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Technological Pedagogical and Content Knowledge (TPACK) Abilities of Early Childhood Education Teachers in Digital-Based Learning

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Abstract
The digital era has significantly transformed the educational landscape, including at the Early Childhood Education (*Pendidikan Anak Usia Dini*/*PAUD*) level, where teachers are expected to master content, pedagogy, and technology integration. However, many PAUD teachers still face challenges in effectively combining these three aspects in their teaching practices. This study aims to describe the Technological Pedagogical and Content Knowledge (TPACK) competency level of PAUD teachers in digital-based learning. Using a quantitative descriptive approach, the study involved six teachers from three *Raudhatul Athfal* (RA, Islamic early childhood education institutions) in *Butuh* District, *Purworejo* Regency. Data were collected through observation and documentation using instruments that covered seven TPACK dimensions: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and the comprehensive TPACK. The findings revealed that the overall TPACK mastery of PAUD teachers was in the good category, with an average score of 84.44%. The highest-scoring dimension was the integrated TPACK, while the lowest was PCK, indicating a need for improvement in objectively assessing children's learning processes and outcomes. These results highlight the ability of RA teachers to integrate technology, pedagogy, and content in digital-based learning and underscore the importance of continuous training and mentoring to enhance their TPACK competencies in meeting the demands of 21st-century education.

Keywords: technological pedagogical and content knowledge (TPACK), early childhood education teachers, digital-based learning

INTRODUCTION

The development of information and communication technology in the current digital era has brought significant changes in various aspects of life, including in the world of education. Early Childhood Education (*Pendidikan Anak Usia Dini*/*PAUD*) is an important phase in children's development, where the foundation of early knowledge and skills is formed (Latief, 2020). According to the Central Statistics Agency (*Badan Pusat Statistik/BPS*) in 2021, around 30% of children aged 0-6 years in Indonesia are enrolled in the PAUD program (BPS, 2022). In this phase, teachers have a strategic role as the main facilitator in creating a learning experience that is meaningful, fun, and appropriate to the child's developmental stage (Faradina et al., 2025). Early childhood education teachers are no longer enough to rely only on conventional teaching skills but also need the ability to integrate technology appropriately in pedagogic practices and mastery of relevant content (Ristiani et al., 2024). The digital alternative in early childhood education is the shift from printed to digital learning materials. Where teachers once relied on physical books and magazines, they can now access a wide range of resources online. This shift highlights the importance of TPACK, enabling teachers to thoughtfully integrate technology to support age-appropriate and engaging learning experiences (Aini et al., 2021). Therefore, the role of teachers in integrating technology in the learning process is very crucial and the ability to develop learning activities that combine simple technology, teaching strategies that are in accordance with children's development, and contextual materials in a balanced manner is essential for achieving effective learning outcomes.

One comprehensive framework that supports this integration is the Technological Pedagogical and Content Knowledge (TPACK) model. It emphasizes the interplay between three core components: content knowledge, pedagogical knowledge, and technological knowledge (Harris et al., 2009; Herring et al., 2016) The application of TPACK in early childhood education not only enhances teaching effectiveness but also helps children adapt to a digitally-driven environment.

Despite widespread access to digital tools, many PAUD teachers continue to face obstacles in implementing technology within their classrooms. A 2022 survey by the Ministry of Education and Culture found that only 40% of PAUD teachers reported confidence in using technology for learning purposes (Kemendikbudristek, 2022). Observations conducted in several *Raudhatul Athfal* (RA) institutions in *Butuh* District, *Purworejo*, indicate that technology is often limited to administrative use or passive media consumption, such as playing videos. The challenges teachers face include insufficient training, low digital literacy, and an adherence to conventional teaching approaches.

Several previous studies in Indonesia have highlighted the importance of mastery of TPACK in the context of education, namely research conducted by Rahmadi (2019) entitled "Technological pedagogical content knowledge (TPACK): a 21st century teacher knowledge framework" showing that the mastery of TPACK among teachers can be used as a framework to design a teacher education curriculum that is more in line with the era and demands of 21st century learning. This study highlighted that strong TPACK competencies improve teachers' ability to use technology to support student engagement. Similarly, research entitled "The Influence of Technological Pedagogical Content Knowledge (TPACK) Competency on Teachers' Skills in Implementing Digital-Based Learning", demonstrated that increased TPACK competencies enhance digital learning skills among teachers (Silvester et al., 2024).

Finally, research conducted by Lim et al. (2024), shows that technology integration courses in early childhood teacher education are able to increase the positive attitude of prospective teachers (preservice teachers (PST) towards the use of educational technology and their understanding of technology-based pedagogy. This study highlights the importance of developing a curriculum that supports the integration of TPACK from the beginning of teacher education, as well as encouraging innovative approaches such as technology-based teacher-apprenticeship placement to address the digital divide that still exists in many early childhood education contexts (Lim et al., 2024). Based on previous research that has been presented, it has been shown that TPACK plays an important role in improving the quality of learning, teachers' skills in managing technology, and supporting the achievement of more relevant and contextual learning in the digital era.

There are several studies that discuss TPACK, but there are still few that explore how to analyze the level of TPACK mastery by PAUD teachers. The level of mastery of TPACK by early childhood education teachers should include a deep understanding of how technology can be used to support effective learning. For example, the use of interactive learning apps can increase child engagement and facilitate more enjoyable learning. However, a research gap remains in understanding how well PAUD teachers. Without strong pedagogical knowledge, the use of such technology may not achieve the expected results. The purpose of this article is to analyze the mastery of TPACK of PAUD teachers in digital-based learning. This research aims to identify the extent to which PAUD teachers understand and apply TPACK in their learning practices, as well as the challenges faced in technology integration. Thus, this article is expected to provide a deeper insight into the importance of mastery of TPACK for PAUD teachers and its contribution to improving the quality of education in the digital era. In addition, the results of this research are expected to be a reference for the development of training programs and the improvement of teacher competencies in facing learning challenges in the digital era. By understanding and implementing TPACK effectively, it is hoped that PAUD teachers can create a learning environment that is more innovative and responsive to children's needs, as well as prepare them to face future challenges.

METHOD

This study adopts a quantitative descriptive research design, which aims to systematically and objectively describe the level of mastery of Technological Pedagogical and Content Knowledge (TPACK) among *Raudhatul Athfal* (RA) teachers in digital-based learning. This design is appropriate for the research objective as it allows for the measurement and analysis of variables as they naturally occur, without manipulation or experimental intervention. The descriptive nature of this design enables the researcher to identify trends and patterns in TPACK mastery, which is essential for understanding the current competency landscape among RA teachers in the field (Ibrahim et al., 2023).

The study utilized purposive sampling, a non-probability sampling technique where participants are selected based on predefined criteria relevant to the research objectives (Sugiyono, 2013). This approach was chosen to ensure the inclusion of respondents who meet the specific qualifications necessary for the study. The sample consisted of six teachers from three RA institutions located in the western region of *Butuh* District. The inclusion criteria required participants to hold a bachelor's degree in early childhood education (*Sarjana Pendidikan/S.Pd.*), ensuring that they possess foundational pedagogical competencies aligned with the implementation of TPACK in digital learning environments.

The research instrument was a structured questionnaire developed based on the TPACK framework introduced by Mishra & Koehler (2006), which encompasses seven interrelated components. Each dimension was measured through multiple statements, rated using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), designed to capture the level of teachers' perceived mastery in each TPACK domain. The questionnaire items were adapted and refined from prior validated TPACK instruments (Schmidt et al., 2009), and subjected to expert review by educational technology and early childhood education specialists to ensure content validity. A pilot study was conducted with a small group of RA teachers (not included in the main sample) to test item clarity, reliability, and internal consistency. Based on the pilot results, several items were revised for better readability and alignment with the local teaching context.

The final questionnaire is managed through Google Forms to facilitate accessibility and efficiency. Quantitative data obtained through questionnaires were analyzed using descriptive statistical techniques with the help of Microsoft Excel and SPSS software. The analysis aims to identify the level of TPACK mastery in seven dimensions by calculating (1) Average score (M) for each dimension (2) Percentage score representing the proportion of mastery. The average score was calculated from participants' responses on a five-point Likert scale (1 = Strongly Agree to 5 = Strongly Agree). These scores are then classified into mastery levels using the intervals shown in Table 1.

Table 1. Mean Interval Value

Interval	Value
4.21-5.00	Very Able
3.41-4.20	Able
2.61-3.40	Doubtful
1.81-2.60	Unable
1.00-1.80	Very Unable

This classification helps identify the extent of teachers' self-reported competence in each TPACK component. To provide an alternative interpretation and support the mean-based findings, the total score obtained from each respondent was converted into a percentage using the following formula.

$$Persentage = \frac{Score\ Obtained}{Maximum\ Score} x100\%$$

Where (1) Obtained Score is total score accumulated by the respondent (2) Maximum Score = Highest possible score for the questionnaire (number of items × 5). These percentage values were interpreted using the categories shown in Table 2.

Table 2. Percentage Values and Category

Presentage Value	Category
84-100	Very Good
68-83	Good
52-67	Fair
36-51	Low
20-35	Very Low

The use of both values and percentage classifications strengthens the analysis by offering two complementary perspectives: central tendency and proportional understanding of TPACK mastery levels.

FINDINGS AND DISCUSSION

Findings

In general, the observed teachers showed enthusiasm for the use of technology in learning. However, mastery of each dimension of TPACK is not evenly distributed. In addition, there are still teachers who tend to use technology only as a presentation tool, which has not been optimally utilized to increase active student engagement. In terms of planning, there is a variety of lesson plan quality that integrates content, pedagogy, and technology. The findings of the research will be presented in the following sub-chapters:

Technological Knowledge (TK)

The Technological Knowledge Dimension (TK) reflects the ability of teachers to operate and utilize technological devices and applications to support the learning process (Budiarti, 2024). Based on the results of the analysis of six RA teachers in *Butuh* Regency, an average score of 78% was obtained which was included in the "Good" category. Further details based on item-level analysis are summarized in Table 3.

Table 3. Mean Score of Kindergarten Mastery

Component TK	Mean	Category
Utilize websites such as *YouTube*, *Zoom*, *WhatsApp*, and some educational games to support learning that is appropriate for early childhood.	4.34	Very Able
Have good technical skills in operating technological devices for learning.	3.67	Able
Understand and master new technologies to be used in the teaching and learning process.	3.83	Able
Combining learning activity materials with the use of the internet to make learning activities more interesting.	3.67	Able
Use conferencing *software* such as *Zoom* or *Google Meet* in learning.	4.00	Able

Teachers showed the highest proficiency in using digital platforms (M = 4.34), mainly YouTube and WhatsApp, while slightly lower scores were observed in technical operations and content integration (M = 3.67). This shows that although teachers are accustomed to basic digital tools, the creative integration of technology into early childhood learning remains an area for improvement.

Moreover, while digital tools can enhance learning engagement when used effectively, they must be applied appropriately in the context of early childhood education. According to Ridanti & Suryana (2024) excessive exposure to screens can negatively affect children's cognitive and emotional development. Therefore, the emphasis should be on balanced and age-appropriate technology use, supported by continuous, practice-oriented professional development for PAUD teachers.

Pedagogical Knowledge (PK)

The Pedagogical Knowledge (PK) dimension reflects the teacher's understanding of learning strategies, approaches, and methods that are in accordance with the characteristics of early childhood. In this study, the PK dimension was analyzed through

a number of indicators that include the ability to design, manage, and evaluate learning. Based on the results of the analysis of six RA teachers in *Butuh* District, an average score of 80.83% was obtained, which was included in the "Good" category. Further analysis of item responses is shown in Table 4.

Table 4. Mean PK Mastery Score

PK Mastery	Mean	Category
Guiding students to learn independently.	4.00	Able
Designing effective independent and group play activities for students.	4.16	Able
Choose a suitable learning theme for independent and group play activities	4.16	Able
Provide differentiated learning strategies that are appropriate to the characteristics of early childhood.	3.83	Able

All indicators fell within the "Able" category. The highest mean scores were observed in designing thematic and engaging learning activities (M = 4.16), suggesting strength in lesson planning aligned with early childhood learning needs. The lowest score appeared in the area of differentiated instruction (M = 3.83), indicating room for growth in tailoring strategies for individual learning differences.

According to (Azro'I et al., 2024), learning strategies in early childhood must include differentiation not only in content but also in assessment, particularly in cognitive and socio-emotional development. Inclusive teaching practices are crucial to ensure that all children regardless of their background, pace, or learning style receive meaningful and developmentally appropriate instruction. As such, teacher development programs should not only focus on general pedagogy but also on differentiated learning, inclusive classroom strategies, and the use of ongoing developmental assessments, especially in the context of PAUD.

Content Knowledge (CK)

The Content Knowledge (CK) dimension describes the level of teachers' mastery of teaching materials that are relevant to the world of early childhood (Silvester et al., 2024). This includes understanding aspects of child development, thematic learning concepts, and skills in delivering material that is in accordance with the needs and age of students. Based on the results of the analysis of six RA teachers in *Butuh* District, an average score of 72.5% was obtained, which was in the "Good" category. Further analysis of item responses is shown in Table 5.

Table 5. CK Mastery Mean Score

CK Mastery	Mean	Category
Have a strategy to improve students' understanding of play activity materials.	4.00	Able
Use a variety of ways to understand advanced learning topics.	3.52	Able
Focus on exploring the material of learning activities like an expert in their field.	3.00	Skeptical
Mastering well the learning activity material that I teach.	4.00	Able

The findings suggest that most RA teachers in *Butuh* District demonstrate sufficient understanding of early childhood content, particularly in delivering themes relevant to the child's world such as environment, self, and family. However, the lower score on expert-level content focus indicates limited confidence in deep subject mastery.

The lack of high confidence in CK may be due to limited training or resource access, as also found by Hapidin et al. (2018), where PAUD teachers struggled to design contextual materials aligned with an integrative thematic curriculum (Hapidin et al., 2018). Variations in teacher performance could relate to factors such as teaching experience, academic qualifications, or participation in training programs. Strengthening teachers' exposure to structured modules, expert mentorship, and collaborative planning may enhance content depth in PAUD classrooms.

Technological Pedagogical Knowledge (TPK)

The Technological Pedagogical Knowledge (TPK) dimension measures teachers' ability to integrate technology into learning strategies that are in accordance with pedagogic approaches for early childhood (Murtafiah et al., 2022). This dimension is key in ensuring that the use of technology is not only technical, but also supports the achievement of learning objectives effectively and enjoyably. Based on the results of the analysis of six RA teachers in *Butuh* District, an average score of 79.17% was obtained, which was in the "Good" category. Further analysis of the indicator-level responses is presented in Table 6.

Table 6. Mean Score of TPK Mastery

TPK Mastery	Mean	Category
Using computer applications to support learning.	3.83	Able
Be careful in choosing the right technology for students.	4.17	Able
Choose different technologies according to the type of learning activity.	3.83	Able
Leveraging technology to support student group discussions.	4.00	Able

Early childhood education teachers began to consider pedagogical suitability in choosing technology, not just the availability of tools. However, there are still limitations in the adaptation of technology in various learning contexts. The mastery of TPK is still partial, so it is necessary to strengthen pedagogical thinking flexibly in the digital era. Recent research by Ding et al. found similar patterns in early childhood education, where teachers often rely on a few familiar apps and lack confidence to diversify due to insufficient training or support systems (Ding et al., 2021). Contextual training and collaboration between teachers can bridge the gap between technical use and learning strategies.

Technological Content Knowledge (TCK)

The Technological Content Knowledge (TCK) dimension shows the extent to which teachers are able to combine technology with teaching materials (content) appropriately. In the context of early childhood education, TCK includes the ability of teachers to choose and use technology that can make it easier for children to understand the content of learning in a fun, concrete, and age-appropriate way (Rahmadi, 2019). The results of the analysis of six RA teachers in *Butuh* District showed that the average score

of TCK was 80%, which was in the "Good" category. Further analysis of item responses is shown in Table 7.

Table 7. TCK Mastery Mean Score

TCK Mastery	Mean	Category
Choosing technology that is suitable for the material of the play activity.	3.83	Able
Selecting the right basic competencies to be taught using technology.	4.00	Able
Using media such as laptops, projectors, and printers in teaching.	4.17	Able
Understand the content of teaching materials combined with technology so that it is easy for students to understand.	4.00	Able

All indicators in the TCK dimension show that PAUD teachers understand the use of technology enough to deliver teaching materials. They are used to using devices such as laptops and projectors, but still do not consider the suitability of the media with the depth of early childhood learning content, especially in the selection of technology for play materials.

This finding is in line with research conducted by Mala (2024) which proves that the use of technology such as thematic videos, moving images, and interactive games has been proven to be able to significantly increase children's understanding of the content of the material, especially in theme-based learning, especially during apperception activities. The real practice in this case is that teachers still choose technology based on availability or habits, not on the compatibility between the material and the characteristics of digital media. For example, in delivering simple science material, there are still many who use passive videos without interaction, even though there are alternatives such as interactive simulations that are more effective.

Pedagogical Content Knowledge (PCK)

The Pedagogical Content Knowledge (PCK) dimension describes the extent to which teachers are able to combine learning strategies (pedagogic) with the appropriate understanding of the content/teaching materials (Herring et al., 2016). PCK is important in early childhood education because teachers must be able to convey content in a concrete, simple, and appropriate approach to play. Based on the results of the assessment of six RA teachers in *Butuh* District, an average score of 71.11% was obtained, which is included in the "Good" category. Further analysis of item responses is shown in Table 8.

Table 8. Mean Score of PCK Mastery

Component PCK	Mean	Criteria
Assess students' learning processes and outcomes objectively.	3.16	Doubtful
Develop curriculum, syllabus, and teaching modules well.	3.67	Able
Designing effective learning activities.	3.83	Able

In the PK dimension, PAUD teachers are quite skilled in designing learning activities and developing teaching tools according to PAUD standards. However, there are still obstacles in conducting objective learning assessments, especially in assessing children's learning processes and outcomes as a whole.

This is an important note, because in early childhood education, assessment is holistic, continuous, and observation-based, which requires a thorough understanding of the characteristics and development of each child. Teachers' confidence in conducting assessments can be caused by (1) Lack of training on authentic early childhood assessments, (2) Unfamiliarity with using observation and anecdotal record formats, (3) Teachers' greater focus on the implementation of activities than developmental assessments. Therefore, it is necessary to: (1) Training on formative and summative assessments based on early childhood education (2) Development of game-based assessment instruments and thematic activities (3) Academic supervision that encourages teachers to reflect on the teaching-learning process

Technological Pedagogical and Content Knowledge (TPACK)

The Technological Pedagogical and Content Knowledge (TPACK) dimension is a complete combination of three core components: technological knowledge (TK), pedagogic (PK), and content (CK). This dimension shows the extent to which teachers are able to integrate these three aspects in a harmonious and comprehensive learning practice (Park & Hargis, 2018). Based on the results of the analysis of six RA teachers in *Butuh* District, an average score of 84.44% was obtained, which was in the "Good" category. Further analysis of item responses is shown in Table 9.

Table 9. TPACK Mastery Mean Score

TPACK Mastery	Mean	Category
Choosing the right strategies and technologies according to the learning materials.	3.83	Able
Effectively blending content, pedagogic, and technological knowledge.	4.50	Very Able
Apply learning strategies and computer applications appropriately in teaching.	4.33	Able

PAUD teachers in *Butuh* District show a fairly high TPACK ability, especially in integrating content, pedagogy, and technology as a whole. They are able to design relevant and meaningful learning using appropriate strategies and digital media. However, there is still a need for strengthening the synchronization between digital media and diverse content needs, especially for complex or project-based thematic materials. In line with Hibana & Rahman (2021), PAUD teachers need to improve not only curriculum understanding, but also digital competence as a soft skill to face the development of the technology-based era. Educational institutions can support it through regular training in digital learning media, by adapting to technological developments and considering readiness, facilities, and other external factors.

Discussion

In this chapter, we will discuss the findings of research that show that early childhood education (PAUD) teachers in *Butuh* District, *Purworejo* Regency show a good level of mastery in general in integrating Pedagogical Knowledge and Technology Content (TPACK) in digital-based learning. Most teachers effectively utilize digital tools such as Zoom, YouTube, and educational games, while demonstrating a solid foundation in pedagogical strategies appropriate for early childhood education. In this case, the

importance of innovative and contextual learning approaches to optimize children's potential from an early age (Saputri et al., 2024). Therefore, strengthening teacher readiness in the digital era requires more targeted professional development, access to contextual digital resources, and collaboration between educators. These strategies are essential to strengthen the mastery of integrated TPACK in early childhood education settings.

The integration of digital tools into early childhood education has shown significant progress, especially in the context of thematic learning. Educators have adapted to platforms such as Zoom, YouTube, and child-friendly education apps, signaling an increase in digital literacy among early childhood teachers, especially in the post-pandemic landscape (Kahar et al., 2020). The use of digital tools among early childhood education teachers reflects an encouraging shift towards theme-based and multimedia-based learning practices. Most educators have adapted to platforms like Zoom and YouTube to facilitate interaction, while incorporating kid-friendly digital games to reinforce learning materials. This reflects a broader trend in the increase in digital literacy of early childhood educators, especially after the educational disruptions caused by the pandemic. Early childhood teachers are expected to be able to guide children in getting to know and utilize digital media to support daily activities. One way is to introduce educational applications at school, so that children are used to using gadgets positively and wisely (Aini et al., 2021). Pedagogically, RA teachers have implemented play-based strategies effectively, which are in harmony with the practice, namely playing with learning and meaningful play that is in accordance with the development and learning needs of young children.

Effective TPACK implementation also requires a balanced mastery of the three domains, namely technological, pedagogical, and content knowledge. This complexity has been recognized in previous studies as a persistent problem in real classroom settings (Yusria et al., 2023). Pedagogically, teachers demonstrate the capacity to implement developmentally appropriate practices, such as game-based and thematic teaching. Their familiarity with learning strategies that align with the characteristics of early childhood education highlights a strong understanding of children's needs. Content delivery is also enhanced through multimedia tools, allowing abstract concepts to be more accessible to young learners. To improve readiness, teachers need access to ongoing professional development, contextual training, and opportunities for collaboration through peer learning communities.

These strategies can help educators better integrate digital tools into pedagogical planning while ensuring developmental relevance in early childhood settings (Hariyono et al., 2024). Despite these advances, some teachers continue to struggle with deeper integration of content and pedagogy especially in planning assessments or choosing custom apps that align closely with learning objectives. The challenge of balancing technological, pedagogical, and content aspects remains and is often associated with the need for further training and reflective teaching practices.

Based on this, it is concluded that RA teachers in *Butuh* District in general have (1) Able to integrate the three main elements of learning well (2) Ready to face the challenges of digital-based learning (3) Need to be facilitated to share best practices with fellow teachers, both through training and learning communities. These findings are in line with Budiarti that emphasized that mastery of TPACK allows teachers to develop

learning that is adaptive, innovative, and in accordance with children's cognitive development (Budiarti, 2024). Thus, the suggested follow-up steps include (1) Assistance in the practice of TPACK implementation in the real context of early childhood learning (2) Improving teachers' ability to choose technology according to the characteristics of the material and objectives (2) Facilitation of a forum for sharing good practices (lesson study/digital teacher community) to learn from each other TPACK integration.

CONCLUSION

Based on the results of a study conducted on six RA teachers in *Butuh* District, *Purworejo* Regency, it can be concluded that the teachers demonstrate a generally good level of competence in applying Technological Pedagogical and Content Knowledge (TPACK) in digital-based learning, with an average overall score of 84.44%. This shows that PAUD teachers in general have sufficient ability to integrate aspects of technology, pedagogy, and learning content in the teaching and learning process. Teachers were able to operate technological tools such as Zoom, YouTube, and educational applications, apply play-based strategies in accordance with the PAUD curriculum, and understand thematic content relevant to child development. Although the integration of TPACK dimensions particularly TPK, TCK, and PCK was carried out well by most teachers, further support is needed to optimize pedagogical content integration and evaluation. The results suggest the importance of strengthening digital pedagogy and the continuous development of TPACK-based training programs to support the readiness of teachers in facing future educational challenges. This study has several limitations, including a small sample size, restricted geographic scope, and potential self-reporting bias. Future research is recommended to involve broader samples to develop more comprehensive strategies for integrating technology in early childhood education.

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