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Empowering STEM Educators: Leveraging Digital Tools for Enhanced Teaching

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Abstract: **Integrating digital tools in STEM education can transform traditional teaching methods and provide enhanced learning experiences. This paper explores the significance of empowering STEM educators through the adoption and effective utilization of digital tools in teaching and learning STEM concepts. The study examines various digital resources, including interactive simulations, virtual labs, Google Classroom, virtual field trips, coding platforms, robotic and engineering kits, Mathematics learning tools, Game-based learning platforms, online learning platforms, and 3D modeling (DT), and their impact on teaching practices and students' engagement. By leveraging tools, STEM educators can create dynamic, immersive learning environments that foster critical thinking, problem-solving, and collaborative skills. This paper highlights best practices for integrating these technologies into curricula, addressing challenges such as digital literacy and access to resources. The findings from the literature suggest that when STEM educators are equipped with the appropriate digital tools and training, they are better positioned to inspire and motivate students, have access to global knowledge, increase students' engagement, and ultimately contribute to a more robust, dynamic, and innovative STEM education landscape.**

Keywords: **Digital Literacy, Digital tools, Empowering, Professional Development, STEM Educator, Students' engagement, Teaching Practices.**

1. INTRODUCTION

The importance of STEM (Science, Technology, Engineering, and Mathematics) education in preparing students for the rapidly evolving technological landscape and fostering innovation has been widely recognized (National Science Board, 2018). Traditional teaching methods that heavily rely on textbooks and lectures are often insufficient to engage and inspire today's digitally native students (Prensky, 2001). Researchers have emphasized the need to incorporate interactive, hands-on, and student-centered approaches that leverage digital tools to enhance STEM learning experiences (Huang et al., 2016).

The rapid pace of technological advancements and the constantly evolving digital landscape can make it difficult for educators to stay up-to-date and effectively leverage these tools in the classroom (Baran & Maskan, 2018). Moreover, a lack of professional development opportunities and training in the use of digital tools can hinder educators' ability to seamlessly integrate them into their lessons (Koh et al., 2019). Numerous studies have highlighted the potential benefits of incorporating digital tools in STEM education. The use of Augmented Reality (AR) technology has been shown to enhance students' understanding of abstract concepts and improve their motivation and engagement in science teaching (Koh et al., 2019). Digital simulations have also been found to foster a deeper understanding of complex concepts and improve problem-solving skills in subjects like physics (Baran & Maskan, 2018). Digital game-based learning has emerged as a promising

approach in STEM education, with research suggesting that well-designed educational games can foster students' engagement, motivation, collaboration, and the development of critical thinking and problem-solving skills (Qian & Clark, 2016). Additionally, the integration of computational thinking activities and coding exercises has been shown to enhance students' problem-solving abilities and prepare them for future STEM careers (Yadav et al., 2017).

However, the effective implementation of digital tools in STEM education requires addressing several key challenges. One primary challenge is the lack of adequate professional development opportunities and training for educators (Trust & Whalen, 2020). Many STEM teachers report feeling unprepared and lacking the necessary knowledge and skills to effectively integrate digital tools into their teaching practices (Tondeur et al., 2017). Another challenge is the limited availability of resources and technical support within educational institutions (Kopcha et al., 2020). Inadequate hardware (DT) and digital infrastructure can hinder the successful implementation of digital tools in STEM classrooms. Furthermore, the alignment of digital tool integration with curricula and learning objectives is often overlooked (Zhao et al., 2020; Koh et al., 2019). Effective integration requires careful planning and design to ensure digital tools are used purposefully and pedagogically, rather than as mere add-ons or gimmicks.

Integrating digital tools in STEM education has become necessary to prepare students for the demands of the 21st-century workforce. As stated by the U.S. Department of Education, "Educators must be given opportunities to develop skills for using technology to support student-centered teaching and learning" (U.S. Department of Education, 2017). Digital tools, such as interactive simulations, virtual reality applications, and online collaboration platforms, have the potential to create immersive and engaging learning experiences, fostering collaboration, critical thinking, and problem-solving skills (Hamari et al., 2016). To address these challenges, a comprehensive approach is required to empower STEM educators with the knowledge, skills, and resources needed to harness the potential of digital tools, which this study seeks to address.

STATEMENT OF THE PROBLEM

STEM (Science, Technology, Engineering, and Mathematics) education plays a crucial role in preparing students for the increasingly technology-driven and innovation-based global economy. However, many STEM educators face challenges in effectively integrating digital tools and technologies into their teaching practices. The rapid pace of technological advancements and the constantly evolving digital landscape can make it difficult for educators to stay up-to-date and leverage these tools effectively in the classroom. Traditional teaching methods, which often rely heavily on textbooks and lectures, may not be sufficient to engage and inspire today's digitally native students. Additionally, the lack of professional development opportunities and training in the use of digital tools can hinder educators' ability to incorporate them seamlessly into their lessons.

Empowering STEM educators with the necessary skills, knowledge, and resources to leverage digital tools effectively is essential for enhancing teaching and learning experiences. By embracing digital technologies, educators can create more interactive, engaging, and personalized learning environments that cater to diverse learning styles and enable students to develop critical 21st-century skills such as problem-solving, critical thinking, and collaboration. Addressing this issue requires a comprehensive approach that involves providing STEM educators with access to relevant professional development programs, fostering a culture of continuous learning and adaptation, and promoting the integration of digital tools across STEM curricula. By empowering educators with the necessary digital skills and resources, we can unlock the full potential of STEM education and better prepare students for the challenges and opportunities of the future. Therefore, this study investigates how empowering STEM educators through strategic use of digital tools can enhance their teaching and student learning outcomes.

PURPOSE OF THE STUDY

The purpose of the study is to examine how STEM educators are empowered through leveraging digital tools for enhanced teaching. Specifically, the study determined

1. The digital tools available for STEM teaching

2**:** The challenges encountered in using digital tools for STEM teaching

3**:** STEM teachers' perception of the effectiveness of digital tools

RESEARCH QUESTION

The following research questions were answered:

1**:** What are the Digital tools available for STEM teaching?

2**:** What are the challenges encountered in using digital tools for STEM teaching?

3**:** How do STEM teachers perceive the effectiveness of digital tools?

2. LITERATURE REVIEW

DIGITAL TOOLS AND STEM EDUCATION

The integration of digital tools in STEM education has been a topic of significant interest among researchers and educators alike. Several studies have highlighted the potential benefits of incorporating technology in the classroom and the challenges educators face in effectively implementing these tools.

A study by Koh et al. (2019) explored the use of augmented reality (AR) in science education. The researchers found that AR technology can enhance students' understanding of abstract concepts and improve their motivation and engagement in learning. However, they also noted that educators often lack the necessary training and support to effectively integrate AR into their teaching practices. Similarly, a study by Baran and Maskan (2018) investigated the use of digital simulations in physics education. Their findings suggested that simulations can help students develop a deeper understanding of complex concepts and improve their problem-solving skills. However, they emphasized the need for professional development programs to equip educators with the knowledge and skills required to effectively utilize these digital tools. In addition to subject-specific applications, researchers have also explored the use of digital tools for fostering computational thinking and coding skills among STEM students. A study by Yadav et al. (2017) examined the integration of computational thinking activities in K-12 education and found that these activities can enhance students' problem-solving abilities and prepare them for future STEM careers. However, they noted that educators often lack the necessary knowledge and confidence to effectively teach computational thinking concepts

PROFESSIONAL DEVELOPMENT FOR STEM EDUCATORS

Effective professional development [PD] is crucial for STEM educators to integrate digital tools into their teaching practices. Darling-Hammond et al. (2017) define effective PD as structured professional learning that results in changes to teacher practices and an improvement in student learning outcomes. The professional development program is a continuous process that begins when a teacher enters teaching service. It includes building digital literacy, pedagogical skills, and content knowledge that can help STEM teachers adopt and utilize innovative and effective ideas to improve their teaching skills. It can also help them to learn new tools that can enhance their teaching and keep them up to date with the demands of 21st-century skills. Studies have shown that ongoing, collaborative, and practice-based professional development is most effective in helping educators adopt and utilize digital tools. Professional development programs a STEM teacher can take/participate in can be in the form of conferences, seminars, periodic workshops, and in-class observation by peers, mentors, and regulatory bodies.

Professional development is crucial for enhancing STEM teachers' content knowledge, pedagogical skills, and ability to engage students effectively in these critical fields. Research has identified several key features of effective professional development programs for STEM teachers, which include the following:

Content Focus: Effective professional development should have a strong emphasis on deepening teachers' understanding of the specific STEM content they teach (Loucks-Horsley et al., 2003). This content-focused approach helps teachers develop a better grasp of the subject matter, which in turn improves their instructional practices and ability to address students' misconceptions (Banilower et al., 2018).

Active Learning: Engaging STEM teachers in active learning experiences, such as hands-on activities, inquiry-based investigations, and collaborative problem-solving, is more effective than traditional lecture-based approaches (Garet et al., 2001). Active learning opportunities allow teachers to experience the same instructional strategies they are expected to implement in their classrooms, fostering a deeper understanding of the content and pedagogical approaches. Coherence and Relevance: Professional development programs should align with STEM teachers' goals, needs, and the curricular standards

they are expected to teach (Loucks-Horsley et al., 2003). This coherence ensures that professional development is relevant and applicable to teachers' daily classroom practices, increasing the likelihood of successful implementation (Nadelson et al., 2013).

Sustained Duration: One-time workshops or short-term professional development programs are generally less effective than sustained, long-term initiatives that provide ongoing support and follow-up (Banilower et al., 2018). Sustained professional development allows for deeper engagement with the content, opportunities for reflection and feedback, and the development of a collaborative learning community among STEM teachers (Bybee, 2013). Collaboration and Communities of Practice: Effective professional development programs foster collaboration among STEM teachers, encouraging the formation of professional learning communities (PLCs) or communities of practice (Bybee, 2013; Nadelson et al., 2013). These collaborative networks enable teachers to share resources, discuss challenges, and engage in ongoing learning and support, leading to improved instructional practices and student outcomes.

Integrative Approaches: Given the interdisciplinary nature of STEM education, professional development programs that integrate multiple STEM disciplines and promote cross-curricular connections are increasingly valued (Nadelson et al., 2013). These integrative approaches help STEM teachers develop a more holistic understanding of the subject matter and pedagogical strategies, enhancing their ability to engage students in authentic, real-world problem-solving.

BENEFITS OF USING DIGITAL TOOLS IN TEACHING AND LEARNING OF STEM

The integration of digital tools in STEM education has gained significant attention in recent years, as these tools offer new opportunities for enhancing teaching and learning experiences. Research has explored the potential benefits and challenges associated with the use of digital tools in STEM classrooms. Some of its benefits are: Visualizing Abstract Concepts: Digital simulations, virtual reality, and interactive multimedia tools can help students visualize and comprehend abstract or complex STEM concepts more effectively (Potkonjak et al., 2016).

Engaging and Motivating Students: Digital tools can increase students' engagement and motivation by providing interactive, hands-on learning experiences and aligning with students' digital preferences (Baran & Maskan, 2018). Facilitating Inquiry-Based Learning: Digital tools can support inquiry-based learning approaches by enabling students to conduct virtual experiments, collect and analyze data, and engage in scientific inquiry processes (Hwang et al., 2015). Promoting Collaboration and Communication: Online collaborative tools, such as wikis, discussion forums, and shared workspaces, can facilitate communication and collaboration among students and between students and teachers (Lan et al., 2015).

Providing Personalized and Adaptive Learning: Adaptive learning technologies can tailor instructional content and pace to individual student needs, providing personalized learning experiences (Pane et al., 2017; Walkington & Bernacki, 2020).

CHALLENGES FOR IMPLEMENTING DIGITAL TOOLS

The integration of digital tools and technologies in the classroom has become increasingly prevalent in recent years, offering new opportunities for enhancing teaching and learning. However, research has identified several challenges that educators and institutions face when implementing digital tools in educational settings. Teacher Professional Development and Training: One of the most significant challenges is the need for adequate professional development and training for teachers to effectively use digital tools (Ertmer & Ottenbreit-Leftwich, 2010). Many teachers may lack the necessary technical skills or pedagogical knowledge to integrate these tools seamlessly into their teaching practices (Inan & Lowther, 2010). Access to Technology and Infrastructure: Disparities in access to digital devices, reliable internet connectivity, and adequate technological infrastructure can create barriers to the effective implementation of digital tools (Hohlfeld et al., 2017). This digital divide can exacerbate existing educational inequalities, particularly in underfunded schools or communities with limited resources.

Technical Support and Maintenance: Implementing digital tools often requires ongoing technical support and maintenance (Kopcha, 2012). Schools or institutions may lack the necessary resources or personnel to provide adequate technical assistance, which can lead to frustration and underutilization of the available tools. Resistance to Change and Pedagogical Beliefs: Some teachers may resist the integration of digital tools due to personal beliefs, comfort levels, or a perceived lack of alignment with traditional teaching methods (Ertmer & Ottenbreit-Leftwich, 2010; Howard, 2013). Overcoming this resistance and fostering a culture of innovation and adaptability can be challenging. Curriculum Integration and Alignment:

Integrating digital tools into existing curricula and aligning them with learning objectives and assessment strategies can be a complex process (Hutchison & Woodward, 2018). Educators may need guidance and support in designing effective learning experiences that leverage the potential of digital tools. Classroom Management and Student Engagement: Implementing digital tools may require new classroom management strategies and techniques to ensure student engagement and prevent distractions or misuse (Heflin et al., 2017). Teachers may need to adapt their pedagogical practices to maintain a productive and focused learning environment. Data Privacy and Security Concerns: The use of digital tools often raises concerns about data privacy, security, and online safety (Hohlfeld et al., 2017; Lindberg et al., 2017). Institutions must address these concerns and implement appropriate policies and safeguards to protect students' data and ensure responsible use of digital tools.

3. METHODOLOGY

The study employed a descriptive survey research design. The research was conducted with STEM teachers in Oyo State at Emmanuel Alayande University of Education. The population for this study included STEM teachers in the university where digital tools are integral to teaching and learning. The sample size comprised 85 respondents, all of whom were Faculty members. Purposive sampling was used to select all the STEM teachers. A structured questionnaire was used as the primary data collection instrument. The questionnaire included items assessing the availability of various digital tools, challenges associated with their use, and perceptions of their effectiveness in engineering drawing education. Responses were measured on a four-point Likert scale (Strongly Agree, Agree, Disagree, Strongly Disagree) for most items, with some questions using a binary (Available, Not Available) format. The questionnaire was administered to the participants. Data analysis involved calculating percentages for each response category across the various items. The results were presented in tabular format, showing the distribution of responses for each question. Ethical guidelines for educational research were followed, including obtaining informed consent from participants and ensuring confidentiality of responses.

4. RESULT

RESEARCH QUESTION 1: WHAT ARE THE DIGITAL TOOLS CURRENTLY AVAILABLE FOR STEM TEACHING AND LEARNING?

Table 1: Digital tools currently available for STEM teaching and learning

S/N	Items	Available (A)	Not-Available (NA)
1	Google Classroom	90.5	9.5
2	Canva	32.3	67.7
3	Online learning platforms	55.5	44.5
4	Game-based learning platforms	21.0	79.0
5	Robotic Platforms	2.0	98.0
6	Coding Platforms	1.0	99.0
7	Creo Parametric	1.5	98.5
8	Virtual field trip	2.5	97.5
9	Interactive Simulation	90.5	9.5
10	Virtual Laboratory	32.3	67.7

The table presents data on the availability of various educational technology tools and platforms (N = 10). The data is presented as percentages, with "Available (A)" and "Not Available (NA)" columns for each item. Google Classroom and Interactive Simulation show the highest availability at 90.5% each, indicating widespread adoption of these tools. Online learning platforms are available in more than half of the cases (55.5%). Canva and Virtual Laboratory have moderate availability, both at 32.3%. Game-based learning platforms are less common, with only 21% availability. The remaining items show very low availability: Virtual field trips (2.5%), Robotic Platforms (2.0%), Creo Parametric (1.5%), and Coding Platforms (1.0%). These findings suggest a significant disparity in the adoption of different educational technologies. While some tools like Google Classroom and Interactive Simulation are widely available, others, particularly those related to more advanced technologies like robotics and coding, are rarely accessible.

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RESEARCH QUESTION 2: WHAT ARE THE CHALLENGES ENCOUNTERED IN USING DIGITAL TOOLS FOR STEM TEACHING?

Table 2: Challenges encountered in using digital tools for STEM teaching

S/N	Item Statement	SA(%)	A(%)	D(%)	SD(%)
1	Lack of adequate training on the use of the digital tools	1.5	18.0	0.5	80.0
2	Digital tools compatibility issues	70.5	28.0	1.5	0.0
3	Insufficient technical support	73.0	25.0	2.0	0.0
4	Limited access to digital tools licenses	70.5	29.0	0.5	0.0
5	Complex user interface	64.0	32.5	3.5	0.0
6	Keeping up with new digital tools updates with the challenge of learning and adapting to the changes	71.5	27.5	1.0	0.0
7	Time constraints between balancing the usage of digital tools with other digital tools emic and extracurricular activities	72.0	27.0	1.0	0.0
8	Hardware requirements/specifications to run Digital tools smoothly	74.0	25.0	1.0	0.0
9	File compatibility issues between different digital tools programs or versions	70.0	29.5	0.5	0.0
10	Lack of helpful feedback from lecturers or instructors	72.0	26.0	2.0	0.0

Hardware requirements for the smooth operation of digital tools received the highest level of strong agreement (74.0% SA), followed closely by insufficient technical support (73.0% SA). Time constraints in balancing digital tool usage with other activities and lack of helpful feedback from instructors both garnered 72.0% strong agreement. The majority of respondents strongly agreed with all statements except for "Lack of adequate training on the use of the digital tools" (1.5% SA, 18.0% A). Notably, this item also had the highest level of strong disagreement (80.0% SD), suggesting a divergent view on this challenge. The complex user interface had the lowest level of strong agreement (64.0% SA) among the challenges, though it still represented a majority view. File compatibility issues, digital tools compatibility issues, and limited access to digital tool licenses all showed similar levels of strong agreement (70.0% - 70.5% SA). Disagreement levels were generally low across all items, with the highest disagreement being for complex user interfaces (3.5% D). Most items showed no strong disagreement, with only "Lack of adequate training" and "Digital tools compatibility issues" having any responses in the SD category (80.0% and 0.5% respectively). These findings suggest that while users face multiple challenges with digital tools in education, hardware requirements, technical support, time management, and instructor feedback are perceived as the most significant issues. The table also indicates a strong consensus on most challenges, with the notable exception of training adequacy.

RESEARCH QUESTION 3: HOW DO STEM TEACHERS PERCEIVE THE EFFECTIVENESS OF DIGITAL TOOLS?

Table 3: STEM teachers perceive the effectiveness of digital tools

S/N	**Item Statement**	**SA%**	**A%**	**D%**	**SD%**
1	Digital tools are very effective in enhancing learning outcomes in engineering drawing	73.0	26.5	0.5	0.0
2	Digital tools improve the accuracy of drawings	64.0	36.0	0.0	0.0
3	Digital tools present a better visualization of designs	72.0	28.0	0.0	0.0
4	Schools need to establish a dedicated digital tools (DT) lab	68.5	29.0	1.5	1.0
5	Digital tools can be intimidating or overwhelming due to their complexity,	73.0	26.5	0.5	0.0
6	Digital tools are essential for future career prospects	66.0	34.0	0.0	0.0
7	Digital tools encourage peer-to-peer learning and collaboration among students using them	66.5	32.0	1.0	0.5
8	Digital tools foster teamwork	64.5	32.5	2.5	0.5
9	Digital tools present faster drafting designs	69.5	30.0	0.5	0.0
10	Digital Tools workshops and competitions are regularly held to engage students, foster a competitive spirit, and encourage continuous learning and improvement	74.5	24.5	1.0	0.0

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The data presented in Table 1 illustrates perceptions regarding the use of digital tools. Results indicate an overwhelmingly positive perception of digital tools in STEM. For all statements, the combined percentage of SA and A responses exceeded 95%, suggesting a strong consensus on the value and impact of these tools. The highest level of strong agreement (74.5% SA) was observed for the statement advocating regular DT workshops and competitions to engage students and foster continuous learning. Interestingly, respondents strongly agreed at the same rate (73.0% SA) that digital tools are both "very effective in enhancing learning outcomes" and "can be intimidating or overwhelming due to their complexity. The data also reveals strong agreement on the improved visualization (72.0% SA) and accuracy (64.0% SA) afforded by digital tools in engineering drawing. The career relevance of digital tools was strongly affirmed, with 66.0% strongly agreeing that they are essential for future career prospects. This perception aligns with industry trends emphasizing digital competencies in engineering professions. Collaborative aspects of digital tools were also positively viewed, with strong agreement that they encourage peer-to-peer learning (66.5% SA) and foster teamwork (64.5% SA). However, these items showed slightly higher disagreement rates compared to others, suggesting potential areas for further investigation. The need for dedicated digital tools labs in schools received strong support (68.5% SA), indicating recognition of the importance of appropriate infrastructure for the effective implementation of these technologies. Notably, disagreement levels were generally very low across all items, with the highest being only 2.5% for fostering teamwork. Most items showed no strong disagreement (SD = 0%), with the highest being only 1.0% for the need to establish dedicated DT labs. These findings suggest a robust consensus on the positive impact of digital tools in engineering drawing education. However, the acknowledged complexity of these tools implies a need for comprehensive training and support systems to ensure their effective integration into educational contexts.

5. DISCUSSION OF FINDINGS

The high availability of basic tools like Google Classroom (90.5%) compared to advanced technologies like robotics (2%) and coding platforms (1%) reflects a trend observed by Vongkulluksn et al. (2018). They noted that while basic educational technology has become widespread, more sophisticated STEM-specific tools remain less accessible, particularly in resource-constrained environments. This disparity echoes concerns raised by Reich et al. (2020) about the "second digital divide" in education. While the first divide concerns access to basic technology, the second relates to access to more advanced, subject-specific tools that can significantly enhance STEM learning experiences. The primary challenges of hardware requirements (74% strong agreement) and insufficient technical support (73%) align with findings by Ifinedo et al. (2020). Their study emphasized the critical role of school-level infrastructure and technical support in the successful integration of educational technology. The challenge of time constraints (72% strong agreement) is a recurring theme in educational technology adoption. Francom (2020) highlighted how the time required to learn and implement new technologies can be a significant barrier for educators, often outweighing perceived benefits. Interestingly, the study found that lack of training was not perceived as a major issue, contrasting with much of the existing literature. For instance, Spiteri and Rundgren (2020) emphasized the importance of teacher training in educational technology. This discrepancy might suggest a need for further investigation into the quality and nature of training provided in the study's context. The strong agreement (73%) that digital tools enhance learning outcomes in engineering drawing is consistent with findings by Radloff and Guzey (2016). Their work demonstrated how digital tools, particularly in engineering education, can significantly improve spatial visualization skills and overall learning outcomes. The perception that digital tools are essential for future career prospects (66% strong agreement) aligns with industry trends and research by Xie et al. (2019). They emphasized the growing importance of digital competencies in STEM careers and the role of educational technology in preparing students for the future workforce. This aligns with research by Bates and Almekdash (2020), who highlighted how digital tools can facilitate collaborative problem-solving and project-based learning in STEM subjects. Heinonen et al. (2019) noted this duality, emphasizing the need for scaffolder approaches to introducing complex digital tools in STEM education.

6. CONCLUSION

The research paints a complex picture of digital tool usage in STEM education. While basic collaborative and simulation tools are widely available, there's a significant gap in access to advanced technologies. Educators largely feel capable of using these tools and strongly believe in their effectiveness in enhancing learning outcomes, improving accuracy, and providing better visualization in areas like engineering drawing.

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7. RECOMMENDATIONS

1. Schools should prioritize establishing dedicated digital tools labs and ensuring adequate hardware to meet the requirements of various STEM software.
2. Institutions should bolster their technical support systems to assist educators in troubleshooting and effectively using digital tools.
3. Develop and implement strategies to help educators balance the use of digital tools with other academic and extracurricular activities.
4. Organize frequent digital tools workshops and competitions to engage students, foster a competitive spirit, and encourage continuous learning.
5. Implement peer-to-peer learning initiatives to leverage the collaborative potential of digital tools and address the complexity challenge.

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