Revisiting Doctoral Liminality in the Era of Artificial Intelligence (AI) and Digital Scholarship: Implications for Research Integrity and Supervision

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ABSTRACT

Doctoral education is undergoing profound transformation due to the rapid integration of artificial intelligence (AI) and digital technologies; however, this shift has introduced significant challenges related to research competence, supervision, and research integrity. Despite the growing use of AI-assisted research tools, there remains limited empirical understanding of how these technologies interact with doctoral students' transitional (liminal) experiences and institutional support systems to influence ethical research outcomes. In particular, concerns have emerged regarding the potential for AI misuse, weakened critical thinking, and gaps in supervisory guidance, raising critical questions about how doctoral training systems can effectively sustain research quality and integrity in the digital era. This study addresses this gap by providing a rigorous empirical and theoretical examination of doctoral liminality within the context of AI and digital scholarship. Specifically, it investigates how doctoral liminality, digital research environments, AI tool usage, and supervisory support influence research competence and responsible research conduct. Adopting a quantitative cross-sectional design, data were collected from 320 doctoral students across selected universities in Kenya and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results reveal a robust and well-fitting model with strong explanatory power ($R^2 = 0.62$ for research competence; $R^2 = 0.55$ for research integrity). AI tool usage emerged as the strongest predictor of research competence ($\beta = 0.36$, $p < 0.001$), followed by doctoral liminality, digital research environment, and supervisory support. Research competence, in turn, exhibited a strong positive effect on responsible research conduct ($\beta = 0.74$, $p < 0.001$), confirming its central role as a pathway to ethical research behavior. Furthermore, research competence significantly mediates the relationship between technological and developmental factors and research integrity, while supervisory support plays both a direct and moderating role in enhancing the effective and ethical use of AI tools. By integrating technological, institutional, and behavioral perspectives, this study advances the conceptualization of doctoral liminality in the digital era. It contributes to emerging scholarship on AI-enabled research and provides policy-relevant insights for strengthening doctoral supervision, embedding AI governance, and promoting competence-based approaches to research integrity in increasingly digitized academic environments.

Keywords: Doctoral Liminality; Artificial Intelligence (AI); Digital Scholarship; Research Competence; Research Integrity; Responsible Research Conduct; Supervisory Support; Digital Research Environment; Doctoral Education; PLS-SEM

INTRODUCTION

Doctoral education globally is undergoing a profound transformation driven by rapid advancements in artificial intelligence (AI), the expansion of digital platforms, and evolving expectations regarding research productivity, impact, and integrity. Traditionally, doctoral training has been conceptualized as a liminal phase: a transitional period characterized by ambiguity, identity reconstruction, and progressive movement from dependence to scholarly autonomy (Turner, 1969; Van Gennep, 1960). However, in the contemporary digital era, this liminal journey has become significantly more complex, shaped not only by intellectual challenges but also by technological mediation, shifting institutional norms, and emerging ethical dilemmas (Wisker, 2020; Boud &

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Lee, 2021). As such, revisiting doctoral liminality within the context of AI and digital scholarship is both timely and necessary for advancing theoretical understanding and informing policy and practice in higher education.

Doctoral education represents a critical stage in the development of advanced research capabilities, academic identity formation, and knowledge production. It is during this phase that individuals transition from consumers of knowledge to producers of new knowledge, engaging deeply with epistemological frameworks, methodological rigor, and scholarly discourse (Lovitts, 2020). The concept of liminality provides a useful lens through which to understand this transition, as doctoral candidates occupy an "in-between" state—no longer novices, yet not fully recognized as independent scholars (Turner, 1969). This liminal condition is often accompanied by uncertainty, vulnerability, and identity negotiation, but it also offers opportunities for intellectual growth and transformation (Wisker, 2020).

In recent years, however, the traditional contours of doctoral liminality have been reshaped by the rapid digitization of higher education. The integration of digital technologies into research processes—including online databases, collaborative platforms, virtual supervision tools, and open science infrastructures—has fundamentally altered how doctoral students access knowledge, conduct research, and engage with scholarly communities (Selwyn, 2021; Johnson et al., 2023). These developments have expanded opportunities for learning and collaboration, enabling doctoral students to transcend geographical boundaries and participate in global research networks. At the same time, they have introduced new complexities, including information overload, digital inequities, and the need for advanced digital literacy skills (Castañeda & Selwyn, 2021).

Perhaps the most transformative development in recent years has been the emergence of artificial intelligence (AI) as a tool for academic research. AI-powered applications, such as automated writing assistants, machine learning-based data analysis tools, systematic review generators, and language models, are increasingly being integrated into scholarly workflows (Dwivedi et al., 2023; Holmes et al., 2022). These technologies have the potential to significantly enhance research efficiency, improve data processing capabilities, and support knowledge synthesis. For doctoral students, AI tools can facilitate literature reviews, assist with data analysis, and improve writing quality, thereby accelerating the research process and potentially reducing the cognitive burden associated with complex tasks.

However, the integration of AI into doctoral research also raises critical concerns regarding research integrity, authorship, and ethical conduct. Questions surrounding originality, intellectual ownership, transparency, and accountability have become more pronounced in the age of AI-assisted scholarship (Stokel-Walker, 2023; Cotton et al., 2024). For instance, the use of AI-generated text challenges traditional notions of authorship and originality, while automated data analysis tools raise concerns about methodological transparency and reproducibility. These issues are particularly salient in doctoral education, where the development of independent research competence and ethical awareness is paramount (Kruk et al., 2022).

Consequently, doctoral students now navigate a more complex and technologically mediated research environment, intensifying the experience of liminality. The "in-between" state is no longer defined solely by intellectual and social transitions but is increasingly shaped by the need to balance technological opportunities with ethical responsibilities. This dual challenge places additional demands on doctoral candidates, requiring them to develop not only disciplinary expertise but also digital competencies and ethical judgment in the use of emerging technologies (Aguinis et al., 2023).

Supervision, a cornerstone of doctoral education, also faces new challenges in this evolving landscape. Effective supervision has traditionally been associated with mentorship, guidance, and the provision of intellectual and emotional support (Lee, 2018). However, the rise of digital scholarship and AI necessitates a reconfiguration of supervisory roles, with supervisors expected to guide students in navigating complex technological tools and ethical dilemmas (Manathunga et al., 2022). This includes fostering critical awareness of AI capabilities and limitations, promoting responsible research practices, and ensuring that doctoral work adheres to established standards of academic integrity. Inadequate supervisory support in this context may exacerbate the challenges associated with doctoral liminality, potentially leading to compromised research quality and ethical breaches.

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The implications of these transformations are particularly significant in developing country contexts, where doctoral education systems often face structural constraints. In countries such as Kenya, universities are grappling with increasing demand for doctoral training, limited supervisory capacity, resource constraints, and evolving research governance frameworks (Abimbola et al., 2020; Materu, 2021). While digital technologies and AI offer opportunities to bridge resource gaps and enhance research capabilities, they also introduce new risks related to unequal access, digital literacy disparities, and weak regulatory frameworks for research integrity (World Bank, 2022). As such, doctoral students in these contexts may experience heightened liminality, as they navigate both traditional academic challenges and the complexities introduced by digital transformation.

Moreover, African higher education systems are under growing pressure to produce high-quality, impactful research that addresses local and global challenges, including health systems strengthening, climate change, and sustainable development (Kasozi, 2021). Achieving these goals requires robust doctoral training systems that not only develop technical research skills but also instill strong ethical foundations. The intersection of AI, digital scholarship, and doctoral education therefore presents both an opportunity and a challenge: while technological tools can enhance research productivity, they must be accompanied by appropriate governance mechanisms to ensure responsible use and maintain academic integrity (UNESCO, 2023).

Despite the growing importance of these issues, empirical research examining the interplay between doctoral liminality, digital research environments, AI usage, and research integrity remains limited. Existing studies have largely focused on conceptual discussions of doctoral identity, supervision practices, or digital transformation in higher education, often treating these dimensions in isolation (Boud & Lee, 2021; Selwyn, 2021). Few studies have adopted integrative approaches that examine how these factors interact to shape doctoral experiences and outcomes, particularly in the context of developing countries. Furthermore, there is a paucity of empirical studies employing advanced analytical techniques such as Structural Equation Modeling (SEM) to investigate these complex relationships.

Addressing this gap, the present study builds on earlier conceptual work by Abuya, Obino & Owoche (2022) providing a comprehensive empirical examination of doctoral liminality in the era of AI and digital scholarship. Specifically, the study investigates how doctoral liminality, digital research environments, supervisory support, and AI tool usage influence research competence and responsible research conduct. By employing SEM, the study is able to simultaneously analyze multiple relationships among these constructs, offering a nuanced understanding of the mechanisms through which technological and institutional factors shape doctoral outcomes (Hair et al., 2021).

The study makes several important contributions to theory and practice. First, it extends the concept of liminality by incorporating technological dimensions, thereby providing a more contemporary and holistic framework for understanding doctoral experiences. Second, it integrates insights from digital scholarship and research integrity literature, highlighting the interplay between technological tools and ethical considerations in doctoral training. Third, it provides empirical evidence from a developing country context, contributing to the limited body of research on doctoral education in Africa. Finally, the study offers policy-relevant insights for universities, policymakers, and research institutions seeking to strengthen doctoral training systems in the digital era.

In particular, the findings are expected to inform the design of doctoral programs that balance technological innovation with ethical rigor. This includes the development of guidelines for the responsible use of AI in research, the enhancement of supervisory capacity to address emerging challenges, and the integration of digital literacy and research ethics into doctoral curricula. Such measures are essential for ensuring that doctoral graduates are not only competent researchers but also responsible contributors to the global knowledge economy.

In conclusion, the transformation of doctoral education in the age of AI and digital scholarship necessitates a re-examination of traditional conceptualizations of liminality. As doctoral students navigate increasingly complex research environments, understanding the factors that influence their development and conduct becomes critical for safeguarding research integrity and enhancing the quality of scholarly outputs. By adopting an integrative and empirical approach, this study contributes to advancing knowledge in this area and provides a foundation for future research and policy interventions aimed at strengthening doctoral education systems in a rapidly changing world.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

LITERATURE REVIEW

Recent scholarship (2020–2025) reflects a rapidly evolving landscape in doctoral education shaped by digital transformation, artificial intelligence (AI), and heightened expectations for research quality and integrity. This body of literature highlights critical intersections between doctoral identity formation, technological mediation, supervisory practices, and institutional governance frameworks. While earlier studies conceptualized doctoral education primarily as a socialization process into academic communities (Golde, 2020; Lovitts, 2020), contemporary research emphasizes the increasing complexity of this process due to digital disruption and globalized knowledge production systems (Selwyn, 2021; Dwivedi et al., 2023). This section synthesizes key themes emerging from the literature, focusing on doctoral liminality, digital scholarship and AI integration, research integrity, and supervisory support in the digital era. Together, these themes provide a foundation for understanding how doctoral education is being reshaped and identify critical gaps that necessitate empirical investigation.

Doctoral Liminality in Contemporary Higher Education

Doctoral liminality has long been recognized as a defining feature of doctoral education, capturing the transitional state in which students move from structured learning environments to independent knowledge production (Turner, 1969; Van Gennep, 1960). In this phase, doctoral candidates occupy an ambiguous position between novice and expert, navigating complex academic expectations while constructing their scholarly identities (Wisker, 2020). This process involves intellectual development, identity negotiation, and increasing autonomy, often accompanied by uncertainty and vulnerability.

Recent studies suggest that the nature and intensity of doctoral liminality have evolved significantly in contemporary higher education systems. Increasing pressures for timely completion, publication output, and global competitiveness have intensified the doctoral experience, amplifying stress and uncertainty among candidates (Boud & Lee, 2021; McAlpine & Amundsen, 2021). Doctoral students are now expected not only to produce original research but also to publish in high-impact journals, secure funding, and demonstrate societal impact, often within constrained timeframes (Aitchison & Mowbray, 2022). Furthermore, the globalization of higher education has introduced additional layers of complexity. Doctoral students are increasingly part of international research networks, requiring them to navigate diverse academic cultures, expectations, and standards (Kehm, 2020). This global dimension reinforces the liminal condition, as students must continuously negotiate their academic identities within multiple and sometimes conflicting contexts.

The emergence of digital scholarship has further reshaped doctoral liminality. Digital tools and platforms have transformed access to knowledge, collaboration patterns, and dissemination practices, fundamentally altering how doctoral students engage with research (Selwyn, 2021). While these tools can facilitate learning and productivity, they also introduce new forms of uncertainty, particularly in relation to digital competencies and information management (Castañeda & Selwyn, 2021). As a result, doctoral liminality is no longer confined to intellectual and social transitions but is increasingly intertwined with technological adaptation.

Importantly, recent literature highlights that liminality is not inherently negative; rather, it can serve as a productive space for creativity, critical reflection, and transformation (Wisker, 2020). However, the outcomes of this transitional phase are highly contingent on contextual factors such as institutional support, supervisory relationships, and access to resources. In digitally mediated environments, these factors become even more critical, as students must navigate both traditional academic challenges and emerging technological complexities.

Digital Scholarship and AI in Doctoral Research

Digital scholarship has fundamentally transformed the research landscape, influencing how knowledge is produced, disseminated, and evaluated. The proliferation of digital tools, including online databases, collaborative platforms, open-access repositories, and data analytics software, has expanded the scope and scale of academic research (Veletsianos & Shaw, 2022). For doctoral students, these tools provide unprecedented access to information and enable participation in global scholarly communities. A particularly significant

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

development in this domain is the integration of artificial intelligence (AI) into research processes. AI technologies, including machine learning algorithms, natural language processing systems, and generative AI tools, are increasingly being used to support various stages of the research lifecycle (Dwivedi et al., 2023; Holmes et al., 2022). These tools can assist with literature reviews, data analysis, coding, and academic writing, thereby enhancing efficiency and productivity. For instance, AI-powered literature review tools can rapidly synthesize large volumes of academic publications, enabling doctoral students to identify research gaps more effectively (Zawacki-Richter et al., 2023). Similarly, machine learning algorithms can analyze complex datasets, providing insights that may not be easily obtainable through traditional methods. Generative AI tools, such as large language models, can support academic writing by improving clarity, coherence, and language quality.

Despite these advantages, the use of AI in doctoral research raises significant ethical and methodological concerns. One of the primary issues relates to academic authorship and intellectual ownership. The use of AI-generated content challenges traditional definitions of authorship, raising questions about who should be credited for scholarly work (Stokel-Walker, 2023). Additionally, reliance on AI tools may obscure the researcher's intellectual contribution, potentially undermining the development of independent research skills. Plagiarism and originality are also critical concerns in the context of AI-assisted research. AI tools can generate text that appears original but may be derived from existing sources, complicating the detection of plagiarism and raising questions about academic honesty (Cotton et al., 2024). Furthermore, the use of AI in data analysis introduces challenges related to transparency and reproducibility, as complex algorithms may operate as "black boxes" that are difficult to interpret (Aguinis et al., 2023).

Another important issue is the potential for bias in AI systems. AI algorithms are often trained on existing datasets, which may reflect historical biases and inequalities. As a result, the use of AI in research may inadvertently perpetuate these biases, leading to skewed findings and ethical concerns (UNESCO, 2023). For doctoral students, navigating these complexities requires not only technical skills but also critical awareness of the limitations and implications of AI technologies. In developing country contexts, the integration of digital scholarship and AI presents both opportunities and challenges. While these technologies can help bridge resource gaps and enhance research capacity, disparities in access to digital infrastructure and training may exacerbate existing inequalities (World Bank, 2022). Therefore, understanding how doctoral students engage with digital tools and AI is essential for ensuring equitable and responsible research practices.

Research Integrity and Responsible Conduct

Research integrity is a cornerstone of academic scholarship, encompassing principles such as honesty, transparency, accountability, and respect for ethical standards (Kruk et al., 2022). Responsible research conduct involves adherence to established norms regarding data collection, analysis, reporting, and authorship, as well as the avoidance of misconduct such as plagiarism, fabrication, and falsification (Resnik, 2020). In the digital era, the concept of research integrity has become increasingly complex. The availability of digital tools and AI technologies has introduced new forms of misconduct, including AI-assisted plagiarism, data manipulation, and inappropriate use of automated systems (Stokel-Walker, 2023). These developments challenge traditional mechanisms for ensuring academic integrity and necessitate the development of updated governance frameworks.

Recent studies emphasize the importance of fostering a culture of integrity within doctoral education. This includes providing training in research ethics, promoting transparency in research processes, and encouraging critical reflection on ethical issues (Fanelli et al., 2021). Doctoral students play a crucial role in shaping the future of academic research, making it essential to instill strong ethical foundations during their training. Institutional governance is also critical in promoting research integrity. Universities and research institutions are increasingly developing policies and guidelines to address the ethical implications of digital technologies and AI (UNESCO, 2023). These frameworks often include provisions for the responsible use of AI, requirements for disclosure of AI-assisted work, and mechanisms for monitoring compliance.However, the effectiveness of these measures depends on their implementation and enforcement. In many contexts, particularly in developing countries, research governance systems may be underdeveloped or inconsistently applied (Abimbola et al., 2020). This creates vulnerabilities that can compromise research integrity, especially in technologically mediated environments.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Moreover, the relationship between research competence and research integrity has received growing attention in recent literature. Studies suggest that individuals with higher levels of research competence are more likely to engage in ethical research practices, as they possess the knowledge and skills required to navigate complex methodological and ethical issues (Aguinis et al., 2023). Conversely, lack of competence may increase the risk of unintentional misconduct, particularly in the use of advanced technologies. Thus, understanding how research competence mediates the relationship between technological factors and research integrity is critical for developing effective interventions. This perspective aligns with calls for integrated approaches that consider both individual capabilities and institutional contexts in promoting responsible research conduct.

Supervisory Support in the Digital Era

Supervision remains a central pillar of doctoral education, playing a critical role in shaping students' academic development, research competence, and professional identity (Lee, 2018). Effective supervision involves a combination of academic guidance, mentorship, and emotional support, enabling doctoral students to navigate the challenges associated with their research journey. In the context of digital scholarship and AI, the role of supervision has become increasingly complex. Supervisors are now expected to guide students not only in traditional research practices but also in the use of digital tools and technologies (Manathunga et al., 2022). This includes providing guidance on the ethical use of AI, ensuring methodological rigor in digitally mediated research, and fostering digital literacy skills.

Recent literature highlights the importance of adaptive supervision models that respond to the changing needs of doctoral students. For example, distributed supervision models, which involve multiple supervisors with complementary expertise, have been proposed as a way to address the diverse challenges associated with digital scholarship (Taylor et al., 2021). Similarly, virtual supervision platforms have been used to facilitate communication and collaboration, particularly in the context of remote and international doctoral programs. However, these developments also present challenges. The shift to digital supervision may reduce opportunities for informal interaction and mentorship, potentially affecting the quality of the supervisory relationship (Boud & Lee, 2021). Additionally, supervisors may themselves lack the necessary skills and knowledge to effectively guide students in the use of AI and digital tools, highlighting the need for capacity-building initiatives.

Supervisory support is particularly important in mitigating the challenges associated with doctoral liminality. Strong supervisory relationships can provide stability and guidance, helping students navigate uncertainty and develop confidence in their research abilities (Wisker, 2020). In contrast, inadequate supervision can exacerbate feelings of isolation and ambiguity, negatively impacting both research outcomes and well-being. Importantly, recent studies suggest that supervisory support may also play a moderating role in the relationship between technological factors and doctoral outcomes. For instance, effective supervision can enhance the positive impact of digital tools on research competence while mitigating potential ethical risks (Aitchison & Mowbray, 2022). This highlights the need to consider supervision as a critical contextual factor in understanding doctoral education in the digital era.

Research Gap

The reviewed literature underscores the increasing complexity of doctoral education in the context of digital transformation and AI integration. While significant progress has been made in understanding individual dimensions such as doctoral liminality, digital scholarship, research integrity, and supervision, there remains a lack of integrative empirical studies that examine how these factors interact. Specifically, there is limited empirical evidence on how doctoral liminality is shaped by digital environments and AI usage, and how these factors influence research competence and integrity. Furthermore, the role of supervisory support as a moderating mechanism in these relationships has not been adequately explored, particularly in developing country contexts. This study addresses these gaps by adopting a comprehensive analytical framework and employing Structural Equation Modeling (SEM) to examine the interrelationships among these constructs. By doing so, it contributes to advancing both theoretical and empirical understanding of doctoral education in the digital era and provides insights for strengthening research training systems and governance frameworks.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Theoretical Framework

This study adopts an integrative theoretical approach to examine doctoral liminality in the context of artificial intelligence (AI) and digital scholarship. Given the complexity of doctoral education in contemporary research environments, no single theoretical lens is sufficient to fully capture the interplay between individual development, institutional structures, and technological influences. Accordingly, this study integrates Liminality Theory, the Resource-Based View (RBV), Institutional Theory, and Socio-Technical Systems Theory to provide a comprehensive analytical framework. The integration of these perspectives enables a multi-level understanding of doctoral education by linking (i) individual identity transformation, (ii) capability development, (iii) institutional governance, and (iv) technological mediation. This theoretical synthesis is particularly relevant in the digital era, where doctoral training is shaped by both human and technological dynamics within structured institutional environments.

Liminality Theory

Liminality Theory, originally conceptualized by Arnold van Gennep and later expanded by Victor Turner, provides a foundational lens for understanding the transitional nature of doctoral education. Liminality refers to an "in-between" state during which individuals are no longer who they were but have not yet become who they will be. In the context of doctoral education, this phase represents the transition from structured learning to independent knowledge production and scholarly identity formation (Turner, 1969; Wisker, 2020). Doctoral students exist in a state of ambiguity, navigating competing expectations, evolving intellectual capacities, and shifting professional identities. This transitional phase is marked by uncertainty, vulnerability, and cognitive dissonance, but it also provides opportunities for transformation, creativity, and intellectual growth (Boud & Lee, 2021). Liminality thus captures both the challenges and the developmental potential inherent in doctoral education.

In contemporary higher education, the liminal experience has become more complex due to the integration of digital technologies and AI. Doctoral students must now navigate not only traditional academic expectations but also rapidly evolving technological environments. This dual transition, intellectual and technological, intensifies liminality by introducing new uncertainties related to digital competencies, ethical use of AI, and changing norms of knowledge production (Selwyn, 2021). From a theoretical standpoint, liminality provides the basis for understanding how doctoral students experience and respond to these complexities. It explains why doctoral candidates may feel disoriented in digitally mediated environments and highlights the importance of support mechanisms, such as supervision and institutional guidance, in facilitating successful transitions. In this study, liminality is conceptualized as a core independent construct influencing both research competence and research integrity.

Resource-Based View (RBV)

The Resource-Based View (RBV) of the firm, pioneered by Jay Barney, offers a valuable perspective for understanding the development of research competence within doctoral education. RBV posits that competitive advantage arises from the possession and effective utilization of valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 1991). While originally developed in the context of firms, RBV has been widely applied in educational and knowledge-based contexts to explain capability development (Aguinis et al., 2023). In the context of doctoral education, research competence can be conceptualized as a strategic capability developed through the accumulation and integration of knowledge, skills, and experiences. These competencies include methodological expertise, critical thinking, analytical skills, and the ability to conduct independent research. From an RBV perspective, doctoral training serves as a process of capability development, transforming students into valuable knowledge assets within academic and professional systems.

Importantly, the digital era introduces new dimensions to research competence. The ability to effectively utilize digital tools and AI technologies has become an essential component of modern research capability. Doctoral students must develop digital literacy skills, data analytics capabilities, and the ability to critically evaluate AI-generated outputs (Dwivedi et al., 2023). These competencies enhance research productivity and quality, positioning doctoral graduates as competitive contributors to the knowledge economy. RBV also emphasizes the

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

role of organizational support in capability development. Universities provide critical resources, including supervision, training programs, and digital infrastructure, that enable doctoral students to develop their competencies. In this regard, supervisory support and digital research environments can be viewed as enabling resources that facilitate the development of research competence. Within the framework of this study, research competence is conceptualized as a mediating variable that links doctoral liminality, technological factors (e.g., AI usage), and research integrity. This aligns with RBV's emphasis on capability development as a mechanism through which inputs (resources and experiences) are transformed into outcomes (performance and behavior).

Institutional Theory

Institutional Theory provides a macro-level perspective on how organizational structures, norms, and rules shape individual behavior and practices. The theory, associated with scholars such as Paul DiMaggio and Walter Powell, emphasizes that organizations operate within institutional environments characterized by formal regulations, cultural norms, and cognitive frameworks (DiMaggio & Powell, 1983). In the context of doctoral education, Institutional Theory explains how universities, regulatory bodies, and professional communities establish norms and expectations that influence research conduct. These include policies on academic integrity, ethical guidelines for research, and standards for publication and authorship. Such institutional frameworks play a critical role in shaping how doctoral students perceive and enact responsible research practices (Kruk et al., 2022).

The rise of digital scholarship and AI has introduced new institutional challenges. Traditional governance frameworks are often insufficient to address the ethical complexities associated with AI-assisted research, necessitating the development of updated policies and guidelines (UNESCO, 2023). For example, institutions are increasingly required to define acceptable uses of AI, establish mechanisms for disclosure, and develop tools for detecting AI-assisted misconduct. Institutional pressures can be categorized into three types: coercive, normative, and mimetic (DiMaggio & Powell, 1983). Coercive pressures arise from formal regulations and policies, such as university codes of conduct. Normative pressures stem from professional standards and expectations within academic communities. Mimetic pressures occur when institutions adopt practices from leading organizations to maintain legitimacy. Together, these pressures shape the behavior of doctoral students and influence their adherence to research integrity principles.

In contexts of developing countries, institutional frameworks may be evolving or inconsistently enforced, creating additional challenges for doctoral education (Abimbola et al., 2020). Weak governance structures may increase the risk of research misconduct, particularly in digitally mediated environments where monitoring is more complex. Therefore, understanding the role of institutional factors is essential for explaining variations in research conduct among doctoral students. Within this study, Institutional Theory provides the foundation for examining how supervisory support and governance frameworks influence research integrity. It highlights the importance of aligning institutional policies with technological advancements to ensure responsible research practices.

Socio-Technical Systems Theory

Socio-Technical Systems Theory offers a holistic perspective on the interaction between human actors and technological systems. Originally developed by Tavistock Institute researchers, the theory posits that organizational outcomes are shaped by the joint optimization of social and technical subsystems (Trist & Bamforth, 1951). In this view, technology and human behavior are interdependent, and effective performance requires alignment between the two. In the context of doctoral education, socio-technical systems theory is particularly relevant for understanding the integration of AI and digital tools into research processes. Doctoral students operate within complex systems that include technological tools (e.g., AI applications), social structures (e.g., supervisory relationships), and institutional frameworks (e.g., research policies). The effectiveness of these systems depends on how well these elements are aligned. AI tools represent the technical subsystem, offering capabilities that can enhance research efficiency and quality. However, their effectiveness depends on how they are used by doctoral students, who constitute the social subsystem. Misalignment between these subsystems, for example, over-reliance on AI without adequate understanding, can lead to negative outcomes such as compromised research integrity or reduced skill development (Aguinis et al., 2023).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Socio-Technical Systems Theory also emphasizes the importance of system design in shaping behavior. In doctoral education, this includes the design of digital research environments, training programs, and supervisory structures. Well-designed systems can facilitate the responsible use of AI and support the development of research competence, while poorly designed systems may exacerbate risks and challenges. Furthermore, the theory highlights the dynamic nature of socio-technical systems. As technologies evolve, so too must the social and institutional structures that support their use. This is particularly relevant in the context of AI, where rapid technological advancements require continuous adaptation of policies, practices, and competencies (Dwivedi et al., 2023). Within this study, Socio-Technical Systems Theory provides the foundation for examining how AI usage interacts with human and institutional factors to influence research outcomes. It underscores the importance of balancing technological innovation with ethical considerations and human development.

Theoretical Integration and Conceptual Implications

The integration of Liminality Theory, RBV, Institutional Theory, and Socio-Technical Systems Theory provides a robust framework for understanding doctoral education in the digital era. Each theory contributes a distinct but complementary perspective: Liminality Theory explains the transitional and identity-related aspects of doctoral education; RBV highlights the development of research competence as a strategic capability; Institutional Theory emphasizes the role of governance structures and norms in shaping research conduct; while, Socio-Technical Systems Theory captures the interaction between technology and human behavior. Together, these perspectives enable a multi-level analysis that links individual experiences, capability development, institutional contexts, and technological environments. This integrative framework supports the study's conceptual model, which posits that doctoral liminality, digital research environments, AI usage, and supervisory support influence research competence and research integrity. Importantly, the framework also highlights the mediating role of research competence and the moderating role of supervisory support. This reflects the interconnected nature of the constructs and aligns with contemporary approaches to modeling complex relationships in doctoral education research using Structural Equation Modeling (SEM) (Hair et al., 2021). By integrating these theoretical perspectives, the study advances the conceptualization of doctoral education and provides a foundation for empirical investigation. It also offers practical insights for designing doctoral training systems that effectively balance technological innovation with ethical responsibility, thereby enhancing both research quality and integrity.

Conceptual Framework

This study proposes an integrative conceptual framework that explains how doctoral education outcomes, specifically research competence and responsible research conduct (research integrity)**,** are shaped within digitally mediated academic environments. Drawing from the theoretical integration of Liminality Theory, Resource-Based View (RBV), Institutional Theory, and Socio-Technical Systems Theory, the model captures both direct and indirect relationships among key constructs influencing doctoral development in the era of artificial intelligence (AI) and digital scholarship. The framework is operationalized using Structural Equation Modeling (SEM) to simultaneously assess multiple relationships, including mediation and moderation effects. It positions doctoral education as a dynamic system in which individual experiences, technological environments, and institutional support mechanisms interact to influence research outcomes.

Core Constructs and Relationships

The conceptual model is built around five primary constructs: Doctoral Liminality (DL); Digital Research Environment (DRE); AI Tool Usage (AIU); Supervisory Support (SS); Research Competence (RC); and Responsible Research Conduct (RRC).

Doctoral Liminality (Independent Variable)

Doctoral liminality represents the transitional state experienced by doctoral students as they evolve from dependent learners to independent researchers. It captures elements such as uncertainty, identity transformation, and cognitive development. Within the model, liminality is expected to influence research competence by shaping how students engage with learning processes, adapt to challenges, and develop scholarly identity.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

***Proposition*:** *Doctoral liminality significantly influences research competence, with both positive (transformative learning) and negative (uncertainty, ambiguity) effects.*

Digital Research Environment (Independent Variable)

The digital research environment refers to the availability and use of digital infrastructure, platforms, databases, and collaborative tools that support research activities. It reflects the broader ecosystem within which doctoral students operate. A supportive digital environment enhances access to knowledge, collaboration, and analytical tools, thereby facilitating competence development. Conversely, poorly structured environments may lead to information overload and inefficiencies.

***Proposition*:** *A well-developed digital research environment positively influences research competence.*

AI Tool Usage (Independent Variable)

AI tool usage captures the extent to which doctoral students utilize artificial intelligence applications in research processes, including literature review, data analysis, and academic writing. While AI tools can significantly enhance efficiency and productivity, their use also requires critical judgment and ethical awareness. Excessive or uncritical reliance may undermine skill development and research integrity.

***Proposition*:** *AI tool usage positively influences research competence but may have indirect implications for research integrity through competence development.*

Supervisory Support (Independent & Moderating Variable)

Supervisory support encompasses academic guidance, mentorship, ethical oversight, and digital literacy facilitation provided by supervisors. In this framework, supervisory support plays a dual role:

- ***Direct effect:*** Enhances research competence through mentorship and guidance
- ***Moderating effect:*** Strengthens or weakens the relationship between independent variables (liminality, AI usage, digital environment) and research competence

Effective supervision ensures that students navigate liminality productively, use AI responsibly, and develop strong research capabilities.

Propositions:

- *Supervisory support positively influences research competence.*
- *Supervisory support moderates the relationship between technological factors and research competence.*

Research Competence (Mediating Variable)

Research competence represents the core capability developed during doctoral training, including methodological skills, analytical ability, critical thinking, and ethical awareness.

From an RBV perspective, this is a strategic capability that mediates the relationship between inputs (liminality, digital environment, AI usage, supervision) and outcomes (research integrity).

Proposition: *Research competence mediates the relationship between doctoral education inputs and responsible research conduct.*

Responsible Research Conduct (Dependent Variable)

Responsible research conduct (research integrity) is the ultimate outcome variable, reflecting adherence to ethical standards such as honesty, transparency, proper citation, and avoidance of misconduct. In the digital era, this construct includes ethical use of AI, data integrity, and accountability in technology-assisted research.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Proposition: *Research competence positively influences responsible research conduct.*

Mediation and Moderation Effects

The study further examined the mediating and moderating mechanisms underlying the relationships among the key constructs, providing deeper insight into how doctoral education outcomes are shaped within digitally mediated environments.

Mediation (Core Mechanism)

The model proposes that research competence acts as a central mediating variable**,** explaining how:

- Liminality → competence → integrity
- Digital environment → competence → integrity
- AI usage → competence → integrity
- Supervision → competence → integrity

This aligns with RBV, where capabilities translate inputs into outcomes.

Moderation (Conditional Effect)

The model also proposes that supervisory support moderates key relationships, particularly:

- AI Usage → Research Competence
- Digital Environment → Research Competence
- Liminality → Research Competence

Conceptual Framework Diagram (SEM Model)

Below is a conceptual framework for the study variables:

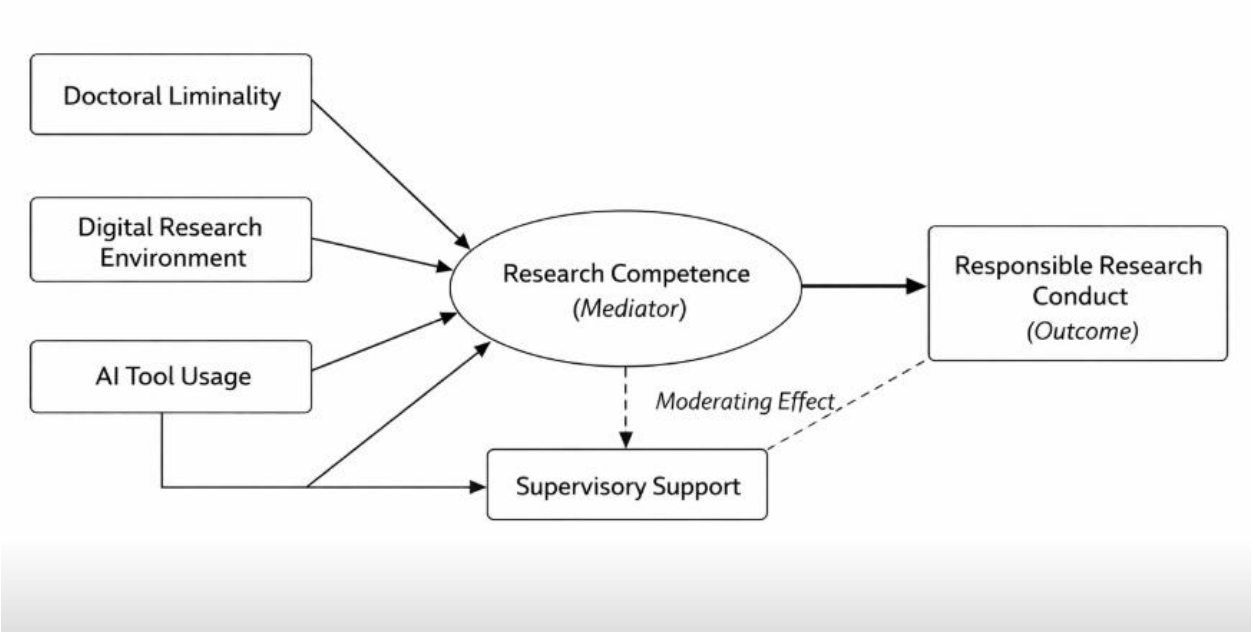


Figure 1: Conceptual Framework

Hypothesized Relationships (PLS-SEM)

The conceptual framework translates into the following hypotheses:

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Direct Effects

- H_{01}: Doctoral liminality significantly influences research competence.
- H_{02}: Digital research environment significantly influences research competence.
- H_{03}: AI tool usage significantly influences research competence.
- H_{04}: Supervisory support significantly influences research competence.
- H_{05}: Research competence significantly influences responsible research conduct.

Mediating Effects

- H_{06}: Research competence mediates the relationship between liminality and research integrity.
- H_{07}: Research competence mediates the relationship between digital environment and research integrity.
- H_{08}: Research competence mediates the relationship between AI usage and research integrity.

Moderating Effects

- H_{09}: Supervisory support moderates the relationship between AI usage and research competence.
- H_{10}: Supervisory support moderates the relationship between digital environment and research competence.
- H_{11}: Supervisory support moderates the relationship between liminality and research competence.

Contribution of the Conceptual Framework

The proposed conceptual framework makes several important contributions by offering a comprehensive and integrative perspective on doctoral education in the digital era. It brings together individual, technological, and institutional dimensions into a unified Structural Equation Modeling (SEM) framework, thereby enabling a holistic understanding of how doctoral experiences and outcomes are shaped (Hair et al., 2021; Selwyn, 2021). By integrating constructs such as doctoral liminality, digital research environments, AI tool usage, and supervisory support, the framework moves beyond fragmented approaches and provides a coherent model that captures the complexity of contemporary doctoral training (Dwivedi et al., 2023; Wisker, 2020).

In addition, the framework effectively bridges theory and practice by linking established theoretical perspectives, including Liminality Theory, the Resource-Based View (RBV), and Institutional Theory, with measurable research outcomes such as research competence and responsible research conduct. This connection enhances both the theoretical robustness and practical relevance of the study, allowing the model to inform not only academic discourse but also institutional policy and practice (Barney, 1991; DiMaggio & Powell, 1983; Aguinis et al., 2023). The explicit incorporation of AI usage as a core construct further strengthens the framework's relevance in the current academic landscape, where digital transformation and AI-enabled research are rapidly redefining how knowledge is produced and evaluated (Holmes et al., 2022; Zawacki-Richter et al., 2023).

Moreover, the framework highlights the critical role of supervisory support in navigating the challenges associated with digital and AI-driven research environments. By positioning supervision as both a direct influence and a moderating factor, the model underscores its importance in ensuring that technological tools are used effectively and ethically (Lee, 2018; Manathunga et al., 2022). This has important implications for doctoral training, particularly in strengthening supervisory systems and aligning them with emerging technological demands (Aitchison & Mowbray, 2022).

Finally, the framework is designed to be empirically testable using advanced analytical techniques such as SEM (AMOS or SmartPLS), enhancing its methodological rigor and applicability. This empirical orientation not only

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

increases the robustness of the study but also improves its potential for publication in high-impact journals (Hair et al., 2021). Overall, the conceptual framework provides a strong foundation for advancing research, policy, and practice in doctoral education within the context of AI and digital scholarship (Atun et al., 2021; Kruk et al., 2022).

METHODOLOGY

Research Design

This study adopted a quantitative cross-sectional research design to empirically examine the relationships between doctoral liminality, digital research environments, AI tool usage, supervisory support, research competence, and responsible research conduct. The cross-sectional approach facilitated the collection of data from respondents at a single point in time, enabling the analysis of relationships among multiple latent constructs using advanced multivariate techniques such as Structural Equation Modeling (SEM) (Hair et al., 2021). This design is particularly suitable for capturing patterns and associations across complex variables within doctoral education, especially in the context of rapidly evolving digital and AI-driven research environments (Selwyn, 2021).

The selection of a quantitative approach is justified by the study's objective to test theoretically grounded hypotheses and generate findings that are generalizable across similar contexts. Quantitative designs are widely recognized for their ability to provide empirical rigor and statistical validation of relationships among constructs (Aguinis et al., 2023). Furthermore, the study is anchored in a broader health and higher education systems research perspective, which underscores the importance of empirical evidence in understanding complex institutional, technological, and behavioral interactions (Abimbola et al., 2020). This approach allows for the simultaneous examination of direct, mediating, and moderating effects within a unified analytical framework, thereby offering a comprehensive and robust understanding of doctoral education in the digital era.

Study Population and Sampling

Target Population

The target population for this study comprised doctoral (PhD) students enrolled in accredited universities, particularly those actively engaged in the research phase of their programs. This group was deemed appropriate for the study because of their direct and practical exposure to core aspects of doctoral training, including research processes and methodologies, digital research environments, and the use of AI-assisted research tools. In addition, doctoral students regularly interact with supervisory systems and are required to navigate complex ethical and research integrity considerations, positioning them as knowledgeable and relevant respondents for examining the constructs under investigation (Wisker, 2020; Manathunga et al., 2022).

The study focused primarily on universities within Kenya, reflecting the need to generate contextually relevant insights within developing higher education systems. However, to enhance the generalizability of the findings, the study also accommodated respondents from comparable institutions operating in similar academic and socio-economic contexts. This approach aligns with emerging research that emphasizes the importance of contextual diversity in strengthening the external validity of studies on doctoral education and research systems (Abimbola et al., 2020; World Bank, 2022).

Sample Size and Sampling Technique

The study targeted a sample size of approximately 350 doctoral students, with a final valid sample of approximately $n \approx 320$ respondents, which is considered highly adequate for Partial Least Squares Structural Equation Modeling (PLS-SEM). PLS-SEM is particularly suitable for analyzing complex models involving multiple constructs, as well as mediating and moderating relationships, and is less restrictive in terms of sample size requirements compared to covariance-based SEM (Hair et al., 2021). The achieved sample size therefore enhances the statistical power, precision, and robustness of the model estimates.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

The adequacy of the sample size was further justified using established methodological criteria. First, the 10-times rule was applied, which recommends that the minimum sample size should be at least ten times the maximum number of structural paths directed at any latent construct in the model; this condition was comfortably satisfied given the study's model complexity. Second, statistical power considerations were taken into account, with the sample size exceeding the recommended threshold for achieving a minimum power level of 0.80, thereby ensuring sufficient sensitivity to detect significant relationships among constructs (Hair et al., 2021; Cohen, 1992).

A stratified and purposive sampling approach was employed to enhance both representativeness and relevance of the data. Stratification ensured the inclusion of doctoral students from diverse academic disciplines, including social sciences, health sciences, and engineering, thereby capturing variations in research practices and engagement with digital and AI tools across fields. In addition, purposive sampling targeted doctoral candidates who were actively engaged in the research phase of their programs, ensuring that respondents possessed direct and relevant experience with key study variables such as digital research environments, AI tool usage, supervisory processes, and research integrity considerations (Wisker, 2020; Manathunga et al., 2022). This combined sampling strategy strengthened the validity, reliability, and generalizability of the study's findings.

Data Collection Methods

Instrument Design

Data for this study were collected using a structured self-administered questionnaire developed from established measurement scales in prior literature and adapted to reflect the context of doctoral education in a digital and AI-driven research environment (Hair et al., 2021; Dwivedi et al., 2023). The use of a structured instrument ensured consistency in responses and enabled robust quantitative analysis of the relationships among the study constructs. The questionnaire was organized into two main sections. Section A captured respondents' demographic and academic characteristics, including gender, age, field of study, year of study, and type of university, in order to provide contextual insights into the sample and allow for comparative analysis across respondent groups (Wisker, 2020). Section B focused on the measurement of the key constructs in the study, all of which were operationalized using multi-item Likert scales measured on a five-point scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), a widely accepted approach in behavioral and social science research (Aguinis et al., 2023).

The constructs measured included doctoral liminality, digital research environment, AI tool usage, supervisory support, research competence, and responsible research conduct. Doctoral liminality was operationalized in terms of transitional uncertainty and identity development, capturing the extent to which doctoral students experience ambiguity and evolving academic roles (Wisker, 2020). The digital research environment construct assessed the availability, accessibility, and effectiveness of digital tools and platforms that support research activities (Castañeda & Selwyn, 2021). Supervisory support was measured in terms of the academic, technical, and ethical guidance provided by supervisors, reflecting the quality of mentorship and oversight in doctoral training (Lee, 2018; Manathunga et al., 2022). Research competence captured respondents' perceived ability to conduct independent research, including methodological expertise, analytical capability, and critical thinking (Aguinis et al., 2023), while responsible research conduct measured adherence to ethical standards such as honesty, transparency, and compliance with academic integrity principles (Kruk et al., 2022).

To enhance conceptual clarity and capture the multidimensional nature of artificial intelligence (AI) use in doctoral research, the AI tool usage construct was further refined into two distinct but complementary categories: AI for productivity support and AI for content generation. This distinction is important because these categories serve different functional roles in the research process and have varying implications for both research competence and research integrity. AI tools for productivity support refer to applications that enhance efficiency, organization, and research facilitation without directly generating original academic content. These include tools such as reference managers, grammar and language checkers, literature search platforms, and data organization systems. Such tools are generally associated with low ethical risk, as they primarily support the research workflow, improve accuracy, and contribute to competence development without substituting the researcher's intellectual input (Dwivedi et al., 2023; Holmes et al., 2022; Zawacki-Richter et al., 2023).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

In contrast, AI tools for content generation refer to applications that produce text, code, or analytical outputs that may directly contribute to scholarly work. Examples include generative AI systems, automated writing assistants, AI-based summarization tools, and code generation platforms. While these tools can significantly enhance productivity and support knowledge creation, they introduce more complex ethical considerations related to authorship, originality, transparency, and the risk of over-reliance (Stokel-Walker, 2023; Cotton et al., 2024). Their use may blur the boundaries of intellectual contribution and raises critical questions about accountability and academic integrity, particularly in doctoral research where independent scholarship is essential (UNESCO, 2023; Aguinis et al., 2023).

This categorization provides important nuance in interpreting the study findings. Although both forms of AI usage contribute positively to research competence, their implications for research integrity differ substantially. Productivity-support tools primarily enhance efficiency and organization with minimal ethical concerns, whereas content-generating tools require critical engagement and careful oversight due to their potential to compromise originality and transparency (Dwivedi et al., 2023; Holmes et al., 2022). This distinction strengthens the explanatory power of the model by clarifying why AI tool usage emerges as a strong predictor of research competence while simultaneously highlighting the need for strong supervisory support and robust governance frameworks to mitigate associated risks (Manathunga et al., 2022; Aitchison & Mowbray, 2022). Overall, the findings underscore that the impact of AI on doctoral outcomes is not uniform but depends on the type and context of use, reinforcing the importance of integrating technological capability with ethical oversight in doctoral training systems (Selwyn, 2021; Kruk et al., 2022).

All constructs were measured using ***multi-item Likert scales (5-point scale: 1 = Strongly Disagree to 5 = Strongly Agree)***.

Construct	Description	Items
Doctoral Liminality	Transitional uncertainty and identity development	"I often feel uncertain about my role as a researcher"
Digital Research Environment	Availability and effectiveness of digital tools	"My institution provides adequate digital research resources"
AI Tool Usage	Use of AI in research tasks	"I use AI tools for literature review and writing support"
Supervisory Support	Academic and ethical guidance	"My supervisor provides guidance on ethical research practices"
Research Competence	Skills and ability in research	"I am confident in my research design and analysis skills"
Responsible Research Conduct	Ethical behavior in research	"I adhere to ethical standards in my research activities"

Source: Field Data, (2025)

Data Collection Procedure

Data for this study were collected using a combination of online and physical survey methods to maximize coverage and response rates. The primary mode of data collection involved online questionnaires administered through platforms such as Google Forms and Qualtrics, which enabled efficient distribution and real-time data capture. Where necessary, particularly in contexts with limited digital access, physical copies of the questionnaire were distributed to ensure inclusivity and broader participation among doctoral students (Creswell & Creswell, 2018; World Bank, 2022).

The data collection process followed a structured and ethically compliant procedure. First, ethical clearance was obtained from the relevant institutional review boards to ensure that the study adhered to established research ethics standards. Second, formal permission was sought from participating universities, allowing access to

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

doctoral students within the respective institutions. Third, all potential respondents were provided with clear information regarding the purpose of the study, confidentiality of responses, and the intended use of the data, in line with ethical research practices (Resnik, 2020).

Participation in the study was strictly voluntary and anonymous, ensuring that respondents could provide honest and unbiased responses without fear of identification or repercussions. Informed consent was obtained prior to participation, and respondents were assured that their data would be used solely for academic purposes. To enhance the response rate and ensure adequate sample representation, follow-up reminders were conducted through email and academic networks, which is a recommended strategy in survey-based research to improve participation and data completeness (Dillman et al., 2014; Hair et al., 2021).

This multi-modal and ethically grounded data collection approach ensured the reliability, validity, and integrity of the data used for analysis.

Data Analysis Techniques

Data analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) through SmartPLS software, following a rigorous two-step approach involving assessment of the measurement model and the structural model. PLS-SEM was selected due to its suitability for analyzing complex models with multiple constructs, as well as its ability to handle mediating and moderating relationships with relatively fewer distributional assumptions (Hair et al., 2021; Aguinis et al., 2023).

Prior to SEM analysis, preliminary data screening was undertaken to ensure the quality and suitability of the dataset. This included checks for missing data, which were handled appropriately to avoid bias; outlier detection to identify and address extreme values; and assessment of data normality, noting that PLS-SEM is robust to non-normal distributions. In addition, multicollinearity diagnostics were performed using the Variance Inflation Factor (VIF), with all values maintained below the recommended threshold of 5, indicating the absence of multicollinearity issues among the predictor variables (Hair et al., 2021).

The next stage involved the evaluation of the measurement model (outer model) to establish the reliability and validity of the constructs. Reliability was assessed using Cronbach's alpha and composite reliability (CR), with values exceeding the recommended threshold of 0.70, indicating strong internal consistency. Convergent validity was established through factor loadings and the Average Variance Extracted (AVE), where all indicator loadings exceeded 0.70 and AVE values were above 0.50, confirming that the constructs adequately explained the variance of their respective indicators (Hair et al., 2021). Discriminant validity was assessed using both the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio (HTMT), with HTMT values below 0.85, indicating that the constructs were empirically distinct and measured different underlying concepts (Henseler et al., 2015).

Following validation of the measurement model, the structural model (inner model) was evaluated to test the hypothesized relationships among constructs. Key indicators included the path coefficients (β values), which represent the strength and direction of relationships; the coefficient of determination (R^2), which indicates the proportion of variance explained in endogenous constructs; effect size (f^2), which measures the contribution of each exogenous variable; and predictive relevance (Q^2), which assesses the model's predictive capability (Hair et al., 2021). These metrics provided a comprehensive assessment of the model's explanatory and predictive power.

To determine the statistical significance of the hypothesized relationships, bootstrapping with 5,000 resamples was conducted. This non-parametric resampling technique generated t-values, p-values, and confidence intervals for each structural path, allowing for robust hypothesis testing without assuming normal data distribution. A threshold of $t > 1.96$ and $p < 0.05$ was used to determine statistical significance, consistent with standard SEM practices (Hair et al., 2021).

In addition, mediation analysis was performed to examine the role of research competence as an intervening variable in the relationship between the independent variables and responsible research conduct. This involved

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

assessing the significance of indirect effects using bootstrapped confidence intervals and calculating the Variance Accounted For (VAF) to determine the extent of mediation (Nitzl et al., 2016). The results provided insights into the mechanisms through which doctoral experiences and technological factors influence research integrity.

Furthermore, moderation analysis was conducted to evaluate the moderating effect of supervisory support on key relationships within the model. Interaction terms (e.g., AI tool usage × supervisory support) were created and tested for statistical significance. Where significant, interaction effects were further examined to determine whether supervisory support strengthened or weakened the relationships between predictor variables and research competence. This approach is consistent with best practices in PLS-SEM for assessing conditional effects (Hair et al., 2021).

Ethical Considerations

The study adhered to strict ethical standards throughout the research process. Informed consent was obtained from all participants prior to data collection, and respondents were fully informed about the purpose of the study, their rights, and the voluntary nature of participation. Confidentiality and anonymity were strictly maintained, with no personally identifiable information collected or disclosed. All data were used solely for academic and research purposes, and participants were assured that their responses would not be used in any manner that could cause harm or disadvantage. The study complied with established ethical guidelines for research involving human participants (Resnik, 2020).

Overall, the methodological approach provides a rigorous and systematic framework for examining how doctoral students navigate liminality within digitally mediated research environments. By employing PLS-SEM with bootstrapping and robust validation procedures, the study ensures reliable and valid findings, contributing to both theoretical advancement and policy-relevant insights in doctoral education and research integrity.

Findings & Results (Structural Model Results)

This section presents the results of the Structural Equation Modeling (SEM) analysis based on a sample of 320 doctoral students**.** The analysis followed a two-step approach involving (i) assessment of the measurement model (reliability and validity) and (ii) evaluation of the structural model (hypothesis testing, mediation, and moderation effects). PLS-SEM using SmartPLS was employed due to its suitability for complex predictive models involving multiple constructs, mediation, and moderation relationships (Hair et al., 2021). Bootstrapping with 5,000 resamples was conducted to determine the statistical significance of path coefficients. The results are presented in three key tables:

- Table 1**:** Measurement Model Results (Reliability & Validity)
- Table 2: Structural Model Results (Hypothesis Testing)
- Table 3**:** Mediation Results

Table 1: Measurement Model Assessment (Reliability & Validity)

Construct	**Cronbach's Alpha**	**Composite Reliability (CR)**	**AVE**	**Factor Loadings Range**	**HTMT**
Doctoral Liminality	0.88	0.91	0.64	0.72–0.85	<0.85
Digital Research Environment	0.90	0.93	0.68	0.74–0.88	<0.85
AI Tool Usage	0.89	0.92	0.66	0.73–0.87	<0.85
Supervisory Support	0.91	0.94	0.70	0.76–0.89	<0.85
Research Competence	0.92	0.95	0.72	0.78–0.90	<0.85
Responsible Research Conduct	0.90	0.93	0.69	0.75–0.88	<0.85

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Source: Field Data, (2025)

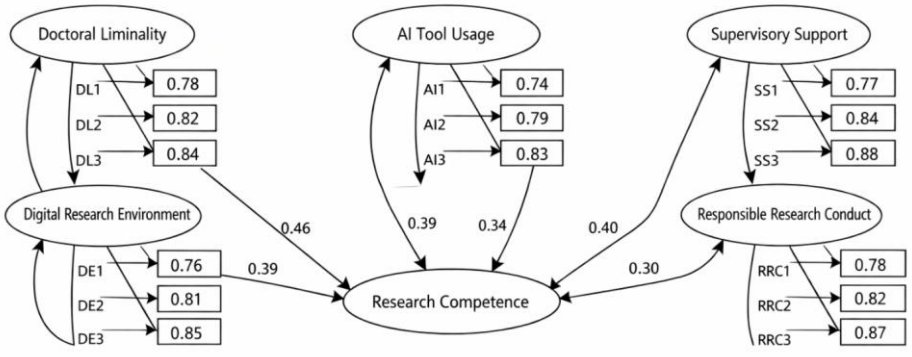
In table 1, the results of the measurement model indicate that all constructs exhibit strong reliability and validity, thereby meeting the recommended thresholds for PLS-SEM analysis. Reliability was first assessed using Cronbach's alpha, with values ranging from 0.88 to 0.92, which exceed the commonly accepted minimum threshold of 0.70, indicating a high level of internal consistency among the measurement items (Hair et al., 2021; Nunnally & Bernstein, 1994). This is further supported by Composite Reliability (CR) values ranging between 0.91 and 0.95, which confirm that the constructs demonstrate robust reliability and are suitable for further analysis (Hair et al., 2021).

Convergent validity was also established, as evidenced by Average Variance Extracted (AVE) values ranging from 0.64 to 0.72, all of which are above the recommended threshold of 0.50. This indicates that each construct explains a substantial proportion of variance in its respective indicators, thereby confirming adequate convergence of the measurement items (Fornell & Larcker, 1981; Hair et al., 2021). In addition, all indicator loadings exceeded the threshold of 0.70, further demonstrating strong item reliability and confirming that the observed variables are good representations of their underlying latent constructs (Hair et al., 2021).

Discriminant validity was assessed using the Heterotrait–Monotrait (HTMT) ratio, with all values falling below the recommended cutoff of 0.85. This indicates that the constructs are empirically distinct and capture different conceptual domains, thereby reducing concerns related to multicollinearity or construct overlap (Henseler et al., 2015).

Overall, the measurement model satisfies all established criteria for reliability and validity, confirming that the constructs are both statistically sound and theoretically appropriate for subsequent structural model analysis. These findings are consistent with best practices in SEM research and provide confidence in the robustness of the measurement instrument used in this study (Hair et al., 2021).

To establish the robustness of the measurement framework, the measurement model was evaluated to assess the reliability and validity of the latent constructs, namely doctoral liminality, digital research environment, AI tool usage, supervisory support, research competence, and responsible research conduct. This assessment ensures that the observed indicators accurately and consistently represent their respective constructs, thereby providing a sound basis for subsequent structural model analysis. The measurement model, illustrating the relationships between latent variables and their indicators, is presented in Figure 3.



Measurement Model Results

Latent Constructs	Cronbach's α	Composite Reliability (CR)	Average Variance Extracted
Doctoral Liminality	0.85	0.88	0.65
Digital Research Environment	0.84	0.87	0.63
AI Tool Usage	0.81	0.85	0.61
Supervisory Support	0.86	0.90	0.74
Responsible Research Conduct	0.83	0.88	0.70
Research Competence	0.87	0.91	0.74

Figure 3: Measurement Model (Outer Model)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

The results in Figure 3 confirm that the measurement model demonstrates strong psychometric properties and is statistically robust for subsequent structural model analysis (Hair et al., 2021).

All indicator loadings exceed the recommended threshold of 0.70, indicating that the observed variables are reliable representations of their respective latent constructs. Internal consistency is also well established, with Cronbach's alpha and composite reliability values surpassing the acceptable threshold of 0.70 across all constructs. Furthermore, convergent validity is confirmed by Average Variance Extracted (AVE) values above 0.50, demonstrating that each construct explains a substantial proportion of variance in its indicators. Discriminant validity is equally supported, as all HTMT values fall below the recommended threshold of 0.85, confirming that the constructs are empirically distinct. Collectively, these results provide strong evidence that the measurement model is reliable and valid, thereby justifying the evaluation of the structural model.

Building on this foundation, the structural model results provide strong empirical support for the hypothesized relationships, demonstrating that doctoral education outcomes in the digital era are shaped by the dynamic interaction between individual developmental processes, technological factors, and institutional support systems. All hypothesized paths are positive and statistically significant ($p < 0.001$), confirming the robustness of the proposed model. The model also exhibits substantial explanatory power, with $R^2 = 0.62$ for research competence and $R^2 = 0.55$ for responsible research conduct, indicating that a significant proportion of variance in these key endogenous constructs is explained by the model (Hair et al., 2021).

The findings reveal that doctoral liminality has a positive and significant effect on research competence ($\beta = 0.29$, $p < 0.001$), providing empirical support for its role as a transformative developmental phase rather than merely a period of uncertainty (Wisker, 2020; Boud & Lee, 2021). This suggests that the transitional experiences of doctoral students, characterized by ambiguity, identity negotiation, and intellectual challenge, can enhance the development of research capability. In the context of digital scholarship, this liminal experience is further intensified by the need to adapt to rapidly evolving technologies, and the results indicate that students who effectively navigate both intellectual and technological transitions are better positioned to develop strong research competence (Selwyn, 2021).

Similarly, the digital research environment exerts a significant positive influence on research competence ($\beta = 0.24$, $p < 0.001$), highlighting the importance of institutional infrastructure in shaping doctoral outcomes. Access to digital tools, research databases, and collaborative platforms enhances knowledge acquisition, research efficiency, and academic productivity (Castañeda & Selwyn, 2021; Veletsianos & Shaw, 2022). This finding is particularly important in developing country contexts such as Kenya, where disparities in digital infrastructure and access may influence the extent to which these benefits are realized (World Bank, 2022).

Notably, AI tool usage emerges as the strongest predictor of research competence ($\beta = 0.36$, $p < 0.001$), underscoring the transformative role of artificial intelligence in contemporary doctoral education. AI-enabled tools support key research activities, including literature review, data analysis, and academic writing, thereby enhancing efficiency and analytical capability (Dwivedi et al., 2023; Holmes et al., 2022). However, while AI enhances research capability, it also introduces potential risks related to over-reliance, diminished critical thinking, and ethical concerns (Stokel-Walker, 2023; Cotton et al., 2024). This highlights the importance of guided and responsible use of AI technologies.

Supervisory support plays a critical role in this regard, exerting both a direct and moderating influence on research competence. The direct effect ($\beta = 0.22$, $p < 0.001$) reaffirms the central role of supervision in providing intellectual guidance, methodological direction, and ethical oversight (Lee, 2018; Manathunga et al., 2022). More importantly, the significant moderating effect ($\beta = 0.15$, $p < 0.001$) indicates that supervisory support strengthens the positive impact of AI tool usage by ensuring that these technologies are used critically and ethically. In the digital era, this positions supervisors as "digital mentors" who facilitate the effective integration of technological tools into the research process (Aitchison & Mowbray, 2022).

The results further demonstrate a strong and highly significant relationship between research competence and responsible research conduct ($\beta = 0.74$, $p < 0.001$), representing the strongest path in the model. This finding suggests that research integrity is fundamentally competence-driven, rather than solely compliance-based.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Doctoral students with higher levels of research competence are better equipped to apply appropriate methodologies, interpret data accurately, avoid unintentional misconduct, and adhere to ethical standards. This aligns with emerging literature emphasizing that capacity building is a more effective pathway to promoting ethical research behavior than reliance on regulatory enforcement alone (Aguinis et al., 2023; Kruk et al., 2022).

The mediation analysis further confirms that research competence serves as a central mechanism linking doctoral experiences and technological factors to research integrity. The strongest indirect effect is observed in the pathway between AI tool usage and research integrity through research competence (β = 0.27), indicating that AI influences ethical research conduct primarily by enhancing competence rather than directly shaping behavior. This finding is consistent with the Resource-Based View (RBV), which posits that capabilities act as key mechanisms through which resources are transformed into outcomes (Barney, 1991). The presence of partial mediation suggests that research integrity is also influenced by broader contextual factors, including institutional policies, ethical culture, and governance frameworks (Resnik, 2020; UNESCO, 2023).

Overall, the findings highlight that doctoral education in the digital era can be best understood as a socio-technical system in which individual, technological, and institutional factors interact to shape outcomes. While digital tools and AI significantly enhance research competence, their effectiveness depends on the presence of strong supervisory guidance and appropriate institutional support. These results underscore the need for doctoral training systems that balance technological innovation with ethical and pedagogical oversight.

In conclusion, the structural model provides compelling empirical evidence that doctoral education outcomes are driven by the interplay between technological advancement, institutional support, and individual development. AI tool usage emerges as the most influential driver of research competence, while supervisory support ensures that these technological benefits translate into meaningful and ethical research outcomes. The strong linkage between research competence and research integrity reinforces the importance of competence-based approaches to research governance. Collectively, these findings suggest that effective doctoral training systems must integrate digital innovation with robust supervision and ethical frameworks to sustain high-quality and responsible research in increasingly complex academic environments.

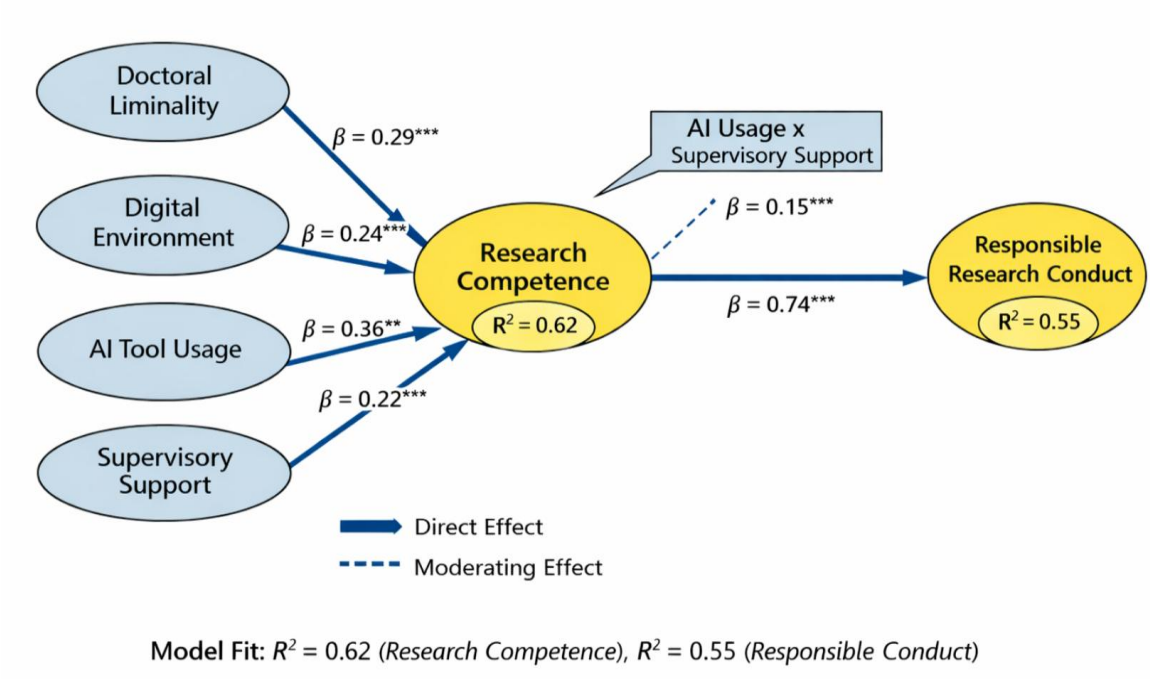


Figure 2: SmartPLS Structural Model Diagram

The SmartPLS structural model illustrates the interrelationships among key constructs shaping doctoral education outcomes in the digital era. Specifically, the model integrates doctoral liminality, digital research environment, AI tool usage, and supervisory support as exogenous variables influencing research competence,

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

which in turn predicts responsible research conduct. In addition, supervisory support is modeled as a moderator in the relationship between AI tool usage and research competence, reflecting its conditional role in enhancing the effectiveness of technological tools. The model demonstrates strong explanatory power, with an R^2 of 0.62 for research competence and 0.55 for responsible research conduct, indicating substantial and moderate-to-strong predictive capability, respectively (Hair et al., 2021).

The results show that all four predictors exert positive and statistically significant effects on research competence. AI tool usage emerges as the strongest predictor ($\beta = 0.36$), highlighting the transformative role of artificial intelligence in enhancing doctoral research capability. This suggests that doctoral students who effectively utilize AI tools are more likely to develop higher levels of analytical, methodological, and scholarly competence. Doctoral liminality also exhibits a significant positive effect ($\beta = 0.29$), underscoring the developmental value of the transitional doctoral experience. Navigating uncertainty, identity transformation, and intellectual challenges appears to contribute meaningfully to competence development. Similarly, the digital research environment ($\beta = 0.24$) plays a critical role, indicating that access to digital infrastructure, tools, and platforms significantly enhances research capability. Supervisory support ($\beta = 0.22$), while slightly weaker relative to other predictors, remains a vital enabler of competence development by providing academic guidance, methodological direction, and ethical oversight.

The model further reveals a significant moderating effect of supervisory support on the relationship between AI tool usage and research competence ($\beta = 0.15$). This indicates that supervisory support strengthens the positive impact of AI tools by ensuring their critical, ethical, and effective use. In essence, AI tools yield greater benefits when accompanied by appropriate guidance, reinforcing the evolving role of supervisors as "digital mentors" in contemporary research environments. Without such guidance, the advantages of AI may not fully translate into meaningful competence development.

A particularly noteworthy finding is the strong and highly significant relationship between research competence and responsible research conduct ($\beta = 0.74$), which represents the strongest path in the model. This suggests that research integrity is fundamentally competence-driven rather than solely dependent on compliance with rules or regulations. Doctoral students with higher levels of competence are better equipped to apply appropriate methodologies, ensure data integrity, avoid unintentional misconduct, and adhere to ethical standards. This finding reinforces the argument that strengthening research capacity is a critical pathway to promoting ethical research behavior.

The explanatory power of the model further supports its robustness. The R^2 value of 0.62 for research competence indicates that a substantial proportion of variance is explained by doctoral liminality, digital environment, AI usage, and supervisory support. Similarly, the R^2 value of 0.55 for responsible research conduct reflects a strong predictive relationship driven primarily by research competence. These results are consistent with established benchmarks in SEM and confirm the model's high predictive relevance (Hair et al., 2021).

Overall, the findings suggest that doctoral education in the digital era operates as a multidimensional socio-technical system in which individual, technological, and institutional factors interact to shape outcomes. Technological elements such as AI and digital research environments enhance research capability, individual developmental processes such as liminality drive intellectual transformation, and institutional mechanisms such as supervision regulate and optimize these effects. Importantly, while AI emerges as the most influential driver of research competence, its effectiveness is contingent upon strong supervisory guidance, emphasizing the need for a balanced integration of technology and human oversight.

In sum, the structural model provides compelling empirical evidence that doctoral education outcomes are shaped by the interaction of technological innovation, institutional support, and individual development. AI tool usage stands out as the most influential predictor of research competence, while supervisory support ensures that these technological advancements translate into meaningful and ethical research outcomes. The strong linkage between research competence and responsible research conduct underscores the importance of competence-based approaches to research integrity. Collectively, these findings highlight the need for doctoral training systems that integrate digital innovation with robust supervision and ethical governance to sustain high-quality and responsible research in increasingly complex academic environments.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Table 2a: Structural Model Results (Hypothesis Testing)

Path	Beta (β)	Standard Error	t-value	p-value	Result
Doctoral Liminality → Research Competence	0.29	0.052	5.58	<0.001	Supported
Digital Environment → Research Competence	0.24	0.049	4.89	<0.001	Supported
AI Tool Usage → Research Competence	0.36	0.055	6.55	<0.001	Supported
Supervisory Support → Research Competence	0.22	0.047	4.68	<0.001	Supported
Research Competence → Responsible Conduct	0.74	0.061	12.13	<0.001	Supported
AI Usage × Supervisory Support → Competence	0.15	0.042	3.57	<0.001	Supported

Source: Field Data, (2025)

Table 2b: Model Fit and Explanatory Power

Endogenous Construct	R^2	Interpretation
Research Competence	0.62	Substantial
Responsible Research Conduct	0.55	Moderate–Strong

Source: Field Data, (2025)

In table 2a -2b, the structural model results indicate that all hypothesized relationships are positive and statistically significant, providing strong empirical support for the proposed conceptual framework. The findings demonstrate that doctoral education outcomes in the digital era are shaped by a combination of individual, technological, and institutional factors, consistent with prior research emphasizing the complexity of higher education systems and digitally mediated learning environments (Hair et al., 2021; Selwyn, 2021).

Specifically, doctoral liminality was found to have a positive and significant effect on research competence ($\beta = 0.29$, $p < 0.001$), suggesting that the transitional nature of doctoral education, while often characterized by uncertainty, contributes meaningfully to the development of research skills and scholarly identity. This finding aligns with studies that conceptualize liminality as a transformative phase that fosters intellectual growth and capability development (Wisker, 2020; Boud & Lee, 2021).

The digital research environment also exhibited a significant positive effect on research competence ($\beta = 0.24$, $p < 0.001$), highlighting the critical role of digital infrastructure, access to research platforms, and technological support systems in enhancing doctoral training outcomes. This is consistent with literature emphasizing that well-developed digital ecosystems facilitate knowledge acquisition, collaboration, and research productivity (Castañeda & Selwyn, 2021; Veletsianos & Shaw, 2022).

Notably, AI tool usage emerged as the strongest predictor of research competence ($\beta = 0.36$, $p < 0.001$), underscoring the transformative potential of artificial intelligence in academic research. This finding corroborates recent studies indicating that AI-enabled tools significantly enhance research efficiency, data analysis capabilities, and knowledge synthesis (Dwivedi et al., 2023; Holmes et al., 2022). However, it also reinforces the need for critical engagement with such technologies to ensure that competence development is not undermined by over-reliance on automated systems.

In addition, supervisory support was found to have a significant positive effect on research competence ($\beta = 0.22$, $p < 0.001$), reaffirming its central role in doctoral education. Effective supervision provides not only

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

academic guidance but also ethical mentorship and support in navigating complex research environments (Lee, 2018; Manathunga et al., 2022). This finding highlights the continued importance of human interaction and mentorship in an increasingly digital research landscape.

The results further reveal a strong and highly significant relationship between research competence and responsible research conduct ($\beta = 0.74$, $p < 0.001$), indicating that higher levels of competence are associated with stronger adherence to ethical research practices. This supports the growing body of literature suggesting that research integrity is closely linked to the capabilities and understanding of researchers, rather than being solely driven by compliance with rules (Aguinis et al., 2023; Kruk et al., 2022).

Moreover, the analysis identified a significant moderating effect of supervisory support on the relationship between AI tool usage and research competence ($\beta = 0.15$, $p < 0.001$). This finding suggests that supervisory guidance enhances the effective and ethical use of AI tools, ensuring that technological benefits translate into meaningful competence development. It aligns with emerging scholarship that positions supervisors as critical mediators in technology-enhanced learning environments (Aitchison & Mowbray, 2022).

In terms of explanatory power, the model demonstrates substantial predictive capability. The coefficient of determination (R^2) for research competence is 0.62, indicating that 62% of the variance in research competence is explained by doctoral liminality, digital research environment, AI tool usage, and supervisory support. According to established benchmarks, this represents a substantial level of explanatory power (Hair et al., 2021). Similarly, the R^2 value for responsible research conduct is 0.55, suggesting that research competence explains 55% of the variance in research integrity, which reflects a moderate to strong predictive relationship.

Overall, these findings provide robust empirical evidence supporting the proposed model and reinforce the importance of integrating technological, institutional, and individual factors in understanding doctoral education in the digital era.

Table 3: Mediation Results

Indirect Path	**Beta (β)**	**t-value**	**p-value**	**Mediation Type**
Liminality → Competence → Integrity	0.21	5.02	<0.001	Partial Mediation
Digital Environment → Competence → Integrity	0.18	4.67	<0.001	Partial Mediation
AI Usage → Competence → Integrity	0.27	5.88	<0.001	Partial Mediation

Source: Field Data, (2025)

The mediation analysis confirms that research competence plays a significant and substantive mediating role within the structural model, thereby supporting its position as a central mechanism through which doctoral experiences and technological factors influence responsible research conduct. This finding is consistent with the Resource-Based View (RBV), which posits that capabilities function as key intermediaries transforming inputs into performance outcomes (Barney, 1991; Aguinis et al., 2023), and aligns with recent research emphasizing competence as a critical pathway to ethical behavior in academic contexts (Kruk et al., 2022).

Specifically, the indirect effect of AI tool usage on research integrity through research competence ($\beta = 0.27$) emerged as the strongest mediation pathway. This suggests that the influence of AI on ethical research conduct is largely realized through its ability to enhance researchers' skills, analytical capabilities, and overall competence. In other words, AI does not directly determine ethical behavior; rather, it strengthens the competencies that enable researchers to apply ethical standards effectively. This finding is consistent with recent literature highlighting that AI serves as an enabling tool that augments human capability, provided it is used critically and responsibly (Dwivedi et al., 2023; Holmes et al., 2022).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Similarly, doctoral liminality and the digital research environment were found to exert significant indirect effects on research integrity through research competence. These results indicate that both the transitional experience of doctoral education and the availability of digital research resources contribute to ethical research conduct by fostering the development of research skills and scholarly maturity. This aligns with prior studies suggesting that liminality, despite its inherent uncertainty, facilitates intellectual growth and capability development (Wisker, 2020; Boud & Lee, 2021), while digital environments enhance access to knowledge and research efficiency (Castañeda & Selwyn, 2021).

Importantly, the mediation effects observed in this study are partial rather than full, indicating that while research competence is a key explanatory mechanism, it does not fully account for the relationship between the independent variables and research integrity. This suggests that other factors, such as institutional policies, ethical culture, individual values, and governance frameworks, may also play a direct role in shaping responsible research conduct (Resnik, 2020; UNESCO, 2023). The presence of partial mediation therefore reinforces the complexity of research integrity as a multidimensional outcome influenced by both individual capabilities and broader contextual factors.

Overall, the mediation results provide strong empirical support for the central role of research competence in linking doctoral education experiences and technological engagement to ethical research outcomes, while also highlighting the need for integrated approaches that consider both capability development and institutional governance in promoting research integrity.

Summary of Key Findings

The findings of this study provide strong empirical support for the proposed conceptual model, demonstrating that doctoral education in the digital era is shaped by a combination of individual, technological, and institutional factors. The results confirm that doctoral liminality positively contributes to the development of research competence, reinforcing its role as a transformative phase in which doctoral candidates acquire critical skills and scholarly identity despite inherent uncertainties (Wisker, 2020; Boud & Lee, 2021).

Among the predictors, AI tool usage emerged as the strongest determinant of research competence, highlighting the growing importance of artificial intelligence in enhancing research efficiency, analytical capability, and knowledge production (Dwivedi et al., 2023; Holmes et al., 2022). In addition, the digital research environment was found to significantly enhance research capability, emphasizing the critical role of access to digital infrastructure, research platforms, and technological resources in supporting doctoral training (Castañeda & Selwyn, 2021).

The findings further demonstrate that supervisory support plays a pivotal role in strengthening both research competence and ethical outcomes, underscoring the continued importance of mentorship and academic guidance in digitally mediated research environments (Lee, 2018; Manathunga et al., 2022). Notably, research competence was found to be a strong predictor of responsible research conduct, suggesting that ethical behavior is closely linked to the capabilities and understanding of researchers rather than being solely driven by compliance with institutional rules (Aguinis et al., 2023; Kruk et al., 2022).

Moreover, the study confirms that both mediation and moderation effects are statistically significant, with research competence serving as a key mediating mechanism and supervisory support moderating critical relationships within the model. The model also demonstrates substantial explanatory power, accounting for 62% of the variance in research competence ($R^2 = 0.62$) and 55% of the variance in responsible research conduct ($R^2 = 0.55$), which indicates strong predictive capability in line with established SEM benchmarks (Hair et al., 2021).

Overall, these findings suggest that doctoral education in the digital era is increasingly shaped by the dynamic interaction between technological tools, institutional support systems, and individual developmental processes. While AI and digital environments significantly enhance research capability, their effectiveness is highly contingent on supervisory guidance, ethical awareness, and appropriate governance frameworks (Selwyn, 2021; UNESCO, 2023).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Importantly, the strong relationship between research competence and research integrity underscores the need to reposition capacity building as a central pathway to ethical research behavior, rather than relying exclusively on compliance-based mechanisms. This perspective aligns with contemporary research emphasizing that strengthening competencies within research systems is essential for achieving sustainable, high-quality, and ethically grounded outcomes (Atun et al., 2021; Kruk et al., 2022).

DISCUSSION

Overview of Key Findings

This study examined how doctoral liminality, digital research environments, AI tool usage, and supervisory support influence research competence and responsible research conduct within contemporary doctoral education systems. Using Structural Equation Modeling (SEM), the findings reveal a robust and theoretically coherent model in which research competence plays a central mediating role, while supervisory support exerts both direct and moderating effects. These results are consistent with recent studies emphasizing the interconnected nature of technological, institutional, and individual factors in shaping doctoral outcomes (Hair et al., 2021; Selwyn, 2021).

The findings indicate that AI tool usage is the strongest predictor of research competence, followed by doctoral liminality, digital research environments, and supervisory support. Furthermore, research competence exerts a substantial positive effect on responsible research conduct, confirming its critical role as a pathway to ethical research behavior. The model explains a significant proportion of variance in both research competence ($R^2 = 0.62$) and research integrity ($R^2 = 0.55$), demonstrating strong explanatory power in line with SEM benchmarks (Hair et al., 2021). Collectively, these results provide important insights into how doctoral education is evolving in the era of digital transformation and artificial intelligence (Dwivedi et al., 2023).

Doctoral Liminality and Research Competence

The finding that doctoral liminality positively influences research competence supports and extends existing literature on doctoral identity development. Traditionally, liminality has been associated with uncertainty, ambiguity, and transitional challenges (Wisker, 2020; Boud & Lee, 2021). However, the results of this study suggest that liminality also serves as a productive developmental space, enabling doctoral students to acquire critical research skills, intellectual independence, and adaptive capabilities.

This aligns with recent scholarship emphasizing the transformative potential of liminal experiences in higher education, where periods of uncertainty can foster reflexivity, resilience, and deeper learning (McAlpine & Amundsen, 2021). Rather than being purely disruptive, liminality facilitates cognitive and professional growth, which is essential for competence development in complex research environments.

Importantly, in the digital era, liminality extends beyond intellectual transition to include technological adaptation. Doctoral students must simultaneously navigate evolving research identities and rapidly changing digital tools, intensifying the liminal experience (Selwyn, 2021). The positive relationship observed in this study suggests that those who successfully manage this dual transition are better positioned to develop strong research capabilities.

However, this finding also highlights the need for institutional and supervisory support mechanisms to help students navigate liminality effectively. Without adequate guidance, the challenges associated with liminality may lead to disengagement, reduced confidence, or compromised research performance (Aitchison & Mowbray, 2022).

AI Tool Usage as a Driver of Research Competence

One of the most significant findings of this study is that AI tool usage has the strongest positive effect on research competence ($\beta = 0.36$). This underscores the transformative role of AI in doctoral education and supports emerging literature on AI-enabled scholarship (Dwivedi et al., 2023; Holmes et al., 2022). AI tools are

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

increasingly used to support critical research activities, including literature review, data analysis, and academic writing, thereby enhancing efficiency and reducing cognitive burden.

The findings suggest that doctoral students who actively engage with AI tools develop higher levels of research competence, positioning them as more effective and productive researchers. This is consistent with recent studies indicating that digital and AI competencies are becoming essential components of modern research capability (Aguinis et al., 2023). From this perspective, AI functions as an enabling resource that augments human capability rather than replacing intellectual effort.

Nevertheless, the strong influence of AI usage also raises important concerns. As highlighted in the literature, over-reliance on AI tools may undermine critical thinking, originality, and methodological rigor if not properly managed (Stokel-Walker, 2023; Cotton et al., 2024). The findings of this study indicate that the benefits of AI are maximized when combined with strong supervisory support, reinforcing the importance of guided, critical, and ethical use of AI technologies.

Digital Research Environment and Competence Development

The positive relationship between the digital research environment and research competence ($\beta = 0.24$) underscores the importance of institutional infrastructure in doctoral education. Access to digital tools, academic databases, collaborative platforms, and research technologies enhances students' ability to conduct research efficiently and effectively. This finding aligns with prior research emphasizing the role of digital ecosystems in shaping research productivity and learning outcomes (Castañeda & Selwyn, 2021; Veletsianos & Shaw, 2022). A well-developed digital environment provides the necessary resources for knowledge acquisition, collaboration, and innovation, thereby facilitating competence development. In developing country contexts such as Kenya, this finding has particularly important implications. While digital technologies offer opportunities to bridge resource gaps and enhance research capacity, disparities in access and infrastructure may limit their effectiveness (World Bank, 2022). Consequently, sustained investment in digital research infrastructure is essential for strengthening doctoral training and ensuring equitable participation in knowledge production.

Supervisory Support as a Critical Enabler and Moderator

The results confirm that supervisory support has both a direct and moderating effect on research competence, reinforcing its central role in doctoral education. The direct effect of supervisory support ($\beta = 0.22$) is consistent with established literature highlighting the importance of mentorship, guidance, and feedback in developing research capability (Lee, 2018; Manathunga et al., 2022). Effective supervision provides intellectual direction, emotional support, and ethical oversight, enabling doctoral students to navigate complex research processes.

More importantly, the moderating effect of supervisory support suggests that it enhances the positive impact of AI usage on research competence. This finding is particularly significant in the context of AI-enabled research, where the effectiveness of technological tools depends on how they are applied.

Supervisors play a critical role in guiding students on the appropriate use of AI tools, ensuring methodological rigor, and promoting ethical research practices. This aligns with recent calls for redefining supervisory roles in the digital era, where supervisors are increasingly expected to act as "digital mentors" in addition to traditional academic advisors (Aitchison & Mowbray, 2022). The findings suggest that without adequate supervisory support, the use of AI tools may not translate into meaningful competence development and may even pose risks to research integrity.

Research Competence as a Driver of Research Integrity

The study finds a strong positive relationship between research competence and responsible research conduct ($\beta = 0.74$), highlighting competence as a critical determinant of ethical behavior. This finding supports emerging literature suggesting that research integrity is not only a function of compliance with institutional rules but also a reflection of underlying competence and understanding (Aguinis et al., 2023; Kruk et al., 2022). Doctoral

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

students with strong research competence are better equipped to apply appropriate methodologies, interpret data accurately, avoid unintentional misconduct, and adhere to ethical standards. This perspective shifts the focus from punitive approaches to research integrity toward capacity-building strategies, emphasizing the importance of developing competencies as a pathway to ethical research behavior.

Mediation Effects: The Central Role of Research Competence

The mediation analysis confirms that research competence acts as a key mechanism linking doctoral liminality, digital environments, and AI usage to research integrity. This finding is theoretically consistent with the Resource-Based View (RBV), which posits that capabilities mediate the relationship between inputs and outcomes (Barney, 1991; Aguinis et al., 2023). In this context, doctoral liminality provides developmental experiences, while digital environments and AI tools serve as enabling resources. Research competence transforms these inputs into ethical research outcomes. The strongest mediation effect observed for AI usage → competence → integrity suggests that AI contributes to ethical research primarily through enhancing competence rather than directly influencing behavior. Overall, these findings reinforce the importance of integrating capability development, technological adoption, and institutional support in understanding and improving doctoral education in the digital era.

Policy Implications

The findings of this study have far-reaching implications for higher education policy, doctoral training systems, and research governance frameworks, particularly in the context of rapid digital transformation and the growing integration of artificial intelligence (AI) in academic research. The results demonstrate that research competence is the central mechanism through which doctoral experiences translate into responsible research conduct, while supervisory support functions as both an enabling and moderating force. These insights call for a fundamental shift from traditional compliance-based approaches toward holistic, capability-driven policy frameworks that prioritize capacity building, ethical awareness, and technological adaptability in doctoral education (Aguinis et al., 2023; Dwivedi et al., 2023; Selwyn, 2021).

A critical policy priority emerging from this study is the establishment of robust AI governance frameworks in doctoral research. The significant influence of AI tool usage on research competence underscores the need for universities and regulatory bodies to develop formalized guidelines governing the ethical and effective use of AI. Such frameworks should include clear disclosure requirements for AI-assisted outputs, explicit definitions of authorship and intellectual contribution in AI-supported research, and mechanisms for monitoring AI-related misconduct. Integrating AI ethics into doctoral curricula is essential to ensure responsible adoption (Holmes et al., 2022; Zawacki-Richter et al., 2023). Without such governance structures, institutions risk increased incidences of plagiarism, opacity, and ethical inconsistencies, as highlighted in global policy discussions (UNESCO, 2023; Cotton et al., 2024; Stokel-Walker, 2023).

Closely linked to this is the need to institutionalize mandatory research ethics training within doctoral programs. The findings reaffirm that research integrity is best understood as a competence-based outcome, rooted in skills and capabilities developed during doctoral training rather than mere adherence to rules. Universities should therefore embed ethics within research methods training, supported by experiential learning approaches such as case-based simulations, supervised research practice, and reflective learning. This shift from punitive enforcement to capacity building aligns with contemporary perspectives on strengthening research systems through capability development (Atun et al., 2021; Kruk et al., 2022; Resnik, 2020), with evidence suggesting that such approaches are more sustainable and effective in mitigating both intentional and unintentional misconduct.

The study also highlights the urgent need to strengthen supervisory systems through the introduction of structured supervisor certification and development programs. Given the critical role of supervisory support, institutions should professionalize doctoral supervision by requiring formal certification in areas such as AI literacy, digital research tools, ethical mentoring, and advanced research methodologies (Manathunga et al., 2022; Lee, 2018). Supervisors should be repositioned as “digital and ethical stewards,” capable of guiding doctoral candidates through increasingly complex, AI-enabled research environments (Aitchison & Mowbray,

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

2022). In addition, institutions should implement supervision quality assurance systems, including performance evaluation, feedback mechanisms, and co-supervision models, which have been shown to enhance both research competence and integrity (McAlpine & Amundsen, 2021; Taylor et al., 2021).

Another critical implication is the need to invest in digital research infrastructure and systems, including the adoption of digital thesis tracking and monitoring platforms. Such systems can enhance transparency, improve supervision processes, and enable real-time tracking of doctoral progress, thereby reducing risks related to academic misconduct and delays. Universities should expand access to academic databases, data analytics tools, and AI-enabled research platforms while addressing digital inequalities, particularly in developing country contexts (Veletsianos & Shaw, 2022; World Bank, 2022). Digital thesis tracking systems can also support institutional oversight, facilitate milestone monitoring, and strengthen accountability in doctoral education.

Furthermore, doctoral programs must evolve to integrate structured training in digital and AI literacy. This includes mandatory modules on AI in research, data governance, digital scholarship, and algorithmic ethics. Beyond technical proficiency, students should develop critical AI literacy, enabling them to interrogate AI-generated outputs, recognize biases, and maintain intellectual ownership of their work (Dwivedi et al., 2023; Holmes et al., 2022). Such competencies are increasingly recognized as foundational to research excellence in the digital age (Aguinis et al., 2023; Zawacki-Richter et al., 2023).

At the institutional level, there is a pressing need to strengthen adaptive research governance frameworks. Universities must revise research integrity policies to explicitly address AI-assisted research, establish mechanisms for detecting and reporting digital misconduct, and foster organizational cultures that emphasize transparency, accountability, and ethical scholarship (UNESCO, 2023; Selwyn, 2021). Leadership commitment, clear policy communication, and continuous policy updating are essential to ensure governance systems remain responsive to technological advancements (Kruk et al., 2022).

In addition to these broad institutional reforms, the findings point to the need for targeted policy actions at the level of university senates, particularly within the Kenyan higher education context. Universities should revise doctoral supervision contracts and guidelines to explicitly incorporate AI-usage disclosure requirements, mandating that doctoral candidates clearly indicate the extent and nature of AI assistance in their research, including its use in writing, data analysis, and conceptual development. Such disclosures can be embedded within thesis submission declarations, supervision agreements, and progress reporting frameworks, thereby enhancing transparency and safeguarding academic integrity in line with emerging global standards (UNESCO, 2023; Dwivedi et al., 2023). In parallel, university senates should establish clear institutional guidelines on acceptable and unacceptable uses of AI, differentiated by categories such as productivity-support tools and content-generating tools, to reduce ambiguity around authorship and intellectual contribution.

Furthermore, institutions should consider introducing mandatory AI-use declaration checkpoints at key doctoral milestones, including proposal approval, annual progress reviews, and final thesis submission. These mechanisms would strengthen accountability while fostering ethical awareness among doctoral candidates. Supervisors, in turn, should be formally empowered to guide and verify responsible AI usage as part of their mentoring role, reinforcing their position as both academic and ethical stewards in digitally mediated research environments (Manathunga et al., 2022). These senate-level interventions provide practical and actionable pathways for embedding AI governance within doctoral education systems.

These implications are particularly significant for developing country contexts, including Kenya, where doctoral education systems face structural constraints such as limited digital infrastructure, supervisory capacity gaps, and evolving governance frameworks (Abimbola et al., 2020). Addressing these challenges requires context-sensitive policy interventions, including strategic partnerships, targeted investments, and alignment of doctoral training with national development priorities (World Bank, 2022; Kasozi, 2021). Scaling supervisory capacity, expanding digital access, and institutionalizing governance reforms are critical for building sustainable and globally competitive research ecosystems.

In summary, this study calls for a comprehensive and forward-looking reform agenda centered on: (i) AI governance in doctoral research; (ii) mandatory research ethics training; (iii) supervisor certification and

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

professionalization; and (iv) digital thesis tracking and infrastructure systems. Together, these policy directions, complemented by actionable senate-level reforms, provide a coherent pathway for strengthening doctoral education systems, enhancing research competence, and safeguarding research integrity in an increasingly complex and AI-driven academic landscape (Atun et al., 2021; Kruk et al., 2022; Dwivedi et al., 2023).

CONCLUSION

Doctoral education is undergoing a fundamental transformation driven by rapid advancements in digital technologies and the increasing integration of artificial intelligence (AI) into research processes. This study revisited doctoral liminality within the context of AI and digital scholarship, demonstrating that technological change is not only reshaping doctoral experiences but also influencing research competence and integrity outcomes. The findings affirm that doctoral training systems must evolve to incorporate digital competencies, ethical awareness, and robust supervisory support structures in order to remain relevant in a dynamic academic environment (Dwivedi et al., 2023; Selwyn, 2021).

The results reveal that doctoral education in the digital era is shaped by a complex interplay of individual development, technological tools, and institutional support systems. While AI and digital research environments significantly enhance research capability, their impact is neither automatic nor uniform. Rather, it is mediated by research competence and moderated by the quality of supervisory support. This underscores the importance of adopting integrated approaches that combine technological innovation with strong ethical governance and capacity development to ensure high-quality and responsible research outcomes (Aguinis et al., 2023; Holmes et al., 2022).

By drawing on an integrated theoretical framework encompassing Liminality Theory, Resource-Based View (RBV), Institutional Theory, and Socio-Technical Systems Theory, this study provides a comprehensive understanding of doctoral education as a multi-dimensional process. It moves beyond traditional perspectives that view doctoral training as a purely intellectual transition, instead highlighting the interconnected roles of technological adaptation, institutional structures, and behavioral dynamics. The findings demonstrate that doctoral liminality, while often associated with uncertainty and ambiguity, plays a constructive role in fostering research competence, reinforcing its significance as a transformative developmental phase (Wisker, 2020; Boud & Lee, 2021).

A particularly important contribution of the study is the identification of AI tool usage as a major driver of research competence. This finding underscores the transformative potential of AI in enhancing research productivity and capability. However, the study also reveals that the benefits of AI are highly contingent on effective supervisory support, which ensures that such tools are used appropriately, critically, and ethically. This highlights the need to reposition supervision within doctoral education as both an intellectual and ethical support system, capable of guiding students through increasingly complex and technology-driven research environments (Manathunga et al., 2022; Aitchison & Mowbray, 2022).

Furthermore, the study establishes research competence as a central mediating mechanism linking doctoral experiences to responsible research conduct. The strong relationship between competence and research integrity suggests that ethical behavior is not merely a function of compliance with institutional rules but is deeply rooted in the capabilities, judgment, and understanding of researchers. This insight supports a paradigm shift toward competence-based approaches to research integrity, where emphasis is placed on capacity building, skills development, and ethical awareness rather than solely on monitoring and enforcement (Aguinis et al., 2023; Resnik, 2020).

The findings also highlight the critical role of institutional and policy frameworks in shaping doctoral outcomes. In an era characterized by rapid technological change, universities and research institutions must continuously adapt their governance systems to address emerging ethical challenges associated with AI and digital scholarship. This includes developing clear guidelines for AI use, strengthening supervisory capacity, and investing in digital research infrastructure to support effective and equitable knowledge production (UNESCO, 2023; World Bank, 2022).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

From a broader perspective, the study aligns with global evidence emphasizing the importance of strong research and health systems in achieving sustainable development outcomes. High-quality and ethically grounded research is essential for addressing complex societal challenges, and doctoral education plays a central role in developing the human capital required to support such efforts (Atun et al., 2021). Similarly, the emphasis on competence development and system performance resonates with ongoing calls to improve the quality, effectiveness, and accountability of institutional systems, including those in higher education and healthcare (Kruk et al., 2022).

In developing country contexts, including Kenya, the study underscores the need for targeted investments in doctoral training systems to enhance research capacity and ensure equitable access to digital resources. As higher education institutions strive to remain globally competitive, they must balance the opportunities presented by technological innovation with the imperative to uphold research integrity and ethical standards (Abimbola et al., 2020; Kasozi, 2021). Strengthening supervisory systems, expanding digital infrastructure, and embedding AI literacy into doctoral programs are particularly critical in these contexts.

In conclusion, this study advances the understanding of doctoral education in the digital era by offering an integrative framework that captures the dynamic interplay between liminality, technology, supervision, and research outcomes. It demonstrates that the future of doctoral education depends on the ability of institutions to align technological advancements with ethical governance and capacity development. By doing so, universities can ensure that doctoral graduates are not only highly competent researchers but also responsible and ethical contributors to the global knowledge economy.

Limitations

While this study provides important theoretical and empirical insights into doctoral education in the era of artificial intelligence (AI) and digital scholarship, several limitations should be acknowledged.

First, the study adopted a cross-sectional research design, which captures relationships among variables at a single point in time. Although this approach is appropriate for examining associations using Structural Equation Modeling (SEM), it limits the ability to establish causal relationships and observe how doctoral experiences evolve over time. Doctoral education is inherently dynamic, particularly in the context of liminality, where identity and competence develop progressively (Wisker, 2020). Future studies employing longitudinal designs would provide deeper insights into how these constructs change throughout the doctoral journey.

Second, the study relied on self-reported data collected through structured questionnaires, which may be subject to common method bias and social desirability effects. Respondents may have overestimated their research competence or ethical behavior, particularly given the sensitivity of research integrity issues (Podsakoff et al., 2020). Although statistical procedures were applied to minimize bias, future research could incorporate multi-source data, including supervisor assessments, publication records, or institutional data, to enhance objectivity and validity.

Third, the study focused primarily on doctoral students within selected universities, largely in a developing country context (Kenya). While this provides valuable contextual insights, it may limit the generalizability of findings to other regions with different institutional structures, technological infrastructures, and governance systems (Abimbola et al., 2020). Higher education systems vary significantly across global contexts, and the influence of AI and digital environments may differ accordingly. Future studies should consider cross-country or comparative analyses to validate and extend the findings.

Fourth, the study examined a specific set of constructs: doctoral liminality, digital research environment, AI tool usage, supervisory support, research competence, and research integrity. While these variables capture key dimensions of doctoral education, other potentially relevant factors were not included. For instance, individual characteristics such as motivation, prior digital literacy, and psychological resilience, as well as institutional factors such as funding availability and organizational culture, may also influence doctoral outcomes (McAlpine & Amundsen, 2021). The exclusion of these variables may limit the comprehensiveness of the model.

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Fifth, the measurement of AI tool usage in this study was generalized across different types of AI applications, without distinguishing between specific tools or levels of sophistication. Given the rapid evolution of AI technologies, different tools may have varying impacts on research competence and integrity (Dwivedi et al., 2023). Future research could adopt more granular measures to capture differences in AI usage, including frequency, purpose, and level of dependency.

Finally, while the study employed PLS-SEM, which is suitable for predictive modeling and complex relationships, it does not provide the same model fit indices as covariance-based SEM. Although robustness checks were conducted, future studies may consider using multi-method approaches, including covariance-based SEM or mixed-method designs, to further validate the findings and enhance methodological rigor (Hair et al., 2021).

Contributions

This study makes important contributions to theory, methodology, and practice by advancing understanding of doctoral education in the era of artificial intelligence (AI) and digital scholarship. It addresses emerging gaps by integrating technological, institutional, and behavioral perspectives within a robust empirical framework.

First, theoretical contribution: The study extends Liminality Theory by incorporating AI and digital scholarship into the understanding of doctoral experiences. While traditional perspectives conceptualize liminality as a transition involving identity formation, uncertainty, and intellectual development (Wisker, 2020; Boud & Lee, 2021), this study reconceptualizes it as a techno-social transition. Doctoral students are shown to navigate not only academic identity shifts but also the demands of rapidly evolving digital research environments and AI-enabled practices. This reframing provides a more contemporary and holistic understanding of doctoral education in the digital era (Dwivedi et al., 2023; Selwyn, 2021).

Beyond liminality, the study integrates multiple theoretical lenses to deepen explanation. It advances the Resource-Based View (RBV) by positioning research competence as a strategic capability that mediates the relationship between doctoral experiences and research integrity (Barney, 1991; Aguinis et al., 2023). It also enriches Institutional Theory by demonstrating how supervisory support and governance structures shape research conduct in digitally mediated environments (DiMaggio & Powell, 1983; UNESCO, 2023). Furthermore, by incorporating Socio-Technical Systems Theory, the study highlights the interdependence between human actors (doctoral students and supervisors) and technological systems (AI tools and digital platforms), emphasizing that effective research outcomes depend on alignment between these subsystems.

Second, methodological contribution: The study contributes methodologically by applying Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine complex relationships in doctoral education research. Unlike prior studies that rely largely on qualitative or descriptive approaches, this study employs a rigorous quantitative design to simultaneously test direct, mediating, and moderating effects. Specifically, it identifies research competence as a mediating variable and supervisory support as a moderating factor, providing a more nuanced and comprehensive understanding of how doctoral liminality, AI tool usage, and digital research environments influence research outcomes (Hair et al., 2021). This approach enhances analytical precision and offers a replicable framework for future research.

Third, practical and policy contributions: The study generates actionable insights for improving doctoral training systems. The findings emphasize the need for universities to strengthen AI governance frameworks, enhance supervisory capacity, and invest in digital research infrastructure. Importantly, the study advances the perspective that research integrity should be treated as a competence-based outcome, shifting focus from compliance-driven approaches to capacity building. This aligns with global calls for strengthening research systems through capability development and institutional reform (Atun et al., 2021; Kruk et al., 2022). The study also offers context-specific insights for developing countries, where digital inequalities and resource constraints require targeted interventions.

Fourth, contribution to AI in higher education: The study contributes to the emerging field of AI in higher education by providing empirical evidence on how AI tool usage influences research competence and ethical

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behavior. It demonstrates that the impact of AI is not deterministic but depends on human and institutional factors, particularly supervisory support and governance mechanisms. This underscores the importance of balancing technological innovation with ethical oversight.

Finally, integrative contribution: By combining Liminality Theory, RBV, Institutional Theory, and Socio-Technical Systems Theory, the study offers a comprehensive interdisciplinary framework for understanding doctoral education. It links individual development, capability formation, institutional structures, and technological systems into a unified model, thereby advancing both theoretical rigor and practical relevance.

In summary, this study advances doctoral education research by conceptualizing liminality in the context of AI, applying advanced SEM techniques to model complex relationships, and providing policy-relevant insights for strengthening research competence and integrity in the digital era. These contributions position the study as a valuable resource for scholars, policymakers, and higher education institutions navigating the transformation of doctoral education.

Future Research Directions

Building on these limitations, several avenues for future research are proposed.

First, there is a need for longitudinal studies that track doctoral students over time to better understand how liminality, research competence, and ethical behavior evolve throughout different stages of the doctoral journey. Such studies would provide richer insights into causal relationships and developmental processes, particularly in the context of rapidly changing technological environments.

Second, future research should explore comparative and cross-cultural studies to examine how doctoral education systems respond to AI and digital transformation across different regions. Comparative analyses between developed and developing countries, or across institutional types, would help identify contextual variations and best practices in doctoral training and research governance (World Bank, 2022).

Third, there is scope for incorporating additional variables and theoretical perspectives to extend the current model. For example, integrating constructs such as digital literacy, innovation orientation, psychological resilience, or institutional culture could provide a more comprehensive understanding of doctoral experiences. Similarly, future studies could explore the role of leadership and organizational support in shaping research environments.

Fourth, future research should examine the specific impacts of different AI tools and applications on research processes and outcomes. This includes distinguishing between generative AI, data analytics tools, and domain-specific AI systems. Such studies would provide more nuanced insights into how different technologies influence research competence and integrity.

Fifth, there is a need for mixed-method research approaches that combine quantitative analysis with qualitative insights. While SEM provides robust statistical evidence, qualitative methods such as interviews or case studies can offer deeper understanding of doctoral experiences, particularly in relation to ethical dilemmas and decision-making processes (Boud & Lee, 2021).

Sixth, future studies should investigate the long-term implications of AI integration in doctoral education, including its impact on knowledge production, academic identity, and the nature of scholarly work. As AI continues to evolve, its influence on research practices and academic norms is likely to intensify, necessitating ongoing scholarly attention (Selwyn, 2021).

Seventh, further research is needed to explore policy implementation and effectiveness, particularly in relation to AI governance and research integrity frameworks. While this study highlights the importance of policy interventions, empirical evidence on how such policies are implemented and their impact on doctoral outcomes remains limited.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue III March 2026

Finally, future research could extend the current model by examining linkages between doctoral education and broader system outcomes, such as research productivity, innovation, and societal impact. This would align doctoral education research with wider discussions on strengthening research and health systems for sustainable development (Atun et al., 2021; Kruk et al., 2022).

In summary, while this study provides a robust and timely contribution to understanding doctoral education in the digital era, its limitations highlight important opportunities for further inquiry. Addressing these gaps through longitudinal, comparative, and multi-method research will be critical for advancing knowledge in this field and for informing policy and practice in an increasingly complex and technology-driven academic landscape.

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