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COMPARATIVE ANALYSIS OF POST-COVID-19 DIGITAL TECHNOLOGY ADOPTION AND ITS IMPACT ON MATHEMATICS TEACHERS' EFFECTIVENESS IN PUBLIC SENIOR SECONDARY SCHOOLS IN NIGERIA AND SOUTH AFRICA

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ABSTRACT

The COVID-19 pandemic accelerated the global adoption of digital technologies in education, transforming instructional practices in mathematics classrooms. This study examined the comparative impact of post-COVID-19 digital technology adoption on the effectiveness of mathematics teachers in public senior secondary schools in Nigeria and South Africa. Specifically, the study investigated the extent of digital technology adoption, its influence on teachers' effectiveness, the challenges affecting integration, and comparative differences between the two countries. A comparative descriptive survey research design was employed. Data were collected using the Digital Technology Adoption and Mathematics Teachers' Effectiveness Questionnaire (DTAMTEQ) and analysed using descriptive statistics and independent-samples t-tests. Findings revealed that mathematics teachers in both countries increasingly adopted digital tools, including learning management systems, video conferencing platforms, multimedia resources, and digital mathematics software. However, adoption levels were slightly higher in South Africa than in Nigeria. The results further indicated that digital technology integration positively influenced teachers' effectiveness, particularly in lesson delivery, student engagement, and assessment practices. Despite these benefits, challenges including poor internet connectivity, limited access to devices, inadequate training, unreliable electricity supply, and insufficient institutional support were identified, with these barriers more pronounced in Nigeria. The study concluded that while digital technology adoption has enhanced mathematics teaching in both contexts, its effectiveness depends largely on infrastructure, teacher competence, and policy support. The study recommends sustained investment in ICT infrastructure, continuous professional development, and strengthened institutional frameworks to ensure sustainable digital integration in mathematics education.

KEYWORDS: Infrastructure, learning, Mathematics, Effectiveness, Engagement.

1. BACKGROUND AND INTRODUCTION

The COVID-19 pandemic fundamentally reshaped education systems worldwide. In early 2020, school closures affected over 1.6 billion learners worldwide, compelling governments and educators to adopt digital technologies almost overnight (UNESCO, 2021). While high-income countries transitioned with relative ease due to pre-existing digital infrastructure, many countries in Sub-Saharan Africa, including Nigeria and South Africa, faced significant structural, technological, and pedagogical challenges. The pandemic did not merely disrupt teaching; it exposed long-standing inequalities in access to digital tools, internet connectivity, and teacher preparedness (World Bank, 2022).

In both Nigeria and South Africa, public secondary schools were particularly vulnerable. Public schools serve the majority of students and often operate within constrained budgets, uneven infrastructure, and varying levels of institutional support. During school closures, many teachers had to rely on improvised digital solutions such as WhatsApp, radio broadcasts, television lessons, Google Classroom, Zoom, and locally developed e-learning platforms. However, the effectiveness of these tools depended heavily on teachers' digital competence, institutional support, and students' access to devices and stable internet connections (OECD, 2021; UNICEF, 2022).

Mathematics education presents a unique case in this transformation. Mathematics is widely regarded as a foundational subject critical for national development, STEM advancement, and economic competitiveness. Yet it has consistently recorded performance challenges in both Nigeria and South Africa, especially within public schooling systems (DBE South Africa, 2023; WAEC Reports, 2022). The sudden shift to digital learning environments intensified concerns about instructional quality, learner engagement, assessment integrity, and conceptual understanding in mathematics classrooms.

Post-COVID-19, educational systems have moved beyond emergency remote teaching toward more structured digital integration. Governments in Nigeria and South Africa have introduced policies to strengthen ICT infrastructure and promote blended learning in public schools. For example, South Africa's Department of Basic Education has expanded its Digital Education Strategy, while Nigeria has advanced initiatives under its National Digital Economy Policy and Strategy (DBE, 2023; Federal Ministry of Communications and Digital Economy, 2022). Despite these efforts, implementation disparities remain significant between urban and rural schools, and between well-resourced and under-resourced public institutions.

Teacher effectiveness in this evolving digital landscape extends beyond content knowledge. It now encompasses digital pedagogical skills, the ability to design interactive online lessons, competence in using virtual assessment tools, and the capacity to maintain student motivation in hybrid environments. Research suggests that teacher digital competence strongly predicts instructional quality and student outcomes in technology-mediated settings (European Commission, 2022; World Bank, 2023). However, in many Sub-Saharan African contexts, professional development for digital integration remains inconsistent and often short-term.

A comparative analysis between Nigeria and South Africa is particularly valuable. While both countries share similarities as leading economies in Sub-Saharan Africa with significant public education systems, they differ in policy implementation frameworks, infrastructure readiness, and teacher professional development structures. South Africa, for instance, generally reports higher internet penetration rates, yet persistent inequalities between former advantaged and disadvantaged schools remain pronounced. Nigeria, with its larger population and decentralized education governance, faces unique coordination and funding challenges affecting digital adoption (ITU, 2023).

Understanding how post-COVID-19 digital technology adoption has influenced mathematics teachers' effectiveness in public senior secondary schools is, therefore, both timely and necessary. Such analysis will illuminate whether digital integration has enhanced instructional delivery, improved learner engagement, and strengthened assessment practices or whether it has widened existing educational gaps. It will also provide insight into policy gaps, teacher preparedness, and sustainable strategies for integrating technology into mathematics instruction in resource-constrained environments.

Ultimately, this study situates itself at the intersection of educational technology, teacher effectiveness, and comparative education. By examining Nigeria and South Africa side by side, it contributes to broader conversations on digital transformation in African public education systems and offers evidence-based recommendations for strengthening mathematics teaching in a post-pandemic era.

1.1. Problem Statement

The COVID-19 pandemic forced education systems in Nigeria and South Africa into an abrupt transition from traditional face-to-face teaching to digitally mediated instruction. For many public senior secondary schools, this shift was not simply a change in delivery mode it was a test of preparedness, infrastructure, and teacher capacity. Mathematics teachers, in particular, faced significant challenges. Unlike some subjects, mathematics often requires step-by-step demonstrations, real-time feedback, symbolic representation, and interactive problem-solving, which can be difficult to replicate effectively in poorly supported digital environments.

While both countries have since moved into a post-pandemic phase with renewed commitments to digital integration, concerns remain about whether the adoption of digital technologies has genuinely improved mathematics teachers' effectiveness in public schools. In many cases, technology was adopted out of necessity rather than strategic planning. Some teachers received minimal training, some schools lacked reliable internet access, and many students struggled with device availability and connectivity issues. These realities raise important questions: Has post-COVID digital adoption strengthened mathematics instruction, or has it deepened existing inequalities? Are teachers now better equipped to deliver mathematics effectively using digital tools, or are they still navigating unfamiliar systems with limited support?

Although emerging studies discuss digital learning during the pandemic, there is limited comparative evidence examining how post-COVID digital technology adoption has influenced mathematics teachers' effectiveness, specifically within public senior secondary schools in Nigeria and South Africa. Given the similarities and differences in policy environments, infrastructure, and teacher professional development in both countries, a comparative analysis is necessary to understand what is working, what is not, and why.

Without such evidence, policymakers and education stakeholders may continue investing in digital initiatives without a clear understanding of their impact on classroom effectiveness and student learning outcomes in mathematics. This study, therefore, seeks to fill this gap by comparing how post-COVID-19 digital technology adoption has affected mathematics teachers' effectiveness in public senior secondary schools in Nigeria and South Africa.

1.2. Objectives of the Study

The main objective of this study is to comparatively examine the impact of post-COVID-19 digital technology adoption on mathematics teachers' effectiveness in public senior secondary schools in Nigeria and South Africa.

The specific objectives are to:

1. Examine the extent of post-COVID-19 digital technology adoption among mathematics teachers in public senior secondary schools in Nigeria and South Africa.
2. Assess the influence of digital technology adoption on mathematics teachers' instructional effectiveness, including lesson delivery, classroom management, and assessment practices.
3. Identify the challenges affecting the effective integration of digital technologies in mathematics teaching in public senior secondary schools in both countries.
4. Compare the experiences and outcomes of digital technology integration among public senior secondary school mathematics teachers in Nigeria and South Africa.

1.3. Significance of the Study

The rapid shift to digital learning during and after the COVID-19 pandemic has permanently altered the educational landscape. However, beyond policy declarations and technological investments, there remains a pressing need to understand how these changes are affecting teachers at the classroom level, particularly in public senior secondary schools, where resources are often limited. This study is significant because it moves beyond general discussions of digital transformation to examine its real impact on mathematics teachers' effectiveness in Nigeria and South Africa.

First, the study will benefit policymakers and educational planners in both countries. By providing empirical evidence on how post-COVID-19 digital technology adoption influences mathematics teaching, the findings will guide more informed decisions regarding ICT investments, teacher training programs, and digital education policies. Rather than adopting technology for its own sake, policymakers will gain clearer insight into what strategies genuinely enhance instructional effectiveness in public school contexts.

Second, the study will be valuable to mathematics teachers and school administrators. Understanding the strengths and limitations of digital integration can help educators refine their instructional strategies, adopt more effective digital tools, and

advocate for targeted professional development. The comparative dimension of the research may also encourage cross-country learning, allowing each system to draw lessons from the other's experiences.

Third, the research will make a meaningful contribution to academic scholarship in educational technology and comparative education. While numerous studies have examined emergency remote teaching during the pandemic, fewer have focused specifically on post-COVID digital adoption and its sustained impact on teacher effectiveness, particularly within the African public school context. By comparing Nigeria and South Africa, this study will expand the body of knowledge on how digital transformation unfolds in developing educational systems with differing policy environments and infrastructural realities.

Additionally, the study is important for students and the broader public. Mathematics is foundational for scientific literacy, technological innovation, and economic development. If digital technologies can enhance teachers' effectiveness, they may also improve students' understanding, engagement, and performance in mathematics. Conversely, if digital integration is poorly implemented, it may widen existing inequalities. The findings of this study can therefore inform strategies that promote equitable and sustainable digital education.

Ultimately, this research is significant because it addresses a critical question facing post-pandemic education systems: Has digital technology truly strengthened teaching effectiveness in public schools, or has it simply introduced new challenges? By answering this question within the contexts of Nigeria and South Africa, the study aims to support more purposeful, inclusive, and impactful digital transformation in mathematics education.

2. CONCEPTUAL FRAMEWORK

The COVID-19 pandemic did more than interrupt schooling; it accelerated the integration of digital technologies into everyday teaching practice. In the post-COVID era, digital technology is no longer an emergency substitute for classroom instruction but an emerging component of mainstream pedagogy. However, the effectiveness of this integration depends largely on how teachers adopt, adapt, and utilise these technologies in their instructional practices.

This study is anchored on the idea that post-COVID-19 digital technology adoption influences mathematics teachers' effectiveness, but this relationship is not automatic. It is shaped by several interconnected factors, including teachers' digital competence, access to infrastructure, institutional support, and contextual challenges in public senior secondary schools in Nigeria and South Africa.

At the core of this framework are three major constructs:

2.1. Independent Variable

Post-COVID-19 Digital Technology Adoption, which includes:

- Use of digital instructional tools (e.g., learning management systems, virtual whiteboards, math software)
- Frequency of technology integration in mathematics lessons
- Participation in digital professional development
- Use of online assessment and feedback platforms

2.2. Mediating/Intervening Factors

The effectiveness of digital adoption is influenced by:

- Teachers' digital competence
- Availability of ICT infrastructure (devices, electricity, internet connectivity)
- Institutional and policy support
- School location (urban/rural)
- Training and professional development opportunities

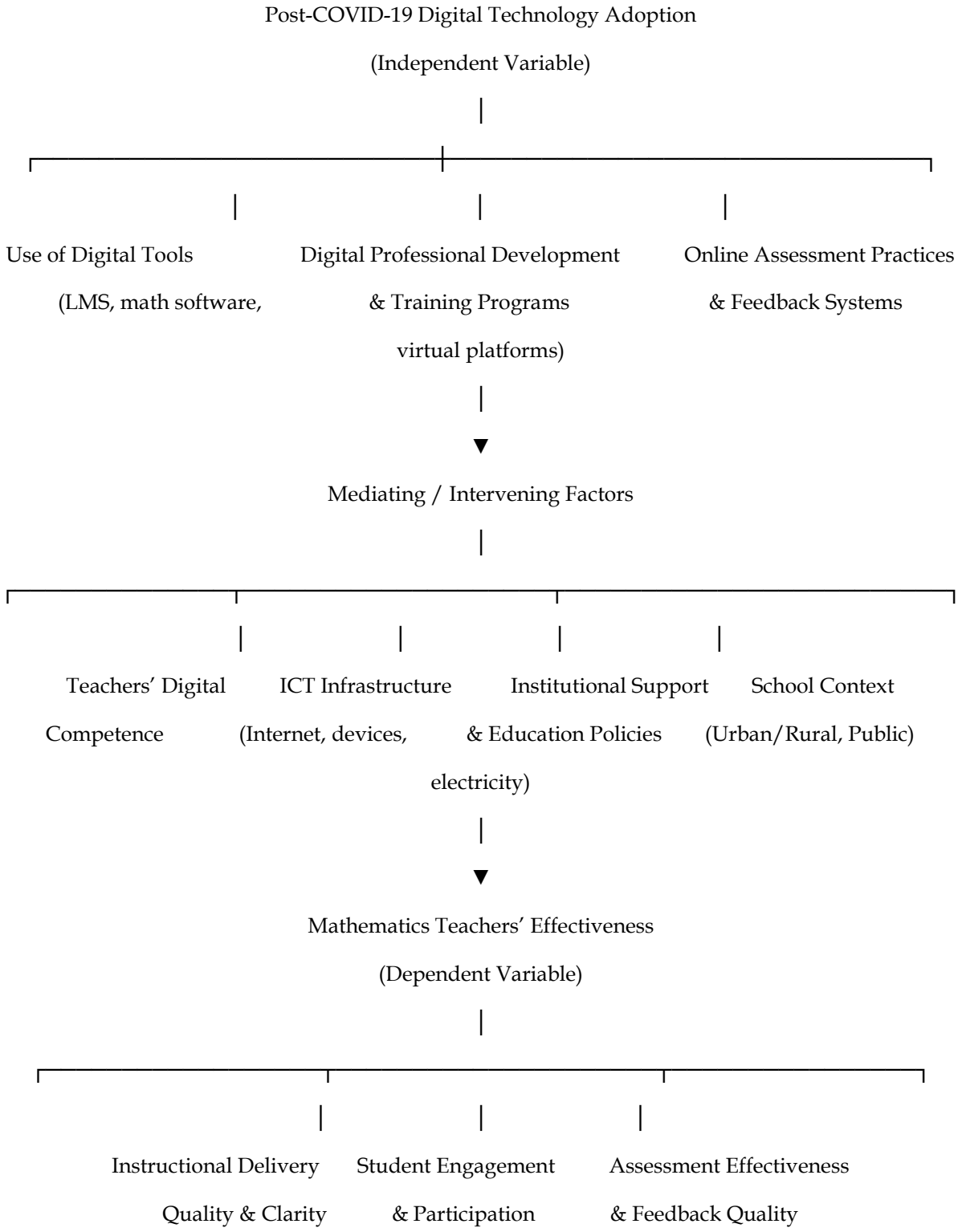
These factors may strengthen or weaken the impact of digital technology on teaching effectiveness.

2.3. Dependent Variable

Mathematics Teachers' Effectiveness, reflected in:

- Quality of instructional delivery
- Classroom management (physical and virtual)
- Student engagement
- Assessment practices
- Improvement in students' understanding of mathematical concepts

Tree Diagram Illustration of the Conceptual Framework



2.4. Explanation of the Framework Flow

The framework illustrates that post-COVID digital technology adoption serves as the primary driving force. However, its influence on mathematics teachers' effectiveness is mediated by contextual and competency-related factors. Where infrastructure is adequate and teachers possess strong digital skills, the impact on teaching effectiveness is likely to be positive. Conversely, limited access, inadequate training, or weak policy implementation may reduce its effectiveness.

The comparative dimension of this study emerges by examining how these relationships operate differently within the public secondary school systems of Nigeria and South Africa.

3. THEORETICAL FRAMEWORK

Understanding how post-COVID-19 digital technology adoption influences mathematics teachers' effectiveness requires a framework that explains both how teachers integrate technology into instruction and how innovations are adopted within educational systems. This study is therefore anchored on two complementary theories: the Technological Pedagogical Content Knowledge (TPACK) Theory and the Diffusion of Innovation (DOI) Theory.

3.1. Technological Pedagogical Content Knowledge (TPACK) Theory

The Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler (2006), builds on Shulman's concept of Pedagogical Content Knowledge (PCK). TPACK emphasises that effective teaching with technology occurs when teachers successfully integrate three core forms of knowledge:

- Content Knowledge (CK) – mastery of the subject matter (in this case, mathematics).
- Pedagogical Knowledge (PK) – understanding of teaching methods and strategies.
- Technological Knowledge (TK) – ability to use digital tools and technological resources effectively.

In mathematics education, these domains must intersect. For example, knowing algebra (content) is not sufficient if a teacher cannot explain it using effective instructional strategies (pedagogy), and both are limited if the teacher lacks the skills to use digital tools such as virtual whiteboards, graphing software, or online assessment platforms (technology).

In the post-COVID context, digital tools have become part of mainstream teaching rather than optional enhancements. Therefore, mathematics teachers' effectiveness increasingly depends on their ability to blend content knowledge, pedagogy, and technology in meaningful ways. A teacher who understands mathematical concepts deeply but lacks digital competence may struggle in a blended or technology-enhanced classroom. Conversely, a teacher who uses digital tools without sound pedagogical strategies may not improve student understanding.

TPACK is particularly relevant to this study because it provides a lens for examining whether post-COVID digital technology adoption has truly strengthened teachers' instructional practices in public senior secondary schools in Nigeria and South Africa.

3.2. Diffusion of Innovation (DOI) Theory

The Diffusion of Innovation Theory, proposed by Rogers (2003), explains how new ideas, practices, or technologies spread within a social system over time. According to this theory, adoption of innovation is influenced by factors such as:

- Perceived usefulness and relative advantage
- Compatibility with existing practices
- Complexity of the innovation
- Institutional support and communication channels
- Social and organisational context

In the post-COVID era, many public-school teachers were compelled to adopt digital tools rapidly. However, sustained and effective adoption depends on whether teachers perceive these technologies as beneficial, easy to use, and supported by school leadership and policy frameworks.

The theory also highlights that individuals adopt innovations at different rates, categorised as innovators, early adopters, early majority, late majority, and laggards. Within public senior secondary schools in Nigeria and South Africa, mathematics teachers may fall into different categories depending on their digital readiness, access to infrastructure, and professional development opportunities.

This theory is relevant because it helps explain variations in digital technology integration between and within the two countries. It also sheds light on systemic factors—such as policy implementation, training programs, and infrastructure that influence whether digital adoption translates into improved teacher effectiveness.

3.3. Integration of the Theories

Together, TPACK and Diffusion of Innovation Theory provide a comprehensive foundation for this study:

- TPACK explains how technology integration influences mathematics teachers' effectiveness at the classroom level.
- Diffusion of Innovation Theory explains why and how digital technologies are adopted, sustained, or resisted within public school systems.

By combining these perspectives, the study recognises that teacher effectiveness in the post-

COVID digital era is shaped not only by individual competence but also by systemic, institutional, and contextual factors.

In the contexts of Nigeria and South Africa, where public schools operate under diverse infrastructural and policy conditions, these theories collectively help to explain differences in digital technology adoption and its impact on mathematics teaching effectiveness.

3.4. Alignment of Theoretical and Conceptual Frameworks

The theoretical and conceptual frameworks of this study are closely interconnected, providing both a foundation for understanding and a practical guide for investigating how post-COVID digital technology adoption affects mathematics teachers' effectiveness in public senior secondary schools.

3.5. Linking TPACK Theory to the Conceptual Framework

The TPACK framework emphasizes the integration of technological knowledge, pedagogical knowledge, and content knowledge as essential for effective teaching. In the conceptual framework:

- Independent Variable (Digital Technology Adoption): The TPACK model supports the idea that teachers' use of digital tools, online platforms, and virtual teaching methods is only effective when combined with strong pedagogical strategies and content mastery.
- Dependent Variable (Teachers' Effectiveness): TPACK directly informs the indicators of teacher effectiveness, such as instructional delivery, classroom management, assessment practices, and student engagement. A teacher's digital competence—central to TPACK—mediates the quality of these outcomes.
- Mediating Factors: The conceptual framework identifies factors such as teachers' digital skills, access to infrastructure, and professional development. These map directly to TPACK's emphasis on teachers' technological knowledge and the necessity of institutional support to optimize integration.

In essence, TPACK provides the classroom-level explanation for why digital technology adoption can improve or hinder mathematics teaching effectiveness, highlighting the role of teacher competence in blending technology, pedagogy, and content.

3.6. Linking Diffusion of Innovation (DOI) Theory to the Conceptual Framework

- The Diffusion of Innovation Theory explains how innovations, such as digital technologies, are adopted, implemented, and sustained within schools over time. In the conceptual framework:
- Independent Variable (Digital Technology Adoption): DOI explains why some teachers adopt digital tools quickly while others resist, depending on perceived usefulness, ease of use, compatibility with existing practices, and access to resources.
- Mediating Factors: DOI aligns with the framework's consideration of institutional support, policy environments, and school context (urban/rural differences). These systemic factors influence the pace and quality of digital adoption, which in turn affects teacher effectiveness.
- Comparative Dimension (Nigeria vs. South Africa): DOI supports examining differences between countries, as adoption patterns may vary due to infrastructural readiness, policy frameworks, and professional development opportunities.

In essence, DOI provides the systemic explanation for adoption patterns, highlighting why some teachers and schools succeed in using digital tools effectively, while others struggle.

Integrated Alignment

By integrating TPACK and DOI with the conceptual framework, we can see a clear, coherent pathway:

1. Post-COVID Digital Technology Adoption (Independent Variable) is implemented differently across schools and teachers, influenced by adoption rates, training, and access to technology (DOI perspective).
2. Mediating Factors: teacher digital competence, ICT infrastructure, professional development, and school context determine how well teachers can blend technology, pedagogy, and content in mathematics lessons (TPACK perspective).
3. Teachers' Effectiveness (Dependent Variable) is the result of this integration, reflected in instructional quality, student engagement, and assessment practices.
4. Comparative Analysis between Nigeria and South Africa highlights how different systemic and contextual factors shape adoption, integration, and effectiveness.

Digital Technology Adoption → Mediating Factors (competence, infrastructure, policy) → Teachers' Effectiveness

- TPACK explains what happens inside the classroom when teachers integrate technology.
- DOI explains how and why adoption occurs across schools and systems.
- Together, they provide a comprehensive lens for understanding both individual teacher behaviour and systemic influences, ensuring strong coherence between theory and conceptual mapping.

4. CONCLUSION:

The integration of TPACK and DOI into the conceptual framework ensures that this study examines both the micro-level (classroom practices) and macro-level (systemic adoption patterns) factors affecting mathematics teachers' effectiveness post-COVID. This alignment strengthens the study's theoretical and practical foundation, justifying its focus on teacher competence, infrastructure, policy, and comparative analysis between Nigeria and South Africa.

4.1. Empirical Review

The global COVID-19 pandemic accelerated the adoption of digital technologies in education, compelling teachers to shift from traditional classroom methods to virtual and blended learning environments. Numerous empirical studies have examined the effects of this shift on teacher effectiveness, particularly in mathematics, a subject that requires both conceptual clarity and interactive pedagogical approaches.

4.1.1. Digital Technology Adoption and Teacher Effectiveness

Recent studies emphasise that the adoption of digital tools positively influences instructional delivery when teachers possess sufficient digital competence. For example, Nwachukwu and Adeyemi (2022) found that Nigerian mathematics teachers who integrated digital platforms such as Google Classroom, Zoom, and mathematics-specific software reported improvements in lesson clarity, interactive teaching, and assessment efficiency. Similarly, in South Africa, Maphosa and Shumba (2023) observed that mathematics teachers in well-resourced public schools who used learning management systems and virtual whiteboards-maintained student engagement and instructional continuity despite disruptions caused by the pandemic.

However, these benefits are often mediated by infrastructure availability, teacher training, and institutional support. In low-resource public schools, limited access to devices, unstable internet connectivity, and inadequate professional development programs hindered effective digital integration (UNICEF, 2022; World Bank, 2023). These findings suggest that technology alone does not guarantee improved teaching; the human and systemic factors supporting its use are equally important.

4.1.2. Mathematics Teachers' Digital Competence

Several studies have highlighted that digital competence is a critical determinant of teacher effectiveness in post-COVID classrooms. Adeoye et al. (2021) reported that Nigerian mathematics teachers with higher digital literacy were more confident in designing interactive online lessons, providing virtual assessments, and giving timely feedback. Similarly, in South Africa, Mouton and Makgato (2022) found that teachers' ability to navigate digital tools significantly affected students' understanding and engagement in mathematics lessons. These studies collectively underscore the TPACK principle that effective teaching requires a combination of content knowledge, pedagogical expertise, and technological proficiency.

4.1.3. Challenges of Digital Technology Adoption

Empirical evidence consistently points to challenges in implementing digital technology in public senior secondary schools. In Nigeria, research by Oladipo and Ojo (2022) revealed that large class sizes, inconsistent electricity supply, and poor internet infrastructure constrained teachers' ability to deliver effective mathematics instruction using digital tools. In South Africa, uneven resource distribution between urban and rural schools created disparities in access to digital platforms, further complicating teacher effectiveness (DBE, 2023). Moreover, inadequate professional development programs often leave teachers unprepared for the pedagogical shift to blended learning (OECD, 2021).

These challenges highlight the role of systemic and contextual factors emphasised in the Diffusion of Innovation theory: adoption is not solely a matter of individual willingness, but also of supportive policies, infrastructure, and sustained professional development.

4.1.4. Comparative Perspectives: Nigeria and South Africa

Comparative studies indicate both similarities and differences in post-COVID digital adoption between the two countries. Both Nigeria and South Africa faced sudden disruptions, yet the extent of technology integration and teacher preparedness varied. South African public schools generally benefited from higher internet penetration and more structured digital education policies, allowing smoother adoption of e-learning platforms (Maphosa & Shumba, 2023; DBE, 2023). In contrast, Nigerian schools often relied on ad hoc solutions such as WhatsApp, radio, and television lessons, which provided temporary relief but were limited in fostering interactive and sustained learning (Nwachukwu & Adeyemi, 2022).

These variations underscore the importance of comparative analysis. Understanding the contextual factors that facilitate or hinder effective digital adoption can inform strategies to strengthen mathematics teaching across different public-school environments in Sub-Saharan Africa.

4.2. Summary of Empirical Insights

4.2.1. Empirical evidence suggests that:

1. Post-COVID digital technology adoption has the potential to enhance mathematics teachers' effectiveness, particularly in instructional delivery, student engagement, and assessment.
2. Teacher digital competence is critical; without the skills to integrate technology with pedagogy and content knowledge, adoption has limited impact.
3. Infrastructure and institutional support strongly mediate the effectiveness of digital tools. Poor connectivity, insufficient devices, and inadequate training significantly reduce the benefits of technology integration.
4. Comparative differences between Nigeria and South Africa highlight the influence of systemic policies and resource distribution on the success of digital adoption in public schools.

In conclusion, while digital technology has provided opportunities to improve mathematics teaching in the post-COVID era, its impact depends heavily on teacher preparedness, infrastructure, and institutional support. These empirical findings reinforce the importance of a study that examines both classroom-level integration (TPACK) and systemic adoption patterns in the public senior secondary school context across Nigeria and South Africa

4.3. Research Methodology

4.3.1. Research Design

This study adopted a comparative descriptive survey research design to examine the impact of post-COVID-19 digital technology adoption on mathematics teachers' effectiveness in public senior secondary schools in Nigeria and South Africa. The descriptive survey design was considered appropriate because it enabled the researcher to collect data directly from mathematics teachers in their natural school environments and gain insights into their experiences, practices, and perceptions regarding the integration of digital technologies in mathematics instruction.

The comparative design enabled the researcher to identify similarities and differences in the adoption and use of digital technologies among mathematics teachers in public senior secondary schools in the two countries. This approach also helped in understanding how contextual factors such as infrastructure availability, policy support, and teacher preparedness influenced teaching effectiveness across different educational settings.

4.3.2. Population of the Study

The study population consisted of all mathematics teachers in public senior secondary schools in Nigeria and South Africa. These teachers were directly involved in classroom instruction and had experienced the transition to digital teaching methods during and after the COVID-19 pandemic.

Focusing on public school teachers provided a more realistic understanding of how digital technology adoption affects teaching effectiveness, since public schools in both countries serve large proportions of students and often operate under varying levels of technological and institutional support.

4.3.3. Sample and Sampling Technique

A multi-stage sampling technique was used to select participants for the study. In the first stage, selected regions or states in Nigeria and provinces in South Africa were purposively chosen to represent different educational contexts, including both urban and rural school settings.

In the second stage, a number of public senior secondary schools were randomly selected from the identified regions. Finally, mathematics teachers within the selected schools were chosen using simple random sampling, ensuring that every teacher had

an equal opportunity to participate in the study.

This sampling procedure helped ensure that the participants represented a wide range of experiences and school environments, thereby improving the credibility and generalizability of the findings.

Instrument for Data Collection

Data for the study were collected using a structured questionnaire titled "Digital Technology Adoption and Mathematics Teachers' Effectiveness Questionnaire (DTAMTEQ)."

The questionnaire was divided into two sections:

- Section A collected demographic information such as gender, academic qualification, years of teaching experience, and school location.
- Section B consisted of items designed to measure key variables of the study, including digital technology adoption, teachers' digital competence, challenges associated with technology integration, and mathematics teachers' effectiveness in terms of instructional delivery, student engagement, and assessment practices.

The questionnaire items were measured using a five-point Likert scale, ranging from Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), to Strongly Disagree (SD).

4.4. Validity of the Instrument

To ensure the instrument's validity, the questionnaire was submitted to experts in mathematics education, educational technology, and research methodology for review. These experts examined the instrument to determine whether the items adequately captured the variables under investigation.

Their suggestions and recommendations were incorporated to improve the clarity, relevance, and content coverage of the questionnaire before it was administered to the respondents.

4.4.1. Reliability of the Instrument

The instrument's reliability was established through a pilot study conducted with a small group of mathematics teachers who were not included in the main sample. The pilot test data were analysed using Cronbach's alpha to assess the questionnaire's internal consistency.

A reliability coefficient of 0.70 or higher was considered acceptable, indicating that the instrument was reliable for the main study.

4.5. Method of Data Collection

The questionnaires were administered to the selected mathematics teachers in the participating public senior secondary schools. In situations where physical access was limited, online survey platforms were also used to distribute the questionnaire.

Respondents were informed of the study's purpose and assured that their responses would be kept strictly confidential and used solely for academic purposes.

4.5.1. Method of Data Analysis

The data collected from the respondents were analysed using both descriptive and inferential statistical techniques.

Descriptive statistics such as frequency counts, percentages, means, and standard deviations were used to summarise demographic information and patterns of digital technology adoption among the teachers.

Inferential statistical methods, such as independent-samples t-tests and comparative analyses, were used to examine differences between mathematics teachers in Nigeria and South Africa in their digital technology adoption and effectiveness in teaching mathematics.

The results of the analysis were presented in tables to facilitate clear interpretation and discussion.

4.5.2. Ethical Considerations

Ethical considerations were observed throughout the study. Participation in the study was voluntary, and respondents were informed that they could withdraw at any stage without any consequences. The identities of the participants were kept anonymous, and all data collected were used strictly for academic and research purposes.

4.6. DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.6.1. Introduction

This section presents the analysis and interpretation of the data collected for the study titled "Comparative Analysis of Post-COVID-19 Digital Technology Adoption and Its Impact on Mathematics Teachers' Effectiveness in Public Senior Secondary Schools in Nigeria and South Africa."

The purpose of this section is to present the results obtained from the questionnaires administered to mathematics teachers in selected public senior secondary schools in both countries. The analysis is organised according to the study's research objectives.

The chapter is divided into four main sections:

1. Demographic characteristics of respondents
2. Analysis of research objectives

3. Comparative analysis between Nigeria and South Africa
4. Discussion of findings

Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to analyse the data, while independent-samples t-tests were used to examine differences between the two countries.

4.6.2. Demographic Characteristics of Respondents

This section presents the background information of the respondents, including gender, teaching experience, academic qualification, and school location.

Table :1

Gender	Frequency	Percentage (%)
Male	68	54.4
Female	57	45.6
Total	**125**	**100**

The results in Table 4.1 show that 54.4% of respondents were male and 45.6% were female. This indicates that both genders were adequately represented in the study.

Table 2: Distribution of Respondents by Teaching Experience.

Teaching Experience	Frequency	Percentage (%)
1–5 years	29	23.2
6–10 years	41	32.8
11–15 years	32	25.6
Above 15 years	23	18.4
Total	125	100

Table 4.2 shows that the majority of the teachers (32.8%) had 6–10 years of teaching experience, indicating that most respondents had sufficient classroom experience to provide reliable information about digital technology adoption in teaching mathematics.

Table 3: Distribution of Respondents by School Location.

School Location	Frequency	Percentage (%)
Urban	**71**	**56.8**
Rural	**54**	**43.2**
Total	**125**	**100**

The results indicate that 56.8% of respondents were from urban schools, while 43.2% were from rural schools, ensuring representation of different educational contexts.

Objective 1

To examine the extent of post-COVID-19 digital technology adoption among mathematics teachers in public senior secondary schools in Nigeria and South Africa.

Table 4: Extent of Post-COVID-19 Digital Technology Adoption among Mathematics Teachers.

Digital Technology Practice	Nigeria (M)	Nigeria (SD)	South Africa (M)	South Africa (SD)
Use of online learning platforms (LMS, Google Classroom)	3.42	0.81	3.78	0.74
Use of virtual meeting tools (Zoom, Microsoft Teams)	3.35	0.87	3.69	0.79
Use of digital mathematics software (GeoGebra, graphing tools)	3.18	0.85	3.55	0.76
Use of online assignments and assessments	3.27	0.83	3.61	0.72
Use of multimedia tools in teaching mathematics	3.36	0.80	3.70	0.75
Overall Mean	**3.32**	**0.83**	**3.67**	**0.75**

Note. M = Mean; SD = Standard Deviation.

The results show that digital technology adoption occurred in both countries after the COVID-19 pandemic. However, the overall mean score indicates that teachers in South Africa adopted digital technologies slightly more than teachers in Nigeria.

Objective 2

To assess the influence of digital technology adoption on mathematics teachers' instructional effectiveness.

Table 5: Influence of Digital Technology Adoption on Mathematics Teachers' Effectiveness.

Indicator of Teacher Effectiveness	Nigeria (M)	Nigeria (SD)	South Africa (M)	South Africa (SD)
Improved clarity of mathematics instruction	3.41	0.79	3.73	0.70
Enhanced student participation	3.29	0.84	3.62	0.76

during lessons				
Better classroom management in blended learning	3.18	0.88	3.54	0.77
Improved assessment and feedback practices	3.34	0.82	3.68	0.73
Increased use of interactive teaching strategies	3.26	0.85	3.60	0.74
Overall Mean	**3.30**	**0.84**	**3.63**	**0.74**

The findings indicate that digital technology contributed positively to mathematics teachers' instructional effectiveness in both countries. Teachers reported improvements in lesson clarity, student engagement, and assessment practices, with slightly higher effectiveness reported in South Africa.

Objective 3

To identify the challenges affecting the effective integration of digital technologies in mathematics teaching.

Table 6: Challenges Affecting Digital Technology Integration in Mathematics Teaching.

Identified Challenge	Nigeria (M)	Nigeria (SD)	South Africa (M)	South Africa (SD)
Limited access to digital devices	3.74	0.76	3.28	0.82
Poor internet connectivity	3.81	0.70	3.36	0.78
Inadequate teacher training in digital tools	3.65	0.79	3.33	0.81
Unreliable electricity supply	3.89	0.66	3.05	0.87
Lack of institutional support	3.52	0.83	3.24	0.84
Overall Mean	**3.72**	**0.75**	**3.25**	**0.82**

The findings reveal that teachers in Nigeria face more significant challenges, particularly with electricity supply and internet connectivity. Although South African teachers also faced challenges, the severity was comparatively lower.

Objective 4

To compare the experiences and outcomes of digital technology integration among mathematics teachers in Nigeria and South Africa.

Table 7: Independent Sample t-Test Comparing Nigeria and South Africa on Digital Technology Integration.

Variable	Country	M	SD	t	p
Digital Technology Adoption	Nigeria	3.32	0.83	3.41	.001
	South Africa	3.67	0.75		
Teacher Effectiveness	Nigeria	3.30	0.84	3.26	.002
	South Africa	3.63	0.74		

Note. $p < .05$ indicates a statistically significant difference between the two countries.

The results in the table above show a statistically significant difference between Nigeria and South Africa regarding digital technology adoption and mathematics teachers' effectiveness.

4.7. Summary of results interpretation

The results indicated that, after COVID-19, mathematics teachers in both Nigeria and South Africa adopted digital technologies in their teaching, though adoption was slightly higher in South Africa. The findings also revealed that digital technology integration positively influenced instructional delivery, student engagement, and assessment practices.

However, several challenges were identified, particularly among Nigerian teachers, including poor internet connectivity, unreliable electricity supply, and limited access to digital devices. The comparative analysis further showed statistically significant differences between the two countries in terms of digital technology adoption and teacher effectiveness.

4.7.1. Discussion of Findings

This section discusses the study's findings in relation to the research objectives and the relevant empirical literature. The discussion highlights how the results of this study align with or differ from previous studies on digital technology adoption and teacher effectiveness in mathematics education.

4.7.2. Post-COVID-19 Digital Technology Adoption among Mathematics Teachers

The findings of this study revealed that mathematics teachers in public senior secondary schools in both Nigeria and South Africa adopted various forms of digital technologies after the COVID-19 pandemic. Tools such as learning management systems, video conferencing platforms, multimedia instructional resources, and digital

mathematics software were commonly used to support teaching and learning.

However, the results indicated that teachers in South Africa demonstrated a slightly higher level of digital technology adoption compared to their counterparts in Nigeria. This difference may be attributed to variations in ICT infrastructure, digital education policies, and teacher professional development opportunities between the two countries.

These findings are consistent with the study conducted by Maphosa and Shumba (2023), who reported that South African teachers increasingly integrated digital platforms such as Google Classroom and Microsoft Teams into their teaching following the pandemic. Similarly, Nwachukwu and Adeyemi (2022) found that Nigerian teachers adopted digital tools during the pandemic, although the extent of integration varied widely due to infrastructural limitations.

The findings also support the Diffusion of Innovation theory, which suggests that the adoption of new technologies occurs at different rates depending on the availability of resources, institutional support, and perceived usefulness of the innovation.

Influence of Digital Technology Adoption on Teachers' Effectiveness

The study further revealed that digital technology adoption positively influenced mathematics teachers' effectiveness in both countries. Teachers reported improvements in lesson delivery, increased student participation during lessons, and enhanced assessment practices.

These findings suggest that digital technologies can serve as important instructional tools that enhance teaching strategies and improve student engagement in mathematics classrooms. For instance, multimedia resources and virtual platforms allow teachers to present mathematical concepts more visually and interactively, helping students better understand abstract ideas.

This result aligns with the findings of Adeoye, Afolabi, and Abimbola (2021) and Morenike (2026), who found that teachers with higher digital competence were more effective in delivering mathematics instruction and engaging students in technology-supported learning environments. Similarly, Mouton and Makgato (2022), and Saziwa and Olaseni, (2025) reported that the use of digital tools such as virtual whiteboards and mathematical software significantly improved classroom interaction and conceptual understanding among learners in South African secondary schools.

These findings also reflect the principles of the Technological Pedagogical Content Knowledge (TPACK) framework, which emphasizes that effective teaching occurs when teachers are able to combine their subject knowledge, pedagogical skills, and technological competence.

4.7.3. Challenges Affecting Digital Technology Integration

Despite the positive outcomes associated with digital technology adoption, the study identified several challenges that hinder effective integration of digital tools in mathematics teaching. Among the major challenges reported by teachers were poor internet connectivity, limited access to digital devices, inadequate teacher training, unreliable electricity supply, and insufficient institutional support.

The results further showed that these challenges were more pronounced among teachers in Nigeria compared to those in South Africa. In particular, unstable electricity supply and limited access to digital infrastructure were major barriers to effective digital teaching.

These findings are consistent with the UNICEF (2022) report, which highlighted that many schools in Sub-Saharan Africa faced significant technological barriers during and after the COVID-19 pandemic, particularly in rural and under-resourced areas. Similarly, Oladipo and Ojo (2022), and Olaseni and Saziwa, (2024) found that Nigerian public school teachers struggled to sustain digital teaching practices due to infrastructure limitations and insufficient professional training.

In South Africa, although challenges remain, previous studies suggest that government initiatives, such as the Digital Education Strategy, have helped improve access to digital resources in schools (DBE, 2023). This may explain why teachers in South Africa reported fewer infrastructure challenges than their Nigerian counterparts.

4.7.4. Comparative Differences between Nigeria and South Africa

The comparative analysis conducted in this study revealed a statistically significant difference between Nigeria and South Africa in terms of digital technology adoption and mathematics teachers' effectiveness. Teachers in South Africa generally reported higher levels of digital integration and slightly higher levels of teaching effectiveness.

This finding supports earlier comparative research indicating that differences in educational policies, technological infrastructure, and teacher

training programs can significantly influence how digital technologies are adopted and utilised in schools.

For instance, the World Bank (2023) reported that countries with stronger digital infrastructure and clearer ICT-in-education policies tend to achieve more successful integration of technology in teaching and learning. Similarly, OECD (2021) emphasised that sustained teacher training and institutional support are key determinants of effective digital education systems.

The results of this study, therefore, suggest that while both Nigeria and South Africa have made progress in integrating digital technologies into mathematics education following the COVID-19 pandemic, systemic and infrastructural differences continue to shape the extent and effectiveness of technology adoption in public secondary schools.

Overall, this study's findings indicate that post-COVID-19 digital technology adoption has contributed positively to mathematics teaching in public senior secondary schools. However, the success of digital integration largely depends on factors such as teacher digital competence, availability of infrastructure, and institutional support.

The study also highlights the importance of addressing technological and training gaps to ensure that digital technologies are effectively utilised to enhance mathematics education in both Nigeria and South Africa.

5. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This section presents the study summary, conclusions drawn from the findings, and recommendations based on the results. The study examined the comparative impact of post-COVID-19 digital technology adoption on the effectiveness of mathematics teachers in public senior secondary schools in Nigeria and South Africa.

The study specifically examined the extent of digital technology adoption among mathematics teachers, its influence on their teaching effectiveness, the challenges affecting technology integration, and the differences between the experiences of teachers in Nigeria and South Africa.

5.2 Summary of the Study

The COVID-19 pandemic significantly disrupted educational systems worldwide and accelerated the use of digital technologies in teaching and learning. In response to these changes, many schools adopted various digital tools to ensure the continuity of education. This study, therefore, investigated how the adoption of digital technologies following the COVID-19 pandemic has influenced the effectiveness of mathematics teachers in public senior secondary schools in Nigeria and South Africa.

A comparative descriptive survey research design was adopted for the study. The population consisted of mathematics teachers in public senior secondary schools in the two countries. Data were collected using a structured questionnaire titled Digital Technology Adoption and Mathematics Teachers' Effectiveness Questionnaire (DTAMTEQ).

Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to analyse the data, while independent-samples t-tests were used to compare responses between Nigeria and South Africa.

The study found that digital technology adoption increased significantly after the COVID-19 pandemic. Teachers in both countries reported using a range of digital tools, including learning management systems, video conferencing platforms, multimedia resources, and digital mathematics software, to support their teaching.

However, the study also found that the level of digital technology adoption was slightly higher among teachers in South Africa than among those in Nigeria. The findings further showed that digital technology integration positively influenced mathematics teachers' effectiveness, particularly in lesson delivery, student engagement, and assessment practices.

Despite these benefits, several challenges affecting the effective use of digital technologies were identified. These challenges included poor internet connectivity, limited access to digital devices, inadequate teacher training, unreliable electricity supply, and insufficient institutional support. These challenges were found to be more severe in Nigeria than in South Africa.

The comparative analysis further indicated a statistically significant difference between Nigeria and South Africa in terms of digital technology adoption and mathematics teachers' effectiveness.

5.3 Conclusion

Based on the study's findings, it can be concluded that post-COVID-19 digital technology adoption has become an important component of mathematics teaching in public senior secondary schools in both Nigeria and South Africa. The integration of digital tools has improved instructional delivery, student engagement, and assessment practices among

mathematics teachers.

However, the study also demonstrates that the effectiveness of digital technology integration depends largely on factors such as teacher digital competence, availability of technological infrastructure, institutional support, and access to reliable internet and electricity.

The comparative findings suggest that although both countries have made progress in integrating digital technologies into their education systems, differences in infrastructure, policy implementation, and professional development opportunities continue to influence the extent and effectiveness of technology adoption.

Therefore, for digital technology to fully enhance mathematics teaching and learning, sustained efforts must be made to address existing infrastructural and training challenges, particularly in public schools, where resources are often limited.

5.4. Recommendations

Based on the findings and conclusions of this study, the following recommendations are made:

1. Improvement of ICT Infrastructure

Governments and educational authorities in both Nigeria and South Africa should invest in improving ICT infrastructure in public secondary schools by providing reliable internet access, digital devices, and a stable electricity supply.

2. Continuous Professional Development for Teachers

Regular training programs and workshops should be organised to enhance mathematics teachers' digital competence and enable them to effectively integrate technology into their instructional practices.

3. Provision of Digital Teaching Resources

Schools should be equipped with appropriate digital teaching tools such as learning management systems, mathematical software, and multimedia instructional materials to support effective mathematics instruction.

4. Strengthening Institutional and Policy Support

Educational policymakers should develop and implement clear policies that encourage the sustainable use of digital technologies in teaching and learning, particularly in public schools.

5. Encouraging Blended Learning Approaches

Schools should adopt blended learning strategies that combine traditional face-to-face instruction with digital technologies to enhance student engagement and improve mathematics learning outcomes.

6. Addressing Rural–Urban Disparities

Special attention should be given to schools in rural areas, where access to digital infrastructure is often limited, to reduce inequalities in educational opportunities.

5.5 Suggestions for Further Studies

Future researchers may consider the following areas for further investigation:

1. A similar study focusing on students' academic performance in mathematics in relation to digital technology adoption.
2. An investigation into the long-term sustainability of digital learning practices in secondary schools after the COVID-19 pandemic.
3. A study examining teachers' attitudes and readiness for digital transformation in education across other African countries.

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