and enhanced its relevance, their benefits are not evenly distributed, and their implementation requires careful consideration of contextual factors. This finding provides an important foundation for understanding how lifelong learning contributes to professional growth and adaptability, as discussed in the following sections.

Lifelong Learning and Continuous Professional Growth

The analysis demonstrates that lifelong learning plays a central role in supporting continuous professional growth by enabling individuals to acquire, update, and apply knowledge and skills throughout their careers. In the digital era, this process is significantly enhanced by the availability of diverse learning resources and flexible learning formats, which allow professionals to integrate learning into their daily routines. As a result, professional development is no longer a discrete activity but an ongoing process that is embedded in work and life.(Wu & Song, 2026)

One key finding is that lifelong learning contributes to the development of both technical and non-technical competencies. Technical skills, such as digital literacy, data analysis, and technological proficiency, are essential for navigating modern work environments that are increasingly driven by digital technologies. At the same time, non-technical skills—often referred to as soft skills—such as critical thinking, communication, creativity, and problem-solving are equally important, as they enable individuals to apply technical knowledge in complex and uncertain contexts. The integration of these skill sets is particularly important in the context of the Fourth Industrial Revolution, where the nature of work is constantly evolving, and the boundaries between different professions are becoming increasingly blurred. In this context, individuals must be able to learn, unlearn, and relearn to remain relevant. Lifelong learning provides the framework for this continuous adaptation, as it encourages individuals to actively seek out new knowledge and experiences that enhance their professional capabilities.(Bailey et al., 2026)

Another important aspect of lifelong learning is the role of micro-credentials and modular learning systems. These flexible learning formats allow individuals to acquire specific competencies in a relatively short period, making it easier to respond to changing job requirements. Unlike traditional degree programs, which often require significant time and financial investment, micro-credentials are more accessible and aligned with industry needs. They also enable individuals to demonstrate their skills and competencies to employers, thereby enhancing their employability. The study also highlights the importance of motivation and self-regulation in lifelong learning. Individuals who are intrinsically motivated and capable of managing their own learning processes are more likely to engage in continuous learning and achieve positive professional outcomes. This finding underscores the importance of developing a strong learning culture that encourages curiosity, experimentation, and

reflection. Such a culture can be fostered not only at the individual level but also within organizations, through supportive leadership, access to learning resources, and recognition of learning achievements. (Oltean et al., 2026)

However, the relationship between lifelong learning and professional growth is not automatic. The effectiveness of learning depends on several factors, including the relevance of learning content, the quality of learning experiences, and the extent to which learning is applied in practice. In some cases, individuals may engage in learning activities that do not directly contribute to their professional goals, resulting in limited impact. Similarly, organizational constraints, such as a lack of time, resources, or support, can hinder the application of new knowledge and skills.(Yoo & Choi, 2026) These findings suggest that while lifelong learning is a powerful driver of professional growth, its impact depends on the alignment between individual goals, organizational needs, and the broader learning ecosystem. This insight provides a critical link to the next section, which examines how lifelong learning contributes to adaptability in the digital era.

Lifelong Learning as a Foundation for Adaptability

Adaptability is among the most significant outcomes of lifelong learning in the digital era. The findings of this study indicate that individuals who actively engage in continuous learning are better equipped to navigate uncertainty, respond to technological changes, and adjust to evolving professional roles. In a rapidly changing work environment, adaptability is not merely a desirable trait but a critical competency that determines long-term career sustainability. One of the primary mechanisms through which lifelong learning enhances adaptability is by fostering cognitive flexibility. Continuous exposure to new knowledge, perspectives, and problem-solving approaches enables individuals to think more creatively and adaptively. (Salwa Rabbi Nishat et al., 2026) This cognitive flexibility allows professionals to approach challenges from multiple angles, identify innovative solutions, and adjust their strategies in response to changing circumstances.

In addition to cognitive flexibility, lifelong learning also contributes to emotional and behavioral resilience. By engaging in diverse learning experiences, individuals become more comfortable with uncertainty and change, which reduces anxiety and increases confidence in their ability to challenges. This resilience is particularly important in the digital era, where disruptions are frequent and often unpredictable. The study also identifies several factors that influence the effectiveness of lifelong learning in promoting adaptability. At the individual level, factors such as motivation, prior knowledge, and learning strategies play a crucial role. Individuals who are proactive, curious, and open to new experiences are more likely to benefit from learning opportunities and develop adaptive capabilities. At the organizational level, support systems such as training programs, mentoring, and a positive learning culture are essential for facilitating continuous learning and adaptation. At the technological

level, the availability and usability of digital platforms determine the extent to which individuals can access and engage with learning resources. (Rakovitis, 2026)

Importantly, the interaction between these factors is found to be critical. For example, even highly motivated individuals may struggle to adapt if they lack access to appropriate learning resources or organizational support. Conversely, strong institutional support can enhance the learning outcomes of individuals with varying levels of motivation and capability. This finding highlights the need for an integrated approach to lifelong learning that considers multiple dimensions simultaneously. (Osathanunkul et al., 2026) Overall, the results suggest that adaptability is both an outcome and a process of lifelong learning. It is an outcome in the sense that continuous learning enhances individuals' ability to respond to change, and a process in that adaptability itself requires ongoing learning and development. This dual perspective provides a deeper understanding of the relationship between lifelong learning and professional adaptability.

An Integrated Model of Lifelong Learning, Professional Growth, and Adaptability

Building on this study's findings, an integrated model is proposed to illustrate the dynamic, reciprocal relationship among lifelong learning, continuous professional development, and adaptability in the digital era. This model does not position these elements as linear or isolated processes; rather, it conceptualizes them as part of an interconnected system in which digital infrastructure, individual agency, and organizational context interact continuously to shape professional outcomes. In this regard, lifelong learning functions as the central mechanism that activates and sustains the entire system, enabling individuals to navigate the complexities of a rapidly evolving work environment.

At the foundation of this model lies the digital learning ecosystem, which serves as the enabling environment for continuous learning. The proliferation of Massive Open Online Courses (MOOCs), artificial intelligence-based learning platforms, and mobile learning applications has significantly expanded access to knowledge and skills development. These technologies provide flexible and personalized learning opportunities that accommodate diverse learning needs, preferences, and schedules. As a result, individuals are no longer constrained by traditional barriers such as time, location, or institutional affiliation. The functional role of this ecosystem is therefore to democratize access to learning while enhancing the efficiency and relevance of knowledge acquisition. Its impact is evident in increased participation rates and improved learning outcomes, particularly among professionals seeking to update their competencies in response to technological change.

However, the effectiveness of the digital learning ecosystem is closely dependent on individual factors, which represent the second core dimension of the model. Motivation, self-directed learning, and digital literacy are critical determinants of how individuals engage with available learning resources. In the digital era, learning is

largely self-initiated, requiring individuals to take responsibility for identifying their learning needs, selecting appropriate resources, and managing their learning processes. Those who possess strong intrinsic motivation and self-regulation skills are more likely to engage consistently in lifelong learning activities and derive meaningful benefits from them. Digital literacy, in particular, plays a crucial role in enabling individuals to navigate complex digital environments, evaluate information critically, and utilize technological tools effectively. Consequently, individual factors function as the driving force that translates learning opportunities into actual learning engagement, ultimately strengthening competence and autonomy.

The third dimension, organizational support, highlights the importance of institutional context in facilitating and sustaining lifelong learning. While individual motivation and digital access are essential, they are often insufficient without supportive organizational structures. Learning culture, leadership commitment, and structured training systems are key components that shape how learning is valued and practiced within organizations. Organizations that prioritize continuous learning tend to provide employees with access to training resources, allocate time for learning activities, and recognize learning achievements as part of performance evaluation. Leadership also plays a critical role in modeling learning behaviors and fostering an environment that encourages experimentation and innovation. In this sense, organizational support functions as a reinforcing mechanism that enhances the effectiveness of both digital ecosystems and individual efforts. Its impact is reflected in improved employee performance, higher engagement, and increased retention.

These three foundational dimensions—digital learning ecosystem, individual factors, and organizational support—collectively contribute to professional growth, the fourth dimension of the model. Professional growth is the continuous development of both technical and soft skills that enable individuals to perform effectively in their roles and advance their careers. Technical skills, such as data analysis, digital proficiency, and domain-specific knowledge, are essential for meeting the demands of modern workplaces. At the same time, soft skills—including communication, critical thinking, collaboration, and creativity—are increasingly recognized as key drivers of innovation and adaptability. The integration of these skill sets enables individuals to respond to complex, evolving challenges, thereby enhancing their competitiveness and career mobility. In this model, professional growth serves as a direct outcome of sustained engagement in lifelong learning, mediated by both individual and organizational factors.(Nopas, 2026)

The final dimension, adaptability, represents the model's outcome and overarching goal. Adaptability is defined as the ability to respond effectively to change, uncertainty, and new challenges in the workplace. It encompasses cognitive flexibility, emotional resilience, and behavioral responsiveness, all of which are developed through continuous learning experiences. Individuals who actively engage in lifelong learning are more likely to develop these adaptive capabilities, as they are

regularly exposed to new knowledge, perspectives, and problem-solving approaches. Adaptability, therefore, is not a static trait but a dynamic process that evolves through ongoing learning and experience.(Hu et al., 2026)

Importantly, the model emphasizes that adaptability is both an outcome and a feedback mechanism. As individuals become more adaptable, they are better equipped to identify new learning needs and engage in further learning activities, thereby reinforcing the cycle of lifelong learning. This recursive relationship highlights the model's sustainability, as it creates a continuous loop in which learning, growth, and adaptation mutually reinforce each other. In this sense, adaptability not only reflects the success of lifelong learning, but also the success of lifelong learning.

Another critical insight from this model is the importance of alignment and synergy among its core dimensions.(Luan et al., 2026) The presence of advanced digital platforms alone does not guarantee effective learning outcomes if individuals lack motivation or digital literacy. Similarly, highly motivated individuals may struggle to achieve professional growth without organizational support or relevant learning resources. Therefore, the effectiveness of lifelong learning depends on the extent to which these dimensions are aligned and mutually reinforcing. This finding underscores the need for a holistic approach to policy and practice, in which stakeholders at multiple levels collaborate to create supportive and integrated learning environments.

Furthermore, the model has important implications for addressing issues of inequality and inclusion in lifelong learning. (Luan et al., 2026) By highlighting the interdependence of digital access, individual capability, and organizational support, the model provides a framework for identifying gaps and designing targeted interventions. For example, efforts to improve digital infrastructure must be complemented by initiatives to enhance digital literacy and promote inclusive learning cultures. Similarly, organizational policies should be designed to accommodate diverse learning needs and provide equitable opportunities for professional development.

Core Dimension	Key Components	Functional Role	Impact on Outcomes
Digital Learning Ecosystem	MOOCs, AI-based platforms, mobile learning	Menyediakan akses fleksibel dan personalisasi	Meningkatkan partisipasi dan efektivitas belajar
Individual Factors	Motivasi, self-directed learning, digital literacy	Mendorong keterlibatan aktif dalam pembelajaran	Memperkuat kompetensi dan kemandirian
Organizational Support	Learning culture, leadership, training systems	Memfasilitasi dan memperkuat proses pembelajaran	Meningkatkan kinerja dan retensi
Professional	Technical and soft	Pengembangan	Daya saing dan

Growth	skills	kompetensi berkelanjutan	mobilitas karir
Adaptability	Cognitive flexibility, resilience	Kemampuan merespons perubahan	Ketahanan profesional jangka panjang

Source: author's interpretation

The model demonstrates that lifelong learning serves as a central mechanism that connects digital infrastructure with individual and organizational factors to produce desired professional outcomes. Continuous professional growth is achieved through the accumulation and application of knowledge and skills, while adaptability represents the capacity to sustain performance in the face of change. In answering the research question, the findings clearly show that lifelong learning in the digital era contributes to continuous professional growth and adaptability through a complex interplay of technological, individual, and organizational factors. The effectiveness of this process depends not only on access to learning resources but also on the quality of learning experiences, the level of individual engagement, and the presence of supportive environments. In conclusion, the results and discussion highlight the transformative potential of lifelong learning in addressing the challenges of the digital era. By adopting an integrated and holistic approach, stakeholders can create learning ecosystems that support continuous professional development and enhance adaptability. At the same time, efforts must be made to address structural inequalities and ensure that the benefits of digital learning are accessible to all.

Conclusion

This study concludes that lifelong learning in the digital era plays a pivotal role in fostering continuous professional growth and adaptability in an increasingly dynamic and technology-driven environment. The findings demonstrate that the interaction between digital learning ecosystems, individual learning behaviors, and organizational support systems shapes the effectiveness of lifelong learning. Digital platforms provide flexible and accessible learning opportunities, while individual factors such as motivation, self-directed learning, and digital literacy determine the extent of engagement. At the same time, organizational support through learning culture, leadership, and training systems reinforces and sustains the learning process. These interconnected dimensions collectively contribute to the development of both technical and soft skills, which, in turn, enhance individuals' capacity to adapt to rapid change, uncertainty, and evolving professional demands. Adaptability emerges not only as an outcome of continuous learning but also as a reinforcing mechanism that sustains lifelong learning itself. Based on these findings, this study suggests that future research should adopt more empirical, context-specific approaches to validate further and refine the proposed integrated model. In particular, quantitative or mixed-method studies could be conducted to examine the causal relationships among

lifelong learning, professional growth, and adaptability across sectors and socio-cultural contexts. Additionally, future studies are encouraged to explore the role of emerging technologies—such as artificial intelligence, immersive learning, and data-driven personalization—in shaping more inclusive and effective learning ecosystems. Expanding the scope to include issues of digital inequality, access, and policy implementation will also be crucial to ensuring that the benefits of lifelong learning are distributed more equitably. Through such continued inquiry, a more comprehensive and actionable understanding of lifelong learning in the digital era can be developed.

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Author Contributions Statement

Muhamad Irfan Hakiim contributed to the conceptualization of the study, the design of the methodology, data analysis, and the drafting of the manuscript. He was also responsible for reviewing, editing, and ensuring the overall quality and coherence of the final version of the article.

AI Usage Statement

The authors declare that artificial intelligence (AI)–assisted tools were used during the preparation of this manuscript. Grammarly was employed for grammar checking and language refinement. Use of these tools was strictly limited to linguistic and editorial purposes. All intellectual content, data analysis, interpretation of results, and conclusions were produced solely by the authors, who retain full responsibility for the accuracy, integrity, and originality of the work.

Conflict of Interest

The authors declare that they have no conflicts of interest related to the publication of this manuscript.

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