



The Impact Pathways of Teachers' Digital Competence on Students' Learning Outcomes in the Era of Educational Technology

QIAO XIAOYAN^{1,2} Nalini Arumugam^{3,4}

¹Faculty of Business, Information & Human Science, Infrastructure University of Kuala Lumpur 43000, Kuala Lumpur, Malaysia

²School of Marxism, Chongqing Hailian Vocational College, China

³SEGI University, 47810 Petaling Jaya, Selangor

⁴Faculty of Business, Information & Human Science, Infrastructure University of Kuala Lumpur 43000, Kuala Lumpur, Malaysia

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Abstract: This study systematically analyzes the pathways through which teachers' digital competence influences students' learning outcomes in the era of educational technology. The findings indicate that teachers' digital competence significantly enhances students' academic performance through direct pathways, such as the optimization of digitalized teaching content. It also affects students' learning engagement and attitudes through indirect pathways, including instructional design and classroom interaction. The literature reveals the multidimensional mechanisms of teachers' digital competence, where these pathways interact to form a complex educational effect system. Additionally, the study highlights the critical role of improving teachers' digital competence in achieving successful digital education and proposes specific recommendations for policy support and teacher training. Future research should focus on the mechanisms of teachers' digital competence across different disciplines and cultural contexts to guide the practice and development of digital education.

KEYWORDS: Teachers' digital competence, Students' learning outcomes, Educational technology, Instructional design, Classroom interaction

I. INTRODUCTION

1.1 Research Background

In recent years, the rapid development of information technology has led to the widespread adoption of educational technology worldwide, driving profound changes in teaching methods. Digitalized teaching has become a significant trend in higher education, significantly enhancing the accessibility of educational resources, the innovation

of teaching models, and the precision of teaching evaluations. In this process, teachers' digital competence has increasingly been recognized as a core factor in successfully implementing digitalized teaching (Umut Zan et al., 2020). Teachers' digital competence includes not only basic operational skills with digital technologies but also the ability to integrate digital teaching resources, utilize educational technology tools, and innovate teaching practices based on technology. Particularly in the context of higher education, teachers' digital competence directly impacts the effectiveness of classroom teaching, thereby influencing students' learning outcomes (Tirado-Olivares et al., 2021). However, current research on teachers' digital competence predominantly focuses on competency models and level evaluations, with limited exploration of the mechanisms through which it influences students' learning outcomes in the context of educational technology.

1.2 Research Questions:

This study aims to address the following two core questions:

How does teachers' digital competence influence students' learning outcomes through direct and indirect pathways?

What insights and debates exist in the literature regarding the relationship between teachers' digital competence and students' learning outcomes?

By exploring these questions, this study seeks to provide a systematic analysis for constructing theoretical pathways of how teachers' digital competence impacts students' learning outcomes.



1.3 Research Significance :

This study has significant theoretical and practical implications:

Theoretical Significance: Through a systematic analysis of relevant domestic and international literature, this study identifies the core dimensions of teachers' digital competence and its mechanisms of influence, providing new perspectives for the development of educational technology theories. Particularly in the context of accelerating digital education, constructing a pathway framework linking teachers' digital competence with students' learning outcomes helps address existing research gaps.

Practical Significance: The findings of this study can serve as a reference for teacher training and development in higher education. They clarify the critical competencies in teachers' digital competence and their specific impact on students' learning outcomes. Furthermore, they provide theoretical support and practical recommendations for universities to formulate digital teaching policies, optimize resource allocation, and promote the application of educational technology.

II. LITERATURE REVIEW AND RESEARCH METHODS

2.1 Scope of Literature Review and Research Methods

This study's literature review is based on major academic databases, including CNKI, Scopus, and Web of Science. The selected literature primarily focuses on three areas: teachers' digital competence, the application of educational technology, and students' learning outcomes. The review encompasses theoretical studies, empirical research, and policy analyses. **Criteria for Literature Selection:**

High-quality research articles published within the past five years to ensure alignment with the rapid development of educational technology.

Studies addressing core theories and practical applications of teachers' digital competence.

Research exploring students' learning outcomes and evaluation metrics, particularly in the context of educational technology.

Research Methods:

This study employs a systematic literature review method to classify, integrate, and compare relevant literature. The aim is to comprehensively present the current state of research on the relationship between teachers' digital competence and students' learning outcomes, as well as identify existing research gaps.

2.2 Definition and Framework of Teachers' Digital Competence Teachers' digital competence refers to their comprehensive ability to effectively apply digital technology in educational processes, encompassing knowledge, skills, and attitudes. The European Digital Competence Framework for Educators (DigCompEdu) provides a key reference for defining teachers' digital competence. The framework identifies six core dimensions:

Professional Engagement: Teachers' ability to communicate, collaborate, and pursue professional development in a digital environment.

Digital Resources: The ability to locate, create, share, and manage digital teaching resources.

Teaching and Learning: The ability to design, implement, and evaluate digitalized teaching activities.

Assessment: The use of digital technology to analyze students' learning performance.

Empowering Learners: Supporting personalized and self-directed learning through technology.

Facilitating Students' Digital Competence: Helping students develop their own digital competence.

In Chinese research, teachers' digital competence often emphasizes the integration of technology and pedagogy, focusing on the practical application of digital tools and innovative teaching practices.

2.3 Connotation and Evaluation Metrics of Students' Learning Outcomes Students' learning outcomes generally refer to the achievements they make during the learning process, encompassing cognitive, emotional, and behavioral aspects. Commonly used evaluation metrics in the literature include:

Academic Performance: Students' performance in exams, writing assignments, and similar assessments, which is the most frequently used metric.

Learning Engagement: The time and effort students invest in classroom activities, including their initiative and interaction.

Learning Attitudes: Students' interest, confidence, and value recognition toward the subject being studied. In the context of educational technology, the evaluation of students' learning outcomes often incorporates technological factors, such as the efficiency of digital learning tools and participation on online interactive platforms.

2.4 Relationship Between Teachers' Digital Competence and Students' Learning Outcomes Existing literature widely acknowledges that teachers' digital competence significantly influences students' learning outcomes through both direct and indirect



pathways:

Direct Impact:

Teachers enhance students' learning efficiency by optimizing instructional design using digital technology. For instance, multimedia resources and interactive tools can make complex concepts more comprehensible, increasing students' interest and retention.

Indirect Impact:

Teachers' digital competence improves teaching methods and classroom interactions, thereby influencing students' learning outcomes. Studies show that teachers with higher digital competence are more adept at leveraging technology to promote students' active and collaborative learning, ultimately enhancing their academic performance and learning satisfaction.

In summary, literature analysis demonstrates that teachers' digital competence is not only a crucial factor in teaching effectiveness but also a core variable in improving students' learning outcomes. However, further research is needed to explore the specific mechanisms through which teachers' digital competence exerts its influence, as gaps still exist in the current body of knowledge.

III. THEORETICAL PATHWAYS OF TEACHERS' DIGITAL COMPETENCE INFLUENCING STUDENTS' LEARNING OUTCOMES

3.1 Direct Pathways: The Direct Impact of Teachers' Digital Competence on Students' Learning Outcomes

Evidence from Literature: Teachers' digital competence directly impacts students' learning outcomes, primarily through the design and implementation of teaching content. High digital competence enables teachers to:

Skillfully utilize digital tools, such as visualization software (e.g., Prezi and GeoGebra), to make teaching content more engaging and comprehensible.

Create multi-modal learning resources, including videos, interactive e-books, and online learning modules, to support diverse learning methods.

Research indicates that such direct technological applications significantly enhance students' academic performance. For instance, teachers using interactive simulation tools in science classes help students better grasp abstract scientific concepts (García-Vandewalle García et al., 2023).

Case Analysis: In practice, successful digitalized teaching cases highlight the importance of teachers' digital competence. For example, at

Chongqing Hailian Vocational and Technical College, teachers leveraged digital simulation platforms to help students more intuitively understand complex computational models. Results showed that students in these courses demonstrated significantly higher exam scores and increased interest in the subject compared to traditional classrooms (Nash, 2023). This case further validates the critical role of teachers' digital competence in directly improving students' learning outcomes.

3.2 Indirect Pathways: Enhancing Learning Outcomes Through Instructional Design Key Role of Instructional Design

Instructional design serves as a crucial bridge between teaching objectives and students' learning outcomes. The literature suggests that improved teachers' digital competence can optimize instructional design in the following ways:

Clearer Teaching Objectives: Using learning analytics tools (e.g., statistical features in learning management systems), teachers can precisely identify students' learning needs and tailor appropriate teaching goals.

Resource Integration: Teachers with high digital competence can effectively integrate diverse resources (e.g., open educational resources, digital libraries, and online course platforms) to meet students' personalized learning needs.

Applications of Teachers' Digital Competence in Instructional Design

Interactive Instructional Design: Teachers use digital platforms (e.g., Mentimeter or Padlet) to create interactive activities that encourage student participation in classroom discussions (McGrew et al., 2018).

Blended Learning Models: By combining online courses (e.g., MOOCs) with traditional in-class teaching, students gain the flexibility of self-paced learning alongside in-depth guidance through classroom activities (Scull et al., 2022).

These optimized instructional designs enhance students' comprehension of the material while increasing their engagement and motivation.

3.3 Indirect Pathways: Enhancing Learning Outcomes Through Classroom Interaction Enhancing Teacher-Student Interaction with Educational Technology

Classroom interaction is a vital driver of students' learning motivation and engagement. The literature highlights how teachers with high digital competence improve interaction:



Using real-time feedback tools (e.g., Kahoot and Socrative) to monitor students' learning progress and adjust teaching pace accordingly.

Leveraging online collaboration platforms (e.g., Google Classroom and Microsoft Teams) to facilitate group activities and strengthen peer interactions. For example, Dani et al. (2010) found that teachers employing online polling and discussion tools significantly boosted students' interest in learning and their deep understanding of the content.

Case Analysis: In a computer science course, teachers introduced online coding platforms (e.g., Code.org and GitHub), which not only increased students' interest in learning but also fostered collaboration among peers. This interactive model led to deeper engagement in learning tasks and higher academic achievements (Cabero-Almenara et al., 2024).

3.4 Composite Pathways: Multidimensional Mechanisms Working Together

Integrated Pathway Models: The impact of teachers' digital competence extends beyond direct or singular indirect pathways. It is the combined effect of multidimensional mechanisms that generates comprehensive learning outcomes. For instance:

Teachers' digital competence directly improves the quality of teaching content while simultaneously enhancing instructional design and interaction strategies to amplify learning effects.

The literature indicates a synergy between instructional design and classroom interaction, where effective instructional design enhances the quality of interactions, collectively influencing students' learning outcome (Nash, 2023).

Discussion and Implications

Further literature explores the composite mechanisms of influence. For example, a comprehensive study found that the effects of teachers' digital competence on students' learning outcomes vary by subject and educational context. In STEM disciplines, the direct impact of digital technology is more pronounced, while in the humanities, interaction and collaboration play a more critical role (Volarić T. et al., 2024).

This research suggests that future studies should explore the applicability of these mechanisms across disciplines and educational environments to provide more targeted guidance for teaching practices.

Through the above analysis, it is evident that teachers' digital competence significantly impacts students' learning outcomes via direct pathways and multiple indirect pathways. The synergy among these

multidimensional mechanisms is particularly crucial. Future research should aim to integrate diverse disciplinary contexts and technological scenarios to deeply investigate the dynamic mechanisms of these pathways.

IV. DISCUSSION AND ANALYSIS

4.1 The Core Role of Teachers' Digital Competence in Students' Learning Outcomes

Through a systematic analysis of relevant literature, this study identifies teachers' digital competence as a key variable influencing students' learning outcomes. Teachers with high digital competence can optimize the presentation of teaching content while leveraging advanced instructional design and classroom interaction strategies to enhance students' learning effectiveness. Literature suggests that teachers with higher digital competence are better equipped to handle the challenges of a digitalized teaching environment, thereby significantly improving students' academic performance and learning satisfaction (Bouhmid, 2019).

Moreover, the enhancement of teachers' digital competence supports the development of students' self-directed learning and lifelong learning skills. This demonstrates that, in an era of rapid educational technology development, teachers' digital competence is not merely a technical skill but an educational capacity essential for fostering students' holistic development.

4.2 Changes in Teaching Models in the Context of Educational Technology

The widespread adoption of educational technology in recent years has driven significant changes in teaching models. The transition from traditional teaching to digitalized instruction imposes higher demands on teachers' digital competence. The literature reveals three notable trends:

From Knowledge Transmission to Knowledge Construction:

Digitalized teaching emphasizes students' autonomous exploration and knowledge construction under teacher guidance. This requires teachers to proficiently design learning activities based on problem-solving or project-based learning (Lin et al., 2024).

From Offline Teaching to Blended Learning:

Blended learning has become mainstream, requiring teachers to balance the strengths of online learning with classroom activities in course design.

From Individualized Teaching to Collaborative Learning:



Technology-supported collaborative learning tools (e.g., online whiteboards and collaborative document platforms) enable students to achieve higher levels of learning through teamwork.

These changes indicate that teachers' roles in digitalized teaching environments have shifted from traditional knowledge transmitters to facilitators and supporters of student learning.

4.3 Implications for Teacher Training and Educational Policy

To address the challenges of digitalized teaching, this study proposes the following recommendations:

Planning and Implementation of Teachers' Professional Development

The enhancement of teachers' digital competence requires targeted training. For example, training programs should cover:

Basic operations of educational technology tools.

Improvements in instructional design capabilities.

The application of data analysis in teaching assessments.

Additionally, personalized training that integrates specific disciplines with digital technologies should be offered to meet the unique needs of teachers in different subject areas (Jeong et al., 2024).

Policy Support and Resource Provision

Policymakers should prioritize the provision of digital teaching resources, such as building educational technology platforms and promoting the open sharing of high-quality digital resources. Furthermore, flexible learning opportunities, such as online training courses and teaching case repositories, should be provided to facilitate teachers' continuous development of digital competence.

These measures not only boost teachers' confidence in digitalized teaching but also provide strong support for schools and teachers in facing the transformative changes brought about by educational technology.

4.4 Research Limitations and Future Directions

Despite systematically analyzing the pathways through which teachers' digital competence influences students' learning outcomes, this study has the following limitations:

Limitations in Timeframe and Scope of Literature Analysis:

The study focuses on literature from the past five years, potentially overlooking theoretical contributions from earlier research. Additionally, the research primarily targets higher education, leaving the applicability to vocational or primary education unexplored.

Applicability Across Disciplines and Cultural Contexts:

The analysis reveals that the requirements for teachers' digital competence vary across disciplines and cultural contexts. For instance, STEM disciplines demand greater proficiency in technical operations, while humanities place more emphasis on the integration of digital resources. Future studies should further explore these differences to provide more targeted training and policy recommendations.

Future Directions:

Conduct empirical research in specific disciplines and teaching scenarios to validate the mechanisms of different pathways.

Explore the impact of teachers' digital competence on students' learning outcomes in various countries and cultural contexts to provide data for international comparative studies.

Investigate how educational technology tools can improve learning outcomes for disadvantaged student groups, contributing to the goal of educational equity.

In summary, Teachers' digital competence is not only a driving force for educational transformation but also a core variable in enhancing students' learning outcomes. By strengthening teacher training, optimizing policy support, and further exploring its mechanisms in different contexts, we can more effectively address the opportunities and challenges brought about by educational technology.

V. CONCLUSION

This study systematically analyzed the mechanisms through which teachers' digital competence influences students' learning outcomes in the era of educational technology. The findings indicate that teachers' digital competence significantly impacts students' learning outcomes through both direct and indirect pathways:

Direct Impact: Teachers with high levels of digital competence directly enhance students' academic performance by optimizing the design of digital teaching content.

Indirect Impact: Teachers' digital competence indirectly influences students' learning engagement and attitudes by improving instructional design and fostering classroom interaction, further enhancing learning outcomes.

The literature review also highlights the multidimensional nature of the pathways through which teachers' digital competence affects students' learning outcomes. These pathways often work synergistically, forming a complex mechanism of teaching effectiveness. This finding provides theoretical support and data references for



constructing teaching models in the context of educational technology. Additionally, the results underscore the critical importance of improving teachers' digital competence, which is a cornerstone for achieving successful digital education. Teachers need to acquire the skills to use educational technology tools systematically and to master strategies for digital instructional design and classroom interaction. To achieve this, policymakers must provide essential resource support and training opportunities to create favorable conditions for the development of teachers' digital competence. Future research should continue to explore the nuanced dimensions of teachers' digital competence and its mechanisms in different disciplines and cultural contexts. This will offer more comprehensive guidance for practical applications and lay a solid foundation for the sustainable development of digital education.

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