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Assessment of Tech-Infused Pedagogical Innovations on Integrated Science Teaching and Learning among Tertiary Institution Pre-Service Teachers in Akwa Ibom State, Nigeria

AKPAN, Anyanime Okopide

anyanimeakpan@aksu.edu.ng

+2348023319141

Department of Science Education, Akwa Ibom State University, Ikot Akpaden, Akwa Ibom State, Nigeria

Abstract

Education in the 21st century has changed, likewise the pattern of teaching and learning due to emergence of digital technology-based innovations in pedagogy; hence the academic landscape is evolving to embrace these innovative teaching and learning methods. The study examined revolutionizing STEM education: tech-infused pedagogical innovations for integrated science teaching and learning in Akwa Ibom State, Nigeria. The study used the descriptive survey design. A sample size of 180 respondents was selected from 752 pre-service Integrated science teachers in the government-owned tertiary institutions using a simple random sampling technique. The instrument, a 32 item-questionnaire on 'Knowledge, Proficiency and Utilization of Tech-Infused Pedagogical Innovations in Revolutionizing STEM Education Questionnaire (KPUTPIRSEQ) was used for data collection. The instrument underwent a series of validations by experts in Test and Measurement, and Science Education to ascertain its validity. A reliability coefficient of 0.77 was obtained for the instrument using Cronbach Alpha statistics. Mean and standard deviation scores were used to answer the research questions. The findings of the study showed a moderate extent of pre-service Integrated Science teachers' knowledge, proficiency and utilization of tech-infused pedagogical innovations for revolutionizing STEM education. Based on the findings, it was recommended among others that pedagogical practices should be made to embrace the use of tech-infused innovations so that teacher trainees have the appropriate knowledge and skills to meet with increasing needs of society. Also, tertiary education and teachers' education curricula be restructured to focus on contextualized and digital abilities for effective teaching and learning.

Keywords: Revolutionizing, STEM Education, Tech-infused, Pedagogical, Innovations

Introduction

STEM an acronym for science, technology, engineering, and mathematics, four areas often integrated into interdisciplinary learning, drives innovations, emphasizes analytical thinking and provide creative solutions to real world problems. It also prepares students for future jobs and global competitiveness. STEM education is the key foundation for any country's economic success, progress and growth, fostering skills essential for technological and economic development (Etiubon, et al, 2018). In teaching practices, integrating modern technology into teaching has transformed how learners construct knowledge and teachers deliver lessons. The Covid-19 pandemic acted as a catalyst for the rapid acceleration and adoption of online learning technologies and the advent of new technologies has revolutionized the educational landscape, making technology assisted education a necessity rather than an option (Akpan, et al 2025a). Revolutionizing education means shifting from rote memorization to student-centred, experiential learning by infusing modern technologies into pedagogies for teaching and learning. It aims to transform traditional educational methods by leveraging technology to improve the quality of education, making learning more engaging, interactive, providing access to a broader range of resources and information (Akpan, et al., 2024). The utilization of these technologies allows for personalized learning experiences, promote student-centred learning approaches, and facilitate the development of critical thinking, problem-solving, digital literacy and other 21st century skills essential for success today (Kokkinos, 2024). In the context of this study, revolutionizing education refers to the infusion of various technological tools, devices, applications and resources in pedagogy to enhance teaching, learning, and educational management (Mishra et al., 2023).

Tech-infused pedagogical innovations are simply new and improved teaching methods that use technology to make learning more effective, engaging, interactive and accessible to students. These innovations in pedagogy have revolutionize education since the onset of covid-19. Ebony et al (2026) note that tech-infused teaching is the use of technology to support and enhance teaching and learning. Here, technologies are selected that align with their pedagogical goals. Akpan (2024) stress that effective tech infusion must prioritize pedagogical use rather than merely adopting new gadgets for sake of novelty. Tech-infused innovations are the infusion of various forms of technology such as software apps, digital devices, online platforms (zoom, google meet), online assessment, podcast, AI, cloud storage, web, emails, online courses,

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educational videos (Itighise et al. 2023). They also include other technologies, such as mobile devices (computers, laptops, tablets, smartphones for extended learning opportunities beyond the walls of the traditional classrooms (Tanrisevdi et al., 2025). Interactive whiteboards -revolutionized the dynamics of teaching and learning, infusing classrooms with a new found sense of interactivity and engagement (Vasilopoulos et al., 2023). Educational software, internet resources, online learning platforms and learning management systems (moodle, multimedia contents, and communication tools (Akpan et al., 2025a). These support asynchronous learning where students could access course materials, lectures, and assignment at their own pace and convenience (Suryadi, 2025; Kokkinos, 2024). Others are adaptive learning technologies propelled by strides in artificial intelligence (AI) which personalize educational experiences, while augmented reality (AR), and virtual reality (VR) create immersive simulations, bringing abstract concepts to life enabling experiential learning (Mishra et al., 2023, Akpan & Udo, 2025). Virtual classrooms became common using videoconferencing platforms like Zoom, Microsoft Teams and Google meet. These platforms facilitate seamless group projects, discussions, and document sharing among students and teachers (Akpan et al., 2025b), transcending geographical boundaries, enabling synchronous or asynchronous collaborations, as well as teaching approaches like blended, simulation, flipped classroom (Umoetuk & Akpan, 2023). In Nigeria, STEM education faces challenges such as inadequate infrastructure, lack of resources for teaching, poor methods of teaching, outdated curricula, lack of qualified teachers (Kangiwa et al., 2024) and recently, technology integrated challenges such teachers' insufficient digital competence, inadequate technological infrastructure, resistance to pedagogical change and limited professional development support (Suryadi, 2025). Since teachers are the driving force in the realization of academic and national goals, they must brace up to the challenges and explore means and ways of being relevant in the face of knowledge explosion (Udo & Akpan, 2016) by revolutionizing STEM teaching and learning.

Integrated science, formerly Basic Science, and Basic Science and Technology, now Intermediate Science encapsulates inter-alia development of learning contents that will lead to the acquisition of functional knowledge, skills and competencies (FME, 2025). Teachers are expected to use technological tools and digital resources to support students learning, therefore their knowledge and competence regarding these resources are of vital importance (Akpan, et al., 2022). It was argued that technology infusion requires teachers to develop new competencies in digital literacy and pedagogical design, these abilities should align with the learning objectives and outcome, ensuring that technology enhances rather than distract students from learning (Suryadi, 2025). Tech-infused innovations in teaching and learning is multifaceted involving various components such as teachers' knowledge, attitude, perception, competences and utilization, therefore the knowledge of tech-infused innovations has become increasingly relevant in the modern-day teaching context. Samuel & Salisu (2025) noted that teachers who posed adequate knowledge in technology integration are more confident and capable in using these innovations to teach. Tanrisevdi, et al (2025) investigating the level of technological pedagogical content knowledge (TPACK) among science teachers found that they possessed low technology-based knowledge, as well as limited technologically related pedagogical knowledge and content awareness. Additionally, several studies Itighise et al., (2023); Samuel & Salihu (2025); Akpan et al., (2025a) have reported teachers' favourable perception towards technology and its integration into teaching and learning, but that do not necessarily translate into strong instructional technology practice. Adebayo (2015) study on awareness and utilization of ICT tools by mathematics lecturers, and students found that 80% of the lecturers knew ICT tools but did not use them due to inadequate skills in how to use the tools. Bashir and Muslim (2022) found that students' knowledge of Zoom technology was moderate and independent of students' gender. Okuonghae, et al (2019) revealed that undergraduates' knowledge and utilization of web 2.0 technologies for collaborative learning in universities is high, while Itighise et al (2023) found no significant difference in the perception of male and female science teacher trainees on their awareness and utilization of web 2.0 technology. Woonhee-Sung, et al (2023); Samuel & Salihu (2025) exploring college students' awareness of AI and ChatGPT observed that students had good knowledge of ChatGPT, and that lecturers were not utilizing the capabilities of AI and ChatGPT to the fullest potentials. According to Kangiwa et al, (2024) academic perception towards the use of Zoom technologies, found that students' usage of Zoom technology was low compared to instructional videos because instructional videos provided a flexible learning environment, unlike Zoom which needed real-time participation during learning. Teachers' perception of the use of YouTube for teaching and learning activities in Nigerian Schools was high, as it enhances effectiveness in finding relevant information about concepts and increases their productivity in the classroom within the shortest time frame (Ogirima, et

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al., 2021). As observed by Olumorin, et al (2022), students' perception of the use of Google Search and Google Classroom. was moderate. Akpan et al (2025c) noted that virtual technology had a positive effect on students' academic performance. Proficiency, refers to the level of competence and skills possess by teachers and students in using the various online technologies for effective academic, social and personal purposes. Albi-Oparaocha et al (2018) note that using global standards for effective learning and teaching in the 21st century to measure the competence of teachers in Nigeria especially in terms of technological skills showed that a significant number of teachers are not vast in knowledge and competence. (Akpan et al., 2024) observe that most teachers cannot effectively deploy the use of technology to achieve the objectives of education, and therefore lack the competence necessary in the present age. Etiubon et al (2018) study on socioeconomic empowerment senior secondary science students in Nigeria and teachers' competence to impart skills to learners as an indicator, the study showed that STEM teachers lacked the competencies and skills to empower students. DeVe et al (2020) and Akpan and Udo (2022) also confirmed that teachers lack competencies related to online instructional preparation, online platforms, interactive content and lack of competence in the critical skills of digital innovation. Akpan et al (2023), showed that science teachers had moderate awareness, but lacked the competence needed in innovation and digital technology, hence their utilization in science teaching is low. Atabang and Babayemi (2024) and Akpan et al (2025c) reported moderate levels of competence in integration of zoom and virtual technology in pedagogy for teaching Postgraduate students.

Statement of the Problem

The Nigerian classrooms have primarily followed a lecture-based model where teachers dominate knowledge delivery. Over the past decades, education systems have increasingly shifted towards technology-driven practices that emphasize flexibility, personalized and collaborative learning. The rapid advancement in digital technologies has greatly re-shaped global educational landscapes, compelling schools, teachers and policy makers to rethink traditional models. This transformation is further accelerated by the fourth industrial revolution which demand digital literacy, critical thinking and problem-solving skills as core competencies for learners. Consequently, tech-infused innovations in teaching and learning is no longer seen as optional. With the revolution in STEM classrooms, the question is, what is the assurance that these innovative technologies are pedagogically infused into Integrated Science lessons? Therefore, this study sought to investigate tech-infused pedagogical innovations and integrated science teaching and learning.

Purpose of the study

The study aims at investigating revolutionizing STEM education: Tech-infused pedagogical innovations for integrated science teaching and learning. Specifically, the study sought to;

1. Assess the extent of Integrated Science Pre-Service teachers' knowledge of tech-infused pedagogical innovations for revolutionizing STEM education.
2. Assess the extent of proficiency possessed by Integrated Science Pre-Service teachers in tech-infused pedagogical innovations for revolutionizing STEM education.
3. Find out the extent of Integrated Science Pre-Service teachers' utilization of tech-infused pedagogical innovations for revolutionizing STEM education.

Research Questions

1. What is the extent of Integrated Science Pre-Service teachers' knowledge of tech-infused pedagogical innovations for revolutionizing STEM education?
2. To what extent do Integrated Science Pre-Service teachers possess proficiency in tech-infused pedagogical innovations for revolutionizing STEM education?
3. What is the extent of Integrated Science Pre-Service teachers' utilization of tech-infused pedagogical innovation for revolutionizing STEM education?

Methodology

A descriptive survey design was used for the study to understand the opinion of respondents on the subject matter. The population of the study comprised 752 pre-service Integrated Science teachers from government-owned tertiary institutions in Akwa Ibom State offering the course. University of Uyo, Akwa Ibom State University, Akwa Ibom State College of Education and Federal College of Education met the condition. One hundred and eighty (180) pre-service Integrated Science teachers were selected for the study using a simple random sampling technique. The instrument for the study was

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a 32 item-questionnaire on 'Knowledge, Proficiency and Utilization of Tech-Infused Pedagogical Innovations in Revolutionizing STEM Education Questionnaire (KPUTPIRSEQ), used for data collection. The instrument was developed on a four-point Likert scale of Very High Extent (VHE), High Extent (HE), Moderate Extent (ME) and Low Extent (LE). The instrument underwent a series of validations by experts in Test and Measurement, and Science Education to ascertain the face, content, and construct validation. The instrument was trial tested on 25 respondents who were not used in the study, and a reliability coefficient of 0.77 was obtained using Cronbach Alpha coefficient. Soft or electronic copies, a Google form was developed, and the link was sent to the respondents during Zoom classes and WhatsApp class platforms, while hard copies of the instrument were distributed physically to respondents. The responses obtained were analysed using mean and standard deviation. To make decisions as regards research questions, whenever the cluster mean score falls between: 1.00-1.49, 1.50-2.49, 2.50-3.49 and 3.50-4.00, it was taken to indicate: Low Extent (LE), Moderate Extent (ME), High Extent (HE), Very High Extent (VHE).

Presentation of Results

The results of the analysis carried out on data collected for the study are presented in this section. The presentation was done in line with the research questions guiding the study.

Research Question One

What is the extent of Integrated Science Pre-Service teachers' knowledge of tech-infused pedagogical innovations for revolutionizing STEM education?

Table 1: Mean and standard deviation of the extent of integrated science pre-service science teachers' knowledge of tech-infused pedagogical innovations (n=180)

S/N	Knowledge of Tech-infused Pedagogical innovations	$\bar{x}$	SD	Remarks
1	Flipped classroom	1.96	0.71	ME
2	Blended learning	1.92	0.74	ME
3	Online Course/Materials			
a	Khan Academy	1.80	0.52	ME
b	U-lesson	1.72	0.77	ME
c	Coursera	1.28	0.68	LE
4	AI Tutor			
a	ChatGPT	3.09	0.72	HE
b	Khamingo	1.88	0.57	ME
c	Duolingo	1.38	0.88	LE
5	Virtual Laboratory Demonstration	1.40	0.72	LE
6	Augmented Reality (AR)			
	AR glasses for virtual field trip	1.17	0.59	LE
7	Collaborative Platforms			
a	zoom	2.70	0.97	HE
b	telegram	1.37	0.88	LE
Cluster Mean		1.81	0.74	ME

The result in Table 1 showed the mean range of response of pre-service Integrated Science teachers on their knowledge of tech-infused pedagogical innovations for items 3c, 4c, 5, 6a, 7b fall within 1.00 -1.49. This means there is a low extent of teachers' knowledge of Coursera online material, Duolingo AI instructor, virtual laboratory demonstration, Augmented Reality glasses for fieldtrip and telegram collaborative platform as tech-infused pedagogical innovations for revolutionizing STEM education. The result also showed that the mean range on the responses for items 1, 2, 3a, 3b and 4b fall within 1.50 – 2.49, meaning that there is a moderate extent of pre-service teachers' knowledge of flipped classroom, blended learning, Khan academy-online material, U-lesson online material, and khamingo – AI tutor tech-infused pedagogical innovation, while items 4a and 7a fall within 2.50 – 3.49, meaning there is a high extent of pre-service Integrated Science teachers' knowledge on the use of ChatGPT -AI tutor and zoom as a collaborative platform. The result in Table 1 also showed the standard deviation scores of the respondents ranged from 0.52 to 0.97, since the standard deviation scores are small, it means that the spread of the scores is not far apart. However, the cluster mean of 1.81 for all the items indicates

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that there is a moderate extent of pre-service Integrated Science teachers' knowledge of tech-infused pedagogical innovations for revolutionizing STEM education.

Research Question Two

What is the extent of Integrated Science Pre-Service teachers' proficiency in tech-infused pedagogical innovations for revolutionizing STEM education?

Table 2: Mean and standard deviation of the extent of integrated science pre-service teachers' proficiency in tech-infused pedagogical innovations (n=180)

S/N	Proficiency of tech-infused Pedagogical Innovations	$\bar{x}$	SD	Remarks
8.	I can access pre-recorded lecture before class session.	1.48	0.68	LE
9.	I learn STEM concepts independently using flipped classroom resources.	1.69	0.82	ME
10.	I have the proficiency to use digital platforms that support flipped classroom learning	1.46	0.56	LE
11.	I have the competence to participate in both virtual and physical class activities	1.38	0.88	LE
12.	I have the ability to navigate systems used in blended learning.	1.29	0.68	LE
13.	I have the competence to use online learning resources to improve STEM knowledge	1.72	0.77	ME
14.	I have the proficiency in using AI tools to explain different STEM concepts.	2.28	0.56	ME
15.	I possess the skills to apply AI tools in research and assignments	3.01	0.97	HE
16.	I can formulate effective prompts when interacting with AI tutor.	2.70	1.04	HE
17.	I have the competence to perform virtual experiments using virtual lab software.	1.40	0.72	LE
18.	I can interpret results generated from virtual lab activities.	1.17	0.59	LE
19.	I can follow laboratory procedure in a virtual environment	1.21	0.64	LE
20.	I have the skills to use AR glasses for virtual field trip	1.03	0.67	LE
21.	I can explain STEM related issues in environment using AR.	1.23	0.62	LE
22.	I have abilities to effectively participate in zoom-based classes	2.74	1.07	HE
23.	I can share educational resources using zoom and telegram	2.12	0.87	ME
24.	I have the capacity to collaborate with peers and teachers using online platforms.	2.84	0.79	HE
25.	I communicate effectively during virtual group discussions.	1.96	0.90	ME
Cluster Mean		1.82	0.77	ME

The result in Table 2 showed the mean range for the response of the pre-service Integrated Science teachers on the extent of their proficiency of tech-infused pedagogical innovations for revolutionizing STEM education for items 8,10, 11, 12, 17, 18,19, 20 and 21 fall within 1.00 – 1.49. This means that to a low extent, pre-service teachers have proficiency: to access pre-recorded lecture, use digital platform that support flipped classroom, to participate in both virtual and physical activities, to navigate systems in blended learning, to perform virtual experiment, interpret results from virtual lab activities, to use AR glasses for virtual field trip, to use AR to explain STEM related issues in the environment. The result also showed that the mean range for responses of the pre-service Integrated Science teachers' on items 9, 13, 14, 23 and 25 falls within 1.50 – 2.49, meaning that to a moderate extent pre-serve Integrated Science teachers have proficiency to: learn STEM concepts independently using flipped classroom, use online learning resources to improve STEM knowledge, in using AI

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tutor to explain STEM concepts, share educational resources using zoom and telegram and communicate effectively during group discussions. While results showed items 15, 16, 22 and 24 fall within the range of 2.50 – 3.49, meaning to a high extent, apply AI tools in research and assignments, formulate effective prompts when interacting with AI tutor, effectively participate in zoom-based classes and collaborate with peers and teachers using online platforms. The result in Table 3 also showed the standard deviation scores of the respondents which ranged from 0.56 to 1.04 and since the standard deviation scores are small, it means that the spread of the scores is not far apart. However, the cluster mean of 1.82 for all the items indicates that there is a moderate extent of pre-service science Integrated Science teachers' proficiency in tech-infused pedagogical innovations in revolutionizing STEM education.

Research Question Three

What is the extent of Integrated Science Pre-Service teachers' utilization of tech-infused pedagogical innovation for revolutionizing STEM education?

Table 3: Mean and standard deviation of the extent of Integrated Science Pre-Service teachers' utilization of tech-infused pedagogical innovations in revolutionizing STEM Education (n=180)

S/N	Utilization of tech-infused pedagogical innovations	$\bar{x}$	SD	Remarks
26	Flipped classroom	2.12	0.87	ME
27.	Blended learning	1.88	0.86	ME
28.	Online Courses/ Materials	1.95	0.85	ME
29	AI-Tutor	3.10	0.90	HE
30	Virtual Lab. Demonstrations	1.48	0.68	LE
31.	Augmented Reality	1.69	0.82	ME
32.	Collaborative Platforms	3.05	0.79	HE
	Cluster Mean	2.18	0.82	ME

The result in Table 3 showed the mean range for the response of pre-service Integrated Science teachers on the extent of their utilization of tech-infused pedagogical innovations in revolutionizing STEM education, item 30 falls within 1.00 - 1.49. This means that there is a low extent of pre-service Integrated science teachers' utilization of virtual laboratory demonstrations as tech-infused pedagogical innovation. The result also showed that the mean range for the responses of teachers for items 26, 27, 28, 31, which falls within 1.50 - 2.49 means that there is a moderate extent of pre-service Integrated Science teachers' utilization of flipped classroom, blended learning, online courses/material and augmented reality (AR)., while the responses for item 29 and 32 fall within 2.50 – 3.49, meaning that there is a high extent of Integrated Science pre-service teachers utilization of AI-tutor and collaborative platforms as tech-infused pedagogical innovations for revolutionizing STEM education.

Discussion of Findings

The findings of the extent of pre-service Integrated Science teachers' knowledge of tech-infused pedagogical innovations in revolutionizing STEM education revealed a moderate extent of teachers' knowledge of tech-infused pedagogical innovations in teaching and learning. This can be attributed to the fact that many students today are considered digital natives, meaning they grow up in a world where digital and internet resources are already established. The finding is contrary to the observation of Tanrisevdi et al (2025) and Kangiwa et al (2024), who noted that science teachers had low technological pedagogical-based knowledge of using ICT tools for teaching, in that case, how then can technology knowledge be imparted to the students? The finding lends credence to that of Woonhee-Sung, et al (2023); Bashir and Muslim (2022); Akpan et al (2025a) who observed that students had good knowledge of chatGPT, zoom technology and online platforms. This result can be attributed to the fact that students are considered. The findings of the extent of pre-service Integrated Science teachers' proficiency in tech-infused pedagogical innovations for revolutionizing STEM education revealed that there is a moderate extent of pre-service Integrated science teachers' proficiency in tech-infused innovation. The finding is contrary to the observation of Albi-Oparaocha (2018) who reported that teachers are not vast in competence and knowledge, as well as lack competence in innovations and digital technology (DeVera et al., 2020; Akpan et al., 2023), how then will the STEM classrooms be revolutionized? The finding lends credence to that of Atabang & Babayemi (2024) and Akpan et al (2025c) who observed that teachers in training had a moderate level of competence in integration of zoom and virtual technology in pedagogy for teaching.



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The findings on the extent of Integrated Science pre-service teachers' utilization of tech-infused pedagogical innovations for revolutionizing STEM education revealed a moderate extent of pre-service Integrated Science teachers' utilization of tech-infused pedagogical innovations. The finding is contrary to the observation of Adebayo (2015) who reported that despite the benefits derived from the use of ICTs in teaching and learning, their usage is still low as they are not yet embraced and utilize them for instructional purpose. The finding aligns with that of Okuonghae et al (2019); Ogirima et al (2021) whose findings revealed the level of undergraduates 'utilization of technologies for collaborative learning in universities are high and they have positive perceptions towards the use of the technology. This could be attributed to early exposure to digital resources, which translates to a natural familiarity and ease with using technology for various aspects of learning.

Conclusion

It took Covid-19 and lockdown to catalyze the rapid adoption of remote online technologies and new instructional approaches for teaching and learning. In conclusion, the study showed that Integrated Science Pre-service teachers exhibit a moderate extent of knowledge, proficiency and utilization of tech-infused pedagogical innovations for revolutionizing STEM education. Students view online learning resources as valuable assets in their educational pursuits and the integration of tech-based pedagogical innovation enrich learning experiences. It could be seen from the results that Integrated Science pre-service teachers are ready to embrace tech-infused pedagogical innovations, but face serious challenges in acquiring relevant skills because their teachers need more knowledge and proficiency on the use of digital technologies for teaching and learning.

Recommendations

Based on the findings and conclusion of the study, the following recommendations were made:

1. Institutions should provide necessary digital facilities and should encourage the lecturers to work remotely, using tech-based resources.
2. professional development programmes for lecturers (workshops, conferences,) should be encouraged and financially supported.
3. the government should fund tertiary institutions sufficiently, and non-governmental organizations and stakeholders should partner to provide interventions in tech-based resources in the classrooms for teachers and students to use practically.
4. The teacher education curriculum should be restructured such that pedagogical practices embrace the use of digital technologies, and provide opportunities for teachers to have appropriate knowledge and skills to meet the needs of their students.

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