Cuban Journal of Public and Business Administration
ISSN 2664-0856 RNPS 2458 / Vol. 9 (2025) / e366
Available in: https://apye.esceg.cu/index.php/apye/article/view/366

Original article

RECONSTRUCTING GRADUATE SUPERVISORS COMPETENCIES FROM THE PERSPECTIVE OF ARTIFICIAL INTELLIGENCE

RECONSTRUYENDO LAS COMPETENCIAS DE LOS SUPERVISORES DE POSGRADO DESDE LA PERSPECTIVA DE LA INTELIGENCIA ARTIFICIAL

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JEL Classification: I21, I23, O33

DOI: https://doi.org/10.5281/zenodo.16948695

Received: 02/07/2025
Accepted: 16/08/2025

Abstract

In the era of artificial intelligence (AI), the model of graduate education is undergoing significant transformation, placing new demands on the competencies and qualities of graduate supervisors. This paper conducts an in-depth exploration of the evolution and enhancement pathways of graduate supervisors' professional competences within the context of AI. It analyzes the impact of generative AI on the roles of teachers and students, as well as on teaching and research in graduate education. Furthermore, the paper examines the age structure of graduate supervisors and relevant policy requirements in the AI era. It elaborates on the new expectations placed on supervisors in areas such as information literacy, technological adaptability, human-AI collaborative competence, innovation capacity, and ethical awareness. Finally, the paper proposes strategies for improving supervisors' competencies, including fostering a proper understanding of digital technology, improving training systems, establishing new evaluation frameworks, and strengthening university-industry collaboration. These measures aim to help graduate supervisors better meet the educational needs of the AI era and promote the deep integration of AI technology into graduate education.

Keywords: artificial intelligence, graduate supervisor, AI literacy, challenges and innovations.

Published by the Higher School of State and Government Cadres, Havana, Cuba

Escuela Superior de Cuadros del Estado y del Gobierno

Resumen

En la era de la inteligencia artificial (IA), el modelo de formación de posgrado está experimentando una transformación significativa, lo que impone nuevas exigencias a las competencias y cualidades de los supervisores de posgrado. Este artículo explora en profundidad la evolución y las vías de mejora de las competencias profesionales de los supervisores de posgrado en el contexto de la IA. Analiza el impacto de la IA generativa en los roles de docentes y estudiantes, así como en la docencia y la investigación en la formación de posgrado. Además, examina la estructura de edad de los supervisores de posgrado y los requisitos de las políticas pertinentes en la era de la IA. Profundiza en las nuevas expectativas de los supervisores en áreas como la alfabetización informacional, la adaptabilidad tecnológica, la competencia colaborativa entre humanos e IA, la capacidad de innovación y la conciencia ética. Finalmente, propone estrategias para mejorar las competencias de los supervisores, incluyendo el fomento de una comprensión adecuada de la tecnología digital, la mejora de los sistemas de formación, el establecimiento de nuevos marcos de evaluación y el fortalecimiento de la colaboración universidad-industria. Estas medidas buscan ayudar a los supervisores de posgrado a satisfacer mejor las necesidades educativas de la era de la IA y promover la integración profunda de la tecnología de IA en la formación de posgrado.

Palabras clave: inteligencia artificial, supervisor de posgrado, alfabetización en IA, desafíos e innovaciones.

Introduction

The rapid development of artificial intelligence (AI) is profoundly transforming a wide range of fields. In the realm of graduate education, the roles of both instructors and students—as well as traditional models of teaching and research—are undergoing unprecedented disruption. As central figures in the educational process, graduate supervisors are now facing both significant challenges and new opportunities in their pedagogical and scholarly responsibilities. On one hand, generative AI offers powerful tools to support innovative teaching practices and enhance the effectiveness of research supervision. On the other hand, it introduces complex issues such as guiding students in the proper use of AI tools and preventing academic misconduct. In this context, improving the competencies and AI literacy of graduate supervisors has become a critical task in adapting to the ongoing educational transformation. In January 2025, the State Council issued the "The 2024-2035 Master Plan For building a Strong Education Country", which explicitly proposes to "promote artificial intelligence to assist educational reform" by advancing teaching reforms and effectively transforming talent cultivation models. Wu Gang, Director of China Academic Degrees and Graduate Education Department of the Ministry of Education, also emphasized the need to "empower all elements of the graduate training process with artificial intelligence, actively explore new forms and models of graduate education and teaching, and foster new momentum and advantages for high-quality development of graduate education".

As of 2023, there were approximately 556,500 graduate supervisors across China, with nearly 200,000 aged 50 and above[1], accounting for around 36%—more than one-third—of the total. Supervisors in this

1 Data source: Calculated based on "Number of Supervisors of Postgraduate Programs (Total)" published by the Ministry of Education of the People's Republic of China.

older age group may struggle to keep pace with rapidly evolving technologies, which can result in rigid supervisory styles that are ill-suited to today's increasingly intelligent research environments. At the same time, many senior supervisors exhibit lower acceptance of AI tools, limited technical proficiency, and in some cases, a tendency to adhere strictly to traditional practices. While students can now use AI to efficiently complete technical tasks, middle-aged and older supervisors who remain confined to conventional knowledge-transmission roles may find it difficult to meet the demands of students who are acquiring knowledge at faster speeds and in larger volumes. Furthermore, AI-driven research methods—such as simulation, big data analysis, and automated experimentation—require supervisors to possess interdisciplinary skills and the ability to integrate advanced technologies. However, older supervisors may face challenges in understanding algorithms and operating AI-based tools, thus intensifying the pressure to adapt to a transformed research paradigm. This study aims to examine the challenges and evolving competency requirements facing graduate supervisors in the age of artificial intelligence, and to explore actionable strategies and development pathways. The goal is to contribute valuable insights toward the high-quality development of graduate education in the AI era.

I. Literature Review

The impact of generative artificial intelligence on graduate education and the enhancement of supervisor competencies has been widely explored in academic research. Wang Zhe argues that generative AI is fundamentally reshaping the traditional roles of teachers and students in graduate education. While it offers new opportunities for innovation in teaching methods and optimization of research supervision, it also presents serious challenges—particularly in guiding students on the proper use of AI tools and in preventing academic misconduct[1]. Li Yan and other scholars point out that the effectiveness of graduate students' application of generative AI in research practice is significantly affected by differences in their disciplinary backgrounds and levels of AI literacy[2]. This highlights the need for instructors to adopt personalized and differentiated teaching strategies that account for students' individual characteristics and specific disciplinary needs, thereby enhancing students' ability to apply AI tools appropriately in academic research. Further, Luo Meina and other scholars emphasize that upgrading tutors' own AI-related competencies is essential for meeting the demands of education in the intelligent era. They argue that tutors must stay abreast of cutting-edge research on AI literacy in education, engage actively in practice, and improve the multidimensional capabilities including human-computer collaboration skills[3], which are understood as composite abilities spanning multiple disciplines and dimensions. Kandlhofer and Long further stress that this literacy for educators entails more than just mastering foundational knowledge and technical skills in AI; it also requires a high level of pedagogical expertise to effectively function within emerging ecosystems of human-AI collaboration[4-5]. Clearly, generative AI is exerting a multifaceted influence on teacher-student interactions, instructional models, and research paradigms in graduate education. In response to these shifts, Arantes underscores the urgency for instructors to proactively enhance their professional literacy and embrace pedagogical innovation, and at the same time prudently deal with its accompanying challenges such as evaluation and ethical risks[6].

II. Challenges for Graduate Supervisors in the Era of Artificial Intelligence

(i) Deficiencies and Lag in Information Literacy

The research data ecosystem is undergoing unprecedented transformation in the age of artificial intelligence. Scientific research data is not only expanding at an exponential rate in terms of volume and

scale, but also presenting a complex blend of structured and unstructured forms. This vast volume, diversity of data types, and high value density[7] pose significant challenges to researchers in both data acquisition and analysis. Increasingly, research data exhibits modal fusion, where structured formats such as text, images, audio, and video are intricately interwoven with unstructured data, forming a dynamic and evolving knowledge network. Traditional methods of information retrieval—such as keyword searches or manual literature reviews—are no longer sufficient to navigate the complexity of this new data landscape. Consequently, researchers often struggle to quickly and effectively access relevant information. In this context, data acquisition methods must evolve, requiring researchers to cultivate an integrative mindset and develop the ability to gather information from diverse sources and synthesize fragmented data in a coherent and systematic manner.

The contradiction between the abundance of data and the effective acquisition of precise knowledge has become a growing barrier to the development of scientific research. While the quantity of available information has increased dramatically, the efficiency of knowledge extraction has not kept pace, leading to heightened cognitive load for researchers engaged in data collection and filtering. Researchers are often constrained by the cognitive inertia brought about by previous experience[8], limiting the scope of information acquisition to the search results of traditional databases, and there is an obvious lag in the development and utilization of emerging data channels. This limitation is not only a neglect of non-traditional academic resources, but also a bias in assessing the value of data. Social media platforms—such as online knowledge communities—are increasingly becoming spaces for open and collaborative knowledge production. The real-time exchange of perspectives and shared experiences on these platforms often contains rich collective intelligence[9], offering broad coverage and deep insight. However, researchers frequently overlook such public discourse or dismiss it as non-professional, thereby ignoring valuable cognitive and innovative perspectives offered by the online community. This oversight can result in missed opportunities for academic advancement and increase the risk of falling into the cognitive trap of the “information cocoons”, where exposure to diverse viewpoints is limited and knowledge production becomes insular.

(ii) Crisis of Adaptation to Technological Change

The rapid pace of technological advancement has given rise to an adaptation crisis that poses a significant challenge for researchers in the era of artificial intelligence. This crisis is manifested in several ways, including cognitive conservatism, psychological resistance, and difficulties in skill iteration.

The first is the conservatism of cognition. At the cognitive level, some researchers lack a clear understanding of the appropriate application of intelligent technologies such as artificial intelligence and cloud computing. They often fail to recognize the educational and research value these tools can offer[10], and do not fully understand the logic behind aligning technological tools with specific research scenarios. As a result, they develop a conservative mindset toward emerging technologies, viewing AI tools merely as optional replacements for traditional methods—or worse, dismissing them as ineffective or irrelevant. Consequently, many researchers remain reliant on conventional research tools and exhibit skepticism toward novel technologies such as intelligent systems and large language models. This cognitive bias can lead to a fundamental misjudgment of AI-integrated research paradigms. Such a misalignment reflects a reductive understanding of technological value.

The second is psychological resistance. This resistance is primarily rooted in a perceived crisis of professional identity and growing anxiety over potential replacement, both of which are exacerbated by the widespread adoption of generative AI technologies. Although generative AI tools can quickly generate textual content such as literature reviews and data analysis reports, the persistent issue of machine hallucinations in AI-generated content increases the burden on graduate supervisors to verify accuracy and reliability. This not only adds to their workload but also raises fears about the erosion of their academic ability. The mechanization of traditional research tasks—such as literature synthesis and logical reasoning—via generative AI is steadily undermining tutors' professional advantages in repetitive and procedural work. Furthermore, as students increasingly rely on AI tools for tasks like literature retrieval, data preprocessing, and even drafting academic papers, the authority of the instructor as a knowledge disseminator and academic mentor is being challenged. The traditional apprenticeship model, which hinges on experience-based guidance, is gradually losing ground to technology-driven platforms. This dual crisis has led some researchers to perceive AI as a competitive threat to their profession. In response, they may develop an instinctive aversion to the technology, expressed through reluctance to engage with or even acknowledge AI tools. However, such resistance inadvertently widens the divide between humans and technology, hindering meaningful integration and adaptation in academic practice.

Finally, there is the challenge of skills iteration. On the one hand, in the age of artificial intelligence, the pace of technological advancement has outstripped the adaptation cycle of the teaching team. According to the OECD Digital Education Outlook 2023, 60% of secondary school teachers received digital education training in 2022, yet 20% still expressed a clear need for continued professional development[2]. This gap is likely to widen further as AI technologies continue to evolve rapidly. As noted earlier, approximately one-third of researchers are over the age of 50. This demographic commonly faces issues such as cognitive rigidity and declining learning capacity, often shaped by years of entrenched academic habits. As a result, their ability to absorb emerging technological knowledge tends to lag behind both the pace of technological development and the learning agility of younger colleagues. Moreover, given their typically heavier research workloads, senior researchers often find it difficult to allocate time and energy to learning and mastering a wide array of new tools. On the other hand, the existing technical training infrastructure is inadequate. In the traditional academic training system, technical instruction is largely concentrated in the early stages of a researcher's career. However, research institutions have not developed a sustained training framework that accompanies graduate supervisors throughout their professional lives. Furthermore, the content of such training has not kept pace with technological advancements, resulting in a lack of systematic AI literacy development[11-12]. Consequently, many graduate supervisors find themselves in a passive position when it comes to understanding and applying new technologies.

(iii) Teacher Role Substitution and Competitive Pressures

The development of artificial intelligence technology has profoundly impacted traditional teaching models. In traditional teaching, teachers typically play the central role of knowledge transmitters, relying on their accumulated knowledge and experience to construct a mode of knowledge delivery. Students are usually in a passive position, receiving knowledge, which to some extent reinforces the authority of teachers. Meanwhile, teachers' roles in instructional design, classroom management, and student

2 Source: Cited in *OECD Digital Education Outlook 2023 Towards an Effective Digital Education Ecosystem*, Organisation for Economic Co-operation and Development, 2023

evaluation also place them in a dominant position within the teaching environment[13]. However, with the gradual application of AI technology, the methods of acquiring and transmitting knowledge in teaching are changing, posing certain challenges to the traditional structure of teacher authority. By breaking down the spatial and temporal constraints of traditional education, AI enables students to build personalized learning paths through adaptive learning platforms and access educational resources via generative AI tools. As a result, teachers are no longer the sole source of knowledge. Their authoritative status is increasingly undermined, and they now face the challenge of functional replacement by artificial intelligence[14]. Consequently, graduate supervisors—who serve as educators in higher education—must begin to view AI as a collaborative partner in the educational process. They should work toward establishing a "subject-object fusion" relationship with AI, rather than simply treating it as a supplementary tool[15]. Graduate supervisors are also confronting new forms of competition from peers in the same field. This pressure arises from AI-driven innovations in research information acquisition. Through natural language processing and data mining, AI can extract relevant information from vast datasets, overcoming the low retrieval efficiency and the barriers of cross-disciplinary knowledge in the traditional research progress. Studies have shown that in K-12 education, students' intrinsic motivation and ability to learn with chatbots are influenced by both teacher support and student expertise (i.e., self-directed learning and digital literacy)[16]. This indicates that learning outcomes in human-AI interaction depend heavily on the roles and cooperation between both parties[17]. Therefore, how AI is deployed and what role it plays must ultimately be guided and regulated by humans[18]. In this context, a core determinant of research competitiveness is the ability to effectively leverage technological tools. Researchers with advanced AI literacy can harness human-AI collaboration to complete complex tasks—such as data cleaning and forecasting research trends—with greater efficiency, resulting in denser knowledge output and innovative breakthroughs within the same time frame. In contrast, those with limited AI literacy may struggle with timely access to information and find themselves at a growing disadvantage in academic competition. This form of competitive pressure is a direct challenge that graduate student instructors must confront in the age of artificial intelligence.

(iv) Higher-Order Thinking Challenges

The widespread application of artificial intelligence has raised the bar for graduate supervisors' critical thinking and innovation capabilities. Although AI can produce seemingly complete analytical conclusions through large-scale data training, its output is inevitably affected by biases in training data, limitations in algorithmic logic, and the phenomenon of machine hallucination—often resulting in factual inaccuracies. Such errors may appear in students' theses or in materials collected by the supervisors themselves, requiring careful identification and verification by graduate advisors. If these inaccuracies go unchecked, misinformation may be further disseminated and even used as the basis for scientific research, potentially leading to flawed conclusions. Detecting these errors demands strong critical thinking and a heightened awareness of the limitations of AI-generated content. This unquestionably places greater demands on the critical faculties of graduate supervisors[19]. Furthermore, the effective use of AI ultimately depends on human oversight. By its very nature, generative AI lacks the capacity for genuine knowledge innovation, and it is incapable of independently discovering the intrinsic connections and underlying patterns between phenomena[20], and knowledge innovation activities can only be initiated and reviewed by humans[21]. A comparative study of human and machine performance in generating math problem-solving strategies found that solution hints created by ChatGPT scored lower on average than those designed by humans[22], which suggests that humans will remain the main force driving knowledge

production in the future[23]. Therefore, graduate supervisors must possess a strong capacity for innovation and cannot rely solely on AI-generated research ideas.

(v) Risks of Ethical Misconduct

The integration of artificial intelligence into academic research exposes researchers to the risk of ethical misconduct. At the core of this challenge lies the difficulty in determining the attribution of originality. When researchers input their proprietary data and ideas into AI systems, the algorithm-generated content may subsequently be incorporated into future training datasets. This process can result in the unauthorized transformation of private intellectual contributions into public training data, and current technologies make it difficult to trace the original source of such information[24]. Moreover, when researchers build upon AI-generated outputs in secondary creations, the boundary between human innovation and machine-generated content becomes blurred. This ambiguity makes it difficult to evaluate the extent of human contribution to academic outcomes, thereby posing a significant challenge to existing frameworks of academic ethics.

III. New Changes in Requirements for Graduate Supervisors Competency in the Age of Artificial Intelligence

The essence of graduate supervisors literacy refers to the quality composition of comprehensively applying knowledge, skills, emotions, attitudes and values to solve practical problems in education or research contexts, particularly within complex scientific research settings[25]. With the advent of the artificial intelligence era, the requirements for tutor competency have undergone significant changes. The overall competency framework is being reshaped and upgraded, shifting from a focus on singular professional expertise to a multidimensional structure encompassing intelligent technology, data literacy, and ethical responsibility. This transformation demands that graduate student tutors and researchers not only master technical capabilities such as information retrieval, data analysis, and the application of machine learning tools, but also possess the ability to sustain critical thinking in human-AI collaboration, overcome algorithmic limitations, and propose innovative research questions. Simultaneously, they must uphold essential ethical standards, including data ethics, academic integrity, and technological accountability. The competency requirements for graduate mentorship in the AI era are illustrated in **Figure. 1**.

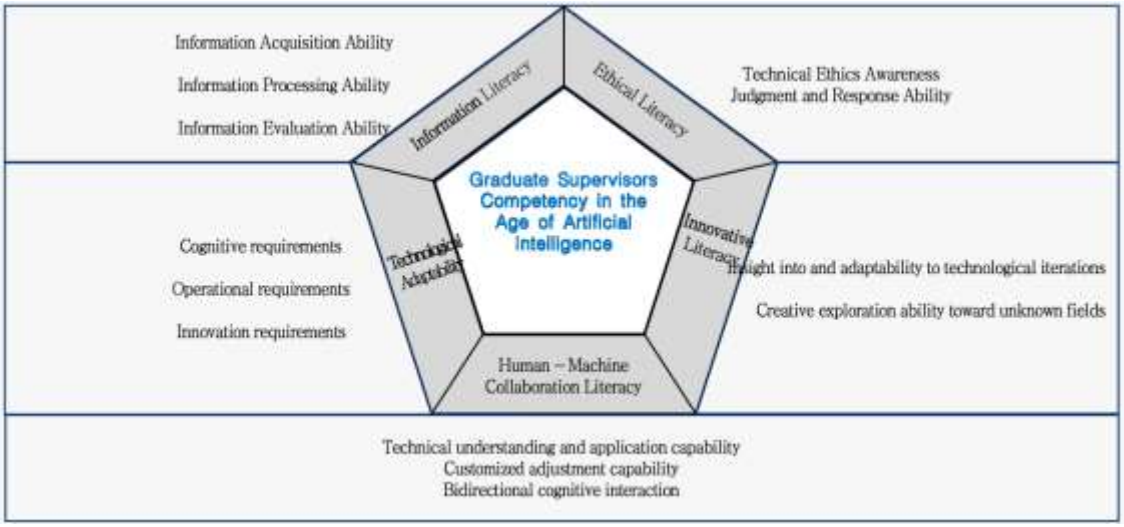

Figure 1 Graduate Supervisors Competency in the Age of Artificial Intelligence

Source: own elaboration

(i) Information Literacy

Information literacy refers to an individual's ability to effectively acquire, process, and apply information in response to personal and environmental needs. It also represents a comprehensive integration of critical thinking and ethical awareness26. In the current context, the openness of the Internet and the ease of content generation by AI have significantly lowered the threshold for information dissemination. Meanwhile, the high fidelity and subtlety of generative AI have facilitated the automated creation and spread of false information27. In a survey of 679 participants, who were asked to distinguish between false information and accurate information, and to determine whether the tweets were generated by AI, the results showed that AI-generated content was generally more comprehensible and accurate than human-generated content, but it was also more capable of producing persuasive misinformation28. Against this backdrop, it is imperative for graduate supervisors and researchers to enhance their abilities in evaluating and discerning information.

Among the new changes in information literacy requirements for graduate supervisors, information acquisition represents the most fundamental area of transformation. Traditionally reliant on linear retrieval models and keyword matching, the process has evolved into an intelligent retrieval system suited for the AI era. This includes semantic search, natural language querying, and cross-modal retrieval technologies, marking a paradigmatic shift from mechanical searching to cognitive discovery in information acquisition. Meanwhile, information processing has become the core dimension of modern information literacy. It has moved beyond simple literature collation to an intelligent knowledge management system powered by artificial intelligence. This shift requires graduate supervisors to efficiently handle vast volumes of academic literature, leverage AI tools for automated data processing, and develop sound data backup habits—ultimately enabling a transition from passive organization to proactive knowledge generation. Finally, information discernment is an essential dimension of contemporary information literacy, particularly crucial in combating the proliferation of misinformation in the age of information explosion. First, researchers must cultivate heightened awareness regarding the

reliability of information. Rather than passively accepting data, they need to verify both the sources and their credibility. A mature and rational approach to source evaluation is now a necessary quality for contemporary researchers. Second, beyond source verification, it is essential to assess the logical coherence of the information itself. Researchers should not be misled by appealing headlines or abstracts, but instead critically evaluate whether the arguments presented are well-supported and logically sound. Lastly, the timeliness and relevance of information are key to determining its reliability. Given the rapid pace of updates in the AI era, researchers must develop a forward-looking perspective—aligning information filtering with emerging research trends and their specific academic needs to extract the most valuable insights.

(ii) Technological Adaptability

In the context of rapid advancements in artificial intelligence, technological adaptability has become an essential core competency for graduate supervisors and researchers. This capability has evolved beyond the traditional notion of mere tool usage into a dynamic, multidimensional ability to intelligently engage with and steer technology—marking a shift from passive acceptance to active mastery. This competence not only requires researchers to be proficient in the operation of technical tools, but also to cultivate a comprehensive literacy that encompasses systematic understanding, critical application, and creative expansion of intelligent technologies. Under the traditional research paradigm, researchers primarily functioned as users of tools, needing only to follow fixed operational procedures. However, in the era of AI where technologies possess self-learning and autonomous decision-making capabilities, graduate supervisors must not only understand how these technologies work, but also guide their application to serve research objectives effectively.

The first breakthrough required is at the cognitive level: researchers must develop a deep understanding of how AI models operate and recognize their inherent limitations in order to demystify the technological "black box". In traditional scientific research, technical tools were often treated as black boxes, requiring only procedural familiarity. However, due to the complexity and autonomy of modern AI technologies, it is now essential for researchers to grasp their internal logic. Equally important is the ability to critically assess the limitations of AI models. Only with such understanding can researchers apply AI tools appropriately in scientific inquiry and avoid erroneous conclusions resulting from blind trust.

The second requirement is flexibility at the operational level. In the age of artificial intelligence, researchers' literacy is increasingly reflected in their ability to adapt and adjust technological application strategies with agility. Unlike the fixed workflows of traditional scientific research, AI technologies are inherently diverse and dynamic. This demands that researchers move beyond reliance on a single technological pathway and instead develop flexible strategies for applying technology—selecting and combining the most suitable tools based on specific research needs. Additionally, researchers must be adept at integrating multiple tools in a coherent manner to optimize research efficiency and outcomes.

Finally, a breakthrough at the level of innovation is essential. This requires researchers to develop the mindset needed to transcend technological limitations and transform the shortcomings of tools into opportunities for innovation. The transition from passive adaptation to active leadership highlights the elevated expectations for innovative thinking in the age of artificial intelligence. Although AI technologies are powerful, they still face significant limitations—such as poor model interpretability and

high data requirements. However, these limitations do not necessarily hinder researchers, but can be the starting point for research and innovation.

(iii) Human-AI Collaborative Competence

In the era of intelligence, researchers must develop human-AI collaborative literacy to establish a new scientific research paradigm that is complementary to the advantages of intelligent machines and collaborative symbiosis. Human-AI collaboration refers to the ability to interact harmoniously with machines and fully leverage the advantages of intelligent technologies to support both scientific research and daily life[29]. With its strengths in massive data storage, data mining, and high-efficiency computing, artificial intelligence can effectively compensate for the limitations of human research capabilities[30]. This new form of literacy emphasizes the importance of researchers being able to customize and adapt AI tools based on their disciplinary backgrounds, cognitive styles, and research needs—transforming AI from a general-purpose tool into a dedicated research partner and transcending traditional subject-object thinking.

In terms of understanding and applying AI technologies. First, researchers are required to develop a deep understanding of the fundamental principles, algorithms, and models of artificial intelligence, which forms the foundation for effective collaboration with intelligent machines. Second, technological application skills not only entail proficiency in using existing AI tools, but also the ability to flexibly adapt these tools in response to specific research needs. Third, the capacity to understand and apply AI is further reflected in the necessity of continuous learning and ongoing knowledge updates.

The second key dimension of human-computer collaborative literacy is the ability to customize and fine-tune AI tools. In the age of intelligence, AI tools are not one-size-fits-all; they must be optimized and adjusted according to specific research scenarios and needs. Researchers should be capable of customizing AI models to meet their individual requirements. Moreover, this ability involves the continuous optimization of AI tools. Such customization not only demands technical expertise but also requires integrating disciplinary knowledge with AI technology to ensure that AI tools effectively support research objectives.

An advanced expression of human-computer collaborative literacy is the ability to engage in two-way cognitive interaction between researchers and AI systems. Traditionally, interactions between researchers and technological tools have been largely unidirectional: humans issue commands, and machines execute tasks and return results. However, in the era of intelligence, such linear interactions are insufficient to address increasingly complex scientific challenges. Researchers must establish deep, reciprocal interaction mechanisms with AI systems to enable more efficient and accurate collaboration. This two-way cognitive interaction is, first, reflected in the researcher's ability to understand the decision-making processes of AI models. Second, AI systems must be capable of self-optimization based on researcher feedback. Finally, this capability extends to collaborative innovation, where researchers, through dynamic interaction with AI, can explore new research directions and methodologies.

(iv) Innovation Competency

In the era of artificial intelligence, graduate student mentors must enhance their capacity for critical adaptation and creative exploration in response to the rapidly evolving capabilities of emerging AI

technologies. This literacy is first reflected in researchers' ability to critically engage with technological iterations, gaining deep insight into their impact while continuously reconstructing professional knowledge systems whose relevance is increasingly short-lived amid the rapid dissolution of disciplinary boundaries. At a deeper level, creative literacy manifests as the ability to explore unknown domains. Researchers are expected to transcend traditional disciplinary boundaries, reorganize knowledge structures, and boldly propose disruptive hypotheses that challenge existing paradigms. Furthermore, they must be adept at uncovering overlooked innovation potential, even in failed experiments, by breaking free from conventional thinking.

The innovation literacy of researchers is first and foremost reflected in their deep insight and critical adaptation to technological iterations. This kind of literacy requires researchers to be keenly aware of the latest developments in technology, and to deeply understand the principles and potential impacts behind the technology. At the same time, researchers need to think critically about the application scenarios and effects of the technologies, not only satisfied with the superficial advantages, but also to explore the feasibility and limitations of their practical applications. In addition, this literacy is also reflected in the ability to adapt to technology iteration. Now that artificial intelligence technology is developing rapidly, the previous knowledge system and research methods can no longer keep up with the requirements of modern research. Researchers need to continuously reconstruct the knowledge system, integrate information across disciplines, and form a more comprehensive and systematic knowledge architecture.

Innovative literacy is also reflected in the ability to creatively explore uncharted domains. This requires researchers to break free from the constraints of traditional thinking and boldly venture into the unknown. It is not merely about the innovative application of existing technologies, but more importantly about approaching problems from entirely new perspectives, proposing disruptive hypotheses, and seeking solutions through interdisciplinary integration. In traditional research models, scholars are often confined by the knowledge systems and methodologies of their own disciplines. However, AI technology has helped dismantle such boundaries, making interdisciplinary research increasingly feasible. Researchers must transcend disciplinary silos, integrating AI with knowledge from other fields to create novel research trajectories. Moreover, they must have the courage to propose hypotheses that challenge established paradigms. Conventional paradigms are often constrained by entrenched theories, whereas AI opens up new possibilities to transcend these limitations. In addition, researchers should be adept at uncovering the innovative value hidden within failed experiments. While failure is often overlooked, in the age of AI, such data may contain patterns or insights that defy conventional expectations. By analyzing failed outcomes, researchers can identify new problems and opportunities, driving scientific breakthroughs. This capacity to discover innovation through failure demands both resilience and an open, inquisitive mindset.

(v) Ethical Literacy

In the era of artificial intelligence, ethical literacy has become a core competency that graduate advisors and researchers must cultivate. It encompasses the ability to recognize, assess, and respond to ethical issues related to technological applications. According to a 2023 Nature survey, 68% of scholars worldwide believe that AI is more prone to being used for falsification and is difficult to detect, while 53% of respondents think that the improper use of AI compromises the reproducibility of research31. These findings underscore the urgency of the ethical challenges brought about by the advancement of AI technologies. Graduate supervisors must possess a comprehensive understanding of the potential ethical

issues arising from the application of AI. Moreover, they need sharp ethical judgment to identify risks in complex technological scenarios and implement effective responses, thereby ensuring that both research processes and outcomes adhere to established ethical standards.

The cognitive literacy of graduate supervisors regarding technological ethics constitutes the foundational core of their overall ethical literacy. This competency requires them to develop a deep understanding of the ethical issues that AI technologies may raise in research practice—particularly those arising during data collection, classification, generation, and interpretation, where biases comparable to those of humans can emerge[32]. Therefore, when designing and applying AI algorithms, graduate supervisors should be aware of the potential for unfair outcomes caused by data imbalance or algorithmic design flaws. This is especially critical in research related to social decision-making, where efforts must be made to minimize the negative impact of bias on specific groups.

Among the components of researchers' ethical literacy, the ability to make sound ethical judgments is particularly critical. This competency requires researchers to identify potential ethical risks in complex research contexts with sensitivity and to make informed decisions grounded in ethical principles. Such judgment is not only based on a thorough understanding of technical details but also reflects the ability to integrate technological applications with broader social values and ethical norms. In addition, researchers must adopt an interdisciplinary perspective—drawing insights from law, sociology, philosophy, and other disciplines—to comprehensively evaluate the ethical implications of emerging technologies. This multidimensional approach enables researchers to pursue technological innovation while maintaining ethical integrity, thereby supporting both the sustainability of scientific progress and the harmonious development of society. Furthermore, this judgmental competence is also reflected in the capacity to assess the long-term societal impacts of technological applications, including their influence on social structures, cultural values, and human behavior. In the era of artificial intelligence, such ethical discernment is an indispensable core competency. It not only helps prevent technological misuse and ethical conflicts but also provides researchers with a strong moral compass to guide scientific research toward ethically sound and sustainable development.

In the era of artificial intelligence, the literacy framework for graduate supervisors and researchers is undergoing profound structural transformation and paradigm shifts. AI literacy—now as essential as reading, writing, and mathematical literacy—has become a critical competency for navigating the intelligent age[33]. The five core dimensions—information literacy, technological adaptability, human-AI collaboration, innovative thinking, and ethical awareness—not only constitute a new competency framework for researchers in the AI era, but also drive a fundamental shift toward more intelligent and multidimensional standards for evaluating research capabilities.

IV. Strategies and Pathways for Enhancing Graduate Supervisors' Competencies in the Age of Artificial Intelligence

As artificial intelligence continues to profoundly reshape the educational landscape, a pressing question arises: how can graduate supervisors adapt to these transformations and enhance their competencies to better fulfill their educational responsibilities? This paper proposes a set of strategies and pathways to address this challenge, as illustrated in **Figure. 2**.

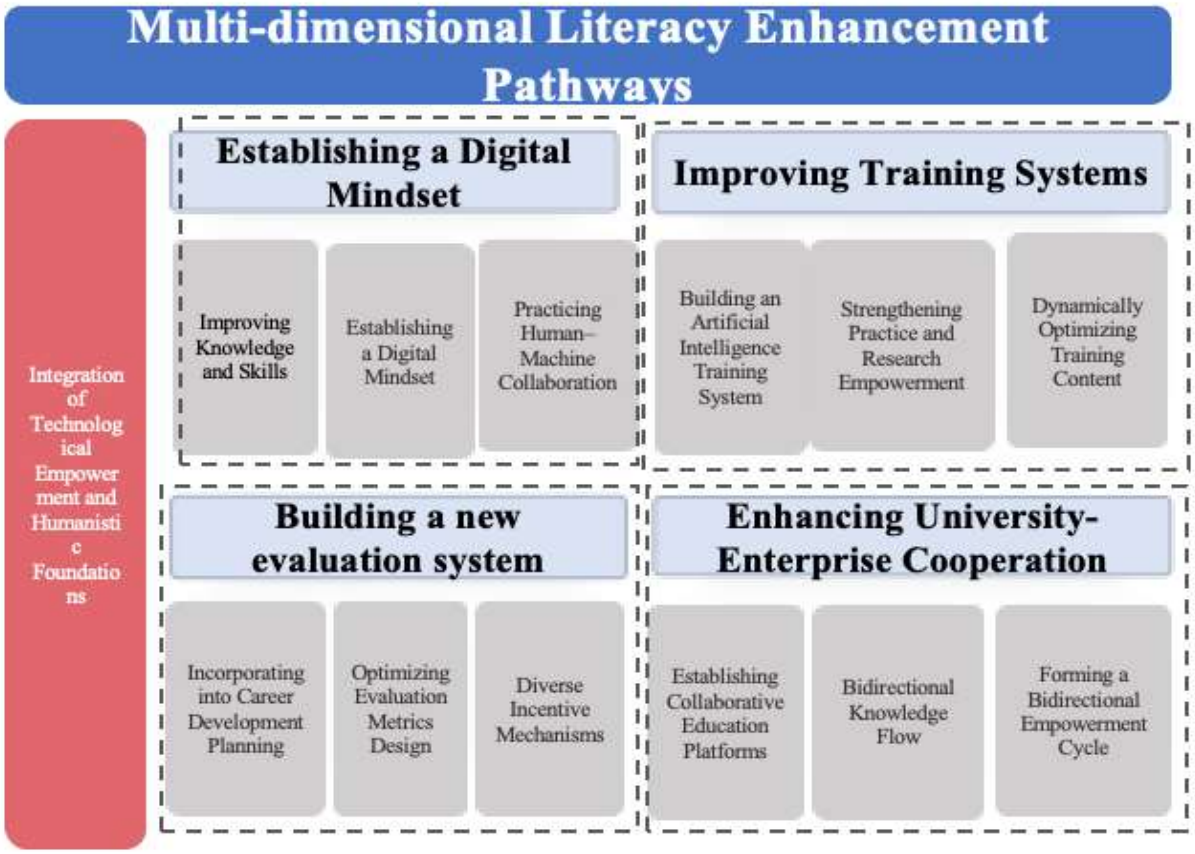

Figure.2 Strategies and Pathways for Enhancing Graduate Supervisors' Competencies in the Age of Artificial Intelligence
Source: own elaboration

(i) Embracing Artificial Intelligence with a Critical Digital Mindset

Graduate supervisors must actively construct new models of professional development suited to the AI era. This includes engaging with online learning platforms and academic communities to deepen their understanding of AI, and continuously enhancing their knowledge and skills. Importantly, learning AI should not be limited to technical tools; it should also involve grasping the underlying principles and logic of AI. Participating in systematic training programs enables supervisors to better understand how AI supports modern scientific research and teaching. At the same time, it is essential to cultivate a critical perspective on digital technologies[34]. When applying AI tools, supervisors should remain vigilant about ethical concerns—especially privacy and data security—and develop strong awareness of responsible data use. In practice, they should explore diverse modes of human-AI collaboration in both academic training and classroom teaching. While leveraging the capabilities of AI, supervisors must also preserve the irreplaceable human elements of emotional engagement and critical thinking, fostering an organic integration of technological empowerment and humanistic guidance.

(ii) Enhancing Training Systems and Designing Effective Courses

Fostering diverse literacies among educators fundamentally depends on institutional support. Institutions should establish comprehensive AI training frameworks that include modules on tool application, ethical review, and human-computer collaboration case studies. Training resources ought to be tiered based on competency assessments to ensure educators at different career stages benefit effectively. Universities should also provide ample practical opportunities for graduate student mentors, encouraging their active involvement in research and teaching projects that integrate AI technologies. Through reflecting on these experiences, mentors can continuously refine their methods and enhance outcomes. Moreover, creating platforms for knowledge exchange among mentors can cultivate a supportive learning environment and foster peer collaboration, thereby elevating the overall quality of the mentoring team. Finally, training programs must be responsive to educators' needs, tailoring content to address their challenges and interests. Regular course updates and optimizations are essential to maintain training effectiveness.

(iii) Constructing a New Evaluation System to Encourage Proactive Teacher Learning

Schools should actively develop a teacher evaluation system aligned with the demands of the AI era. Recognizing that some teachers may resist AI adoption, institutions ought to incorporate AI skills training and application capabilities into career development plans. Evaluation criteria for teacher appraisals, professional titles, and awards should reasonably include AI-related competencies. Through diverse incentives—such as special rewards, preferential access to training resources, and priority in promotions—schools can motivate teachers to proactively learn and master AI technologies. This approach effectively boosts teachers' enthusiasm and initiative in using AI to support teaching and student guidance, thereby fostering deeper integration of AI within education.

(iv) Strengthening School-Enterprise Cooperation and Leveraging Enterprise Advantages

Schools should enhance in-depth cooperation with enterprises related to artificial intelligence and digital education. By leveraging enterprises' keen market insight, forward-looking strategic vision, and advanced technological resources—often ahead of societal needs—schools can build collaborative education platforms with industry partners. Inviting outstanding engineers and technical experts from enterprises to provide training for teachers enables educators to stay up-to-date with industry cutting-edge developments and gain a comprehensive understanding of AI applications and trends in education. Meanwhile, enterprise technicians can gain deeper insights into the practical challenges teachers face in their daily work. This mutual understanding encourages enterprises to develop AI tools better aligned with teachers' actual needs and oriented by educational scenarios. Such cooperation creates a cycle of reciprocal empowerment between schools and enterprises, fostering deep integration of technology and education. Ultimately, this provides practical support and resource assurance to help teachers enhance the literacy required in the AI era.

From updating concepts to building systems, and from evaluation and incentives to university-enterprise collaboration, these multi-dimensional pathways for literacy enhancement together form a comprehensive support system for the development of graduate supervisors in the era of artificial intelligence. This helps promote the construction of high-quality tutor teams empowered by technology and enriched with a humanistic foundation.

Conclusions

The advent of the artificial intelligence era has brought brand-new requirements for the literacy of graduate supervisors, shifting from traditional single-discipline expertise to comprehensive literacy encompassing multiple dimensions such as intelligent technology, data-driven thinking, and ethics.

Analysis shows that graduate supervisors face varying degrees of challenges in areas including information literacy, technological adaptability, human-computer collaboration, innovation literacy, and ethical literacy. However, opportunities and challenges coexist.

By proactively adapting to the changing times, establishing a correct digital mindset, engaging in effective training, and leveraging university-enterprise collaboration, graduate supervisors can better harness the advantages of AI in teaching and research. This will enable a deep integration of education and technology, thereby advancing graduate education to a higher level and cultivating more high-quality talents suited for the intelligent era.

Acknowledgments: Supported by the 2024 Special Research Project of the Beijing Association of Higher Education (ZX202405)

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Conflict of interests:

The author declares that he has no conflict of interest.