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Development of a mathematics e-module using Polypad to improve fractional concept comprehension

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ABSTRACT

Understanding math concepts, especially on fraction material, is often a difficulty for students. This problem is exacerbated by the limitations of available learning resources and the underutilization of technology in schools, which results in low student interest and learning outcomes. The purpose of this study was to develop and evaluate the feasibility and effectiveness of Polypad-assisted math e-modules in improving understanding of the concept of fractional numbers. This research uses the Research and Development (RnD) method with the ADDIE model. The feasibility of the product is measured through validation from material, media, language, and teacher experts, while the effectiveness is measured through tests. The validation results indicate that the e-module is highly feasible to use. The effectiveness test demonstrated a significant increase in concept understanding, as evidenced by a rise in the average post-test score from 54.83 to 90.50, with an N-Gain score of 0.80, indicating a high category. Thus, this Polypad-assisted e-module proved to be feasible and effective as an alternative learning media that helps students understand the concept of fractions more concretely and visually.

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ABSTRAK

Pemahaman konsep Matematika, khususnya pada materi pecahan, seringkali menjadi kesulitan bagi peserta didik. Masalah ini diperparah oleh keterbatasan sumber belajar yang menarik dan minimnya pemanfaatan teknologi di sekolah, yang berakibat pada rendahnya minat dan hasil belajar peserta didik. Tujuan penelitian ini untuk mengembangkan serta mengetahui kelayakan dan efektivitas e-modul Matematika berbantuan Polypad untuk meningkatkan pemahaman konsep bilangan pecahan. Penelitian ini menggunakan metode Penelitian dan Pengembangan (RnD) dengan model ADDIE. Kelayakan produk diukur melalui validasi dari ahli materi, media, bahasa, dan guru, sedangkan efektivitasnya diukur melalui tes. Hasil validasi menunjukkan e-modul sangat layak digunakan. Uji efektivitas menunjukkan peningkatan pemahaman konsep yang signifikan, dibuktikan dengan peningkatan nilai rata-rata post-test menjadi 90,50 dari pre-test 54,83, dengan skor N-Gain sebesar 0,80 dalam kategori tinggi. Dengan demikian, e-modul berbantuan Polypad ini terbukti layak dan efektif sebagai media pembelajaran alternatif yang membantu peserta didik memahami konsep pecahan secara lebih konkret dan visual.

Kata Kunci: *bilangan pecahan; e-modul; pemahaman konsep; Polypad*

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INTRODUCTION

Mathematics learning plays a crucial role in our daily lives, with its primary objective being the mastery of Mathematics itself. In solving various problems, Mathematics highly emphasizes understanding, particularly conceptual understanding, rather than mere memorization (Nurani *et al*., 2021). Conceptual understanding in Mathematics serves as the foundation for achieving the meaning that learners derive from these abstract ideas, enabling them to connect various topics and apply their knowledge to real-world situations or problems. Furthermore, conceptual understanding is essential because it functions as a powerful tool for thinking and communication while facilitating the interpretation of Mathematics' abstract nature (Kowiyah et al., 2024).

Based on observations at one of the *Sekolah Dasar Negeri* (public elementary schools) in Cakung Barat, East Jakarta, findings from interviews with classroom teachers revealed four main issues: limited availability of engaging learning resources, low student problem-solving activity, minimal utilization of technology, and Mathematics learning outcomes that still fall below the standard. These issues result in a lack of student engagement during lessons, making it difficult for them to grasp concepts effectively. An engaging and effective teaching module is essential to enhance students' conceptual understanding. A high-quality instructional material must be able to achieve learning objectives efficiently and effectively. Furthermore, such material should be easily understandable and capture students' interest to optimize the learning process (Fitriasari & Ningsih, 2021).

In acquiring learning resources and instructional media, technological advancement plays an indispensable role. It is crucial for teachers to utilize technology as a supportive tool in the teaching and learning process. The integration of technology can enhance learning skills, foster teacher innovation, and strengthen the ability to use information technology effectively (Yusuf et al., 2023). Therefore, the integration of technology in mathematics education also plays a critical role at the elementary level, particularly through technology-enhanced instructional materials such as e-modules. E-modules help students grasp the material more effectively by facilitating a learning process that extends beyond mere reading to incorporate diverse instructional methods (Putri et al., 2024).

The integration of Polypad into e-modules can address these issues through visual and interactive approaches. These findings indicate that Indonesia still needs to make improvements to catch up with other participating countries (Syawaludin, 2024). Recent research demonstrates that digital technology can enhance students' mathematical understanding. Several studies have confirmed the effectiveness of e-modules in elementary school (SD) mathematics education. Research indicates that the development of problem-solving-based e-modules on fraction materials yields significant results in improving students' conceptual comprehension (Aulia & Prahmana, 2022). Platforms such as Polypad have been tested as interactive mathematics learning tools. However, their use remains limited to supplementary roles rather than serving as a core component within structured e-modules.

While numerous studies have examined e-modules and Polypad independently, no research has systematically integrated the two. Existing studies on Polypad have only evaluated its

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use as a supplementary tool, without designing it as an embedded component of curriculum-based e-modules (Utomo & Purwati, 2024). Meanwhile, research on fraction e-modules has yet to leverage Polypad's interactive features (Rahma et al., 2024). This gap highlights the need for developing a Polypad-assisted mathematics e-module designed holistically for fraction instruction in elementary schools (SD). This study examines the development of a Polypad-integrated e-module to dynamically visualize fraction concepts while providing a structured learning framework. The research aims to design an interactive Polypad-based e-module to enhance conceptual understanding of fractions among fourth-grade elementary schools (SD) students. It is expected that this study will not only address localized challenges at SDN Cakung Barat, East Jakarta, but also establish an adaptive instructional model with broader applicability.

LITERATURE REVIEW

E-Modul

An e-module is a self-contained learning resource systematically organized and presented in electronic format, incorporating audio, animation, and navigational elements (Idil et al., 2024). An e-module is a digital module comprising text, images, or a combination of both, containing instructional material on digital electronics along with simulations for use in learning (Lastri, 2023). An e-module is a self-contained learning resource systematically organized and presented in electronic format, incorporating audio, animation, and navigational elements (Idayanti & Suleman, 2024). The use of e-modules offers teachers several advantages, such as transforming conventional teaching materials into digital formats, developing and updating teaching methods, and acquiring skills aligned with modern advancements. A module must include fundamental functionalities that distinguish it from other educational materials through these features. An effective e-module possesses several key characteristics: self-instruction, self-contained, stand-alone, adaptive, and user-friendly (Lastri, 2023).

E-modules offer significant benefits in fostering independent learning by enabling students to study autonomously without direct reliance on face-to-face instruction. Learners can access materials anytime and anywhere, progressing at their individual pace which effectively supporting self-directed and personalized learning experiences. E-modules offer several benefits as follows: 1) facilitating the expansion and enrichment of knowledge through the use of electronic media; 2) stimulating students' interest and attention to think more critically; 3) increasing student engagement and motivation in learning activities; 4) providing solutions for students to overcome difficulties encountered during learning; 5) assisting teachers in delivering instructional materials more effectively; 6) enabling students to better comprehend the subject matter being taught; and 7) contributing to more efficient and effective learning processes (Laili et al., 2019).

Mathematics Instruction

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Mathematics is a compulsory subject taught to all students, from elementary school through higher educational levels, to develop logical, analytical, systematic, and critical thinking skills. However, in practice, many students still perceive Mathematics as a daunting and monotonous subject (Permatasari, 2021). Mathematics learning is a process in which students are guided to comprehend mathematical concepts through direct engagement with the abstract properties of mathematical objects (Aprillia & Fitriana, 2022). This approach must be adapted to students' developmental levels to ensure that mathematics instruction in schools proceeds smoothly and effectively (Susanti, 2020).

Since ancient times, mathematics has served as a critical tool across various disciplines, from the sciences to technology (Andinasari et al., 2024; Mauliana et al., 2025). Mathematics education is a process designed to develop each student's thinking abilities, logical reasoning, and intellectual capacity. The primary objective of mathematics instruction is to enhance students' cognitive skills and conceptual understanding. However, in practice, children often receive insufficient encouragement to develop their thinking abilities (Wandini et al., 2021). Elementary-level mathematics instruction is grounded in the principle of consistent truth without contradiction. In mathematics, a statement is considered false if proven false and true if demonstrated true, based on previously accepted and verified theoretical foundations (Sulistyaningsih et al., 2024).

According to the *Peraturan Menteri Pendidikan Nasional* (Permendiknas), the objectives of Mathematics learning are: 1) to comprehend Mathematical concepts, explain the relationships between these concepts, and apply them flexibly, precisely, and accurately in problem-solving; 2) to utilize intellectual capabilities in deriving general conclusions by organizing data or expressing Mathematical ideas and thoughts; 3) to develop problem-solving skills, including the ability to understand, make Mathematical references, address challenges, and articulate the solutions obtained; 4) to communicate ideas using tables, symbols, and diagrams to clarify situations or problems; and 5) to cultivate an attitude of appreciation and understanding of the role of Mathematics in daily life (Wandini et al., 2021).

Polypad

One effort teachers can undertake to enhance the quality of abstract Mathematics instruction is by utilizing instructional media (Febriyandani & Kowiyah, 2021). Polypad is presented as an interactive digital platform, developed to support both students and teachers in comprehending Mathematical concepts through customizable visual tools (Genç, 2024). Polypad is commonly employed in the learning process to facilitate a more hands-on teaching approach, where students can directly interact with various Mathematical elements. This includes using geometric blocks to understand spatial concepts, representing numbers with number boards or other numerical models, and creating diagrams and graphs to illustrate data (Amelia et al., 2025).

Students can conduct mathematical experiments, solve problems, and visualize mathematical concepts in a more profound and engaging manner through the use of Polypad. This platform is frequently utilized in project-based learning or collaborative learning environments, where students can work together to solve problems or independently explore mathematical concepts (Utomo & Purwati, 2024). Polypad offers various features designed

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to support interactive and visual mathematics learning (Amelia et al., 2025). Polypad contains several key features that enhance mathematical learning:

1. The Geometry and Visual Shapes component provides various geometric tools, including circles, squares, triangles, and other polygons to create visual models of mathematical concepts such as fractions, area, volume, and more
2. The Blocks and Tiles feature enables users to manipulate movable blocks or tiles to visualize fractions, mathematical operations, and related concepts. For example, students can use blocks to demonstrate the division of an object into smaller partsl
3. The Number Board and Calculator tool offers a customizable number board to represent integers, fractions, decimals, and other numerical concepts. An integrated calculator allows for real-time computations within Polypad
4. The Fraction Models feature facilitates fraction visualization through geometric representations (e.g., circles divided into smaller sections). This aids students in understanding fraction division and comparative relationships

The advantages of Polypad include its interactive and visual nature, diverse manipulative tools, learning flexibility, easy web-based access, support for collaborative learning, user-friendly interface, exploration-based learning approach, integration of various mathematical concepts, and customizable learning experiences (Agustin et al., 2024). However, Polypad has several limitations, including dependence on internet connectivity, restricted offline functionality, limited features for advanced mathematical concepts, lack of seamless integration with formal curricula, a learning curve for new users, constrained tools for specialized topics, challenges in collaborative implementation, and varying levels of technological familiarity among students and teachers.

Pemahaman Konsep

Conceptual understanding refers to the extent to which an individual comprehensively grasps the relationships between mathematical ideas, procedures, or facts. This depth of understanding enables one to classify objects based on mathematical criteria (Hernawati & Pardipta, 2021). Conceptual understanding offers significant advantages in educational contexts. Below are its primary benefits (Fauzi et al., 2022).

1. Enables students to organize and present mathematical ideas they have mastered in novel contexts, while using manipulatives to model concepts and articulate outcomes, thereby supporting comprehension of abstract ideas.
2. Teaches students to demonstrate multiple representations of the same mathematical situation, a critical skill for developing conceptual understanding.
3. Encourages students to leverage prior knowledge to construct new understanding and apply it to solve problems in unfamiliar contexts, which is equally vital for conceptual mastery.
4. Helps students recognize connections between current mathematical content and previous knowledge, thereby deepening their conceptual grasp.

The indicators of mathematical conceptual understanding referenced in this study include the ability to define concepts, provide examples and non-examples of concepts, and apply concepts to solve problems (Siregar et al., 2020; Saadah et al.,

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2023). In this research, the operational definition of conceptual understanding is students' competence in articulating the meaning of an abstract idea. Specifically, this is measured by their ability to reformulate the definition of fraction concepts using their own language, based on the fundamental characteristics of those concepts.

In this study, defining concepts refers to students' ability to comprehend the meaning of abstract ideas, enabling them to explain the definition of fraction concepts in their own words based on their essential properties or characteristics. Providing examples and non-examples of concepts pertains to students' capacity to distinguish between examples and non-examples of fractions. Meanwhile, applying concepts to solve problems is measured by how students address real-world problems presented in word problem formats.

METHODS

To achieve the research objective of producing a valid and effective e-module product, the study employs the Research and Development (RnD) methodological framework. The product development process systematically follows the ADDIE model stages, which include Analysis (*Analisis*), Design (*Perancangan*), Development (*Pengembangan*), Implementation (*Implementasi*), and Evaluation (*Evaluasi*). Below are the five development stages conducted to yield an applicable final product:

1. Analysis Phase: In this stage, researchers identify the needs of teachers and students at SDN (public elementary school) Cakung Barat, East Jakarta, and design learning media tailored to these requirements
2. Design Phase: Researchers develop a preliminary product design based on the identified needs, including the conceptual framework and structure of the e-module
3. Development Phase: The finalized design is transformed into a tangible product. The product undergoes validity testing by experts to ensure its appropriateness
4. Implementation Phase: The product is piloted with experts, teachers, and students to gather feedback on its effectiveness and usability
5. Evaluation Phase: The tested product is refined based on received input. Upon completion of the evaluation process, the final product, a Polypad-assisted Mathematics e-module on fractions is ready for deployment.

Fourth-grade students participated as subjects in this study. The testing was conducted in two phases, a small group trial involving 7 students and a large group trial involving 30 students. Data collection techniques included classroom observations, expert validation questionnaires to evaluate product feasibility, as well as assessment questionnaires and tests to measure the e-module's effectiveness. The data obtained from validations by content experts, media specialists, linguists, teachers, and students were analyzed using specific quantitative formulas.

$$P = \frac{f}{n} \times 100\%$$

P = Validation Percentage
f = Total score from data collection
n = Maximum possible score

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According to the established formulas, a product can be categorized as valid and effective when it meets the predetermined criteria in the expert assessment instruments. The content expert evaluation encompasses aspects such as e-module components, content feasibility, language usage, and content alignment with students' conceptual understanding levels. Meanwhile, the media specialist evaluation examines navigation systems, visual design, and the e-module's pedagogical utility in the learning process. The linguistic expert assessment focuses on proper language and spelling usage, terminological consistency, and language appropriateness for students' developmental stages.

Table 1. Feasibility Level Criteria

No	Score	Category
1	81% - 100%	Highly Feasible
2	61% - 80%	Feasible
3	41% - 60%	Moderately Feasible
4	21% - 40%	Not Feasible
5	0% - 20%	Highly Not Feasible

Source: Research, 2025

The expert assessments encompass three main aspects: content validity, e-module presentation quality, and language usage. Meanwhile, the student evaluation instruments focus on the ease of understanding the e-module content, clarity of illustrations and examples, and the usefulness of the e-module as a learning resource. All aspects of the evaluation instruments, including pre-test and post-test questions, are used to measure the effectiveness of the developed instructional media based on product feasibility and relevance. The feasibility achievement criteria are presented in **Table 1**, which outlines the standards for determining product viability.

RESULTS AND DISCUSSION

Analyze

The analysis phase consists of two components, work analysis and needs analysis. The work analysis was conducted to identify existing school-related issues, such as students' low problem-solving abilities which negatively impact both academic performance and interest in Mathematics. This problem stems from the lack of engaging instructional media. Additionally, the school's teaching materials remain in printed module format that has yet to be digitized. Consequently, during the needs analysis phase, teachers require innovation by transforming conventional modules into Polypad-assisted e-modules.

Design

During this phase, the researcher designed the concept for the Polypad-assisted e-module. The design process involved creating the media interface, compiling instructional content, and selecting language appropriate for students' comprehension levels. Following the conceptual design, the researcher proceeded with developing the instructional materials in

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e-module format. After compiling all analytical materials, the subsequent step involved designing the teaching materials using Canva, beginning with the formulation of the product framework.

1. The opening section features the title *"E-Modul Matematika: Menguasai Bilangan Pecahan Dengan Mudah".* Subsequent pages present the author's biography, usage instructions, e-module overview, menu, and preface (see **Figure 1**).

Figure 1. Front Section of the E-module
Source: Research, 2025

2. The content section of the e-module includes learning outcomes and objectives, along with instructional materials (see **Figure 2**).

Figure 2. Content Section of the E-module
Source: Research, 2025

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3. The closing section contains the bibliography, the final framework of the e-module linked to additional learning resources, and learning evaluations in the form of practice questions (see **Figure 3**).

Figure 3. Closing Section of the E-module
Source: Research, 2025

Development

This phase represents the product development process, which is subsequently validated by experts, followed by revisions to the developed product. After completing these stages, the product is deemed feasible and ready for testing with research subjects, specifically fourth-grade students. During the development stage, the completed e-module design undergoes feasibility testing. This process is crucial to ensure product quality before implementation with students. Feasibility assessment is conducted through a validation process involving relevant field experts and practitioners (teachers).

Table 2. Validation Results

No	Experts	Percentage	Category
1	Content	94,67%	Highly Feasible
2	Media	89,33%	Highly Feasible
3	Language	74,00%	Feasible
4	Teachers	95,33%	Highly Feasible

Source: Research, 2025

Based on the validation results (see **Table 2**), the Polypad-assisted Mathematics e-module meets the criteria for validity and is deemed suitable for pilot testing with students.

Implementation

This phase represents the implementation of trials after the e-module's validation by experts. The researcher conducted trials at two different scales at SDN Cakung Barat, East Jakarta. The purpose of these trials was to evaluate the effectiveness of the developed Polypad-

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assisted e-module in teaching fraction concepts. Below are the questionnaire results from both trial groups.

Tabel 3. Trial Questionnaire Results

No	Scale	Result	Category
1	Limited	98,00%	Highly Effective
2	Extensive	91,00%	Highly Effective

Source: Research, 2025

The overall questionnaire results from the trial phase (see **Table 3)** indicate that the e-module was rated as effective and suitable for use as a learning resource, particularly in teaching *Bilangan Pecahan*. During the large-scale trial, pre-test and post-test assessments were administered to measure the e-module's effectiveness in enhancing students' conceptual understanding. Analysis of the pre-test and post-test scores was conducted using the formula established by (Saputra et al., 2022).

The small-group trial yielded a result of 98,00%, categorized as highly effective. This indicates that the Polypad-assisted e-module is ready for student use and suitable for large-scale testing in Class IV-D at SDN Cakung Barat, East Jakarta. The large-scale trial yielded a 91,00% student response rate, classified as highly practical. This demonstrates that the developed e-module successfully aligns with students' cognitive developmental stages and contributes positively to enhancing conceptual understanding of the subject matter.

Evaluation

The evaluation phase was conducted to measure the quality and effectiveness of the developed e-module. This evaluation consisted of two main components: product feasibility (validity) testing by experts and teachers, and product effectiveness testing to assess improvements in students' conceptual understanding through N-Gain Score analysis. The evaluation also incorporated feedback from students after using the Polypad-assisted e-module. At this stage, the effectiveness of the Polypad-assisted e-module was assessed through formative tests completed by students. These formative tests consisted of multiple-choice questions administered to Class IV students to measure their learning outcomes after using the Polypad-assisted e-module. The results of the student evaluation assessments are presented in the following table.

Table 4. Comparison of Pre-test and Post-test Scores with N-Gain Metrics

No	Scale	Category
1	*Pre-test*	54,83
2	Post-test	90,50
3	N-Gain Score	0,80
	Criteria	Highly Effective

Source: Research, 2025

Based on the effectiveness test results presented in **Table 4**, a significant improvement in student achievement is evident. The average pre-test score before using the e-module was 54,83, while the average post-test score after e-module implementation increased to 90,50.

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The N-Gain score of 0,80 falls within the high category. These findings conclusively demonstrate that the developed e-module is highly effective in enhancing students' conceptual understanding.

Discussion

This study has produced a Polypad-assisted Mathematics e-module rated as highly feasible by experts and practitioners. The exceptional feasibility level, evidenced by an overall validation score of 89,33% from content and media specialists, indicates the e-module's robust design. Individual validation scores for content (94,67%), language (74,00%), and teacher evaluations (95,33%) demonstrate the material's curriculum alignment and practical utility in educational settings. Consistent with the assertion that Polypad's features enable visual and interactive learning, thereby facilitating students' comprehension of mathematical concepts (Amelia et al., 2025). The user-friendly interface design and intuitive navigation align with the characteristics of an effective e-module (Lastri, 2023). The e-module presents diverse instructional materials in concise modular formats (Hadiapurwa et al., 2021).

The primary finding of this research is the demonstrated effectiveness of the e-module in enhancing students' conceptual understanding, as evidenced by the improvement in average test scores from 54,83 in the pre-test (prior to e-module implementation) to 90,50 in the post-test (following e-module use), with an N-Gain score of 0,80. This improvement can be interpreted as a positive impact of Polypad integration. Consistent with learning theory, understanding abstract concepts like fractions requires a bridge from concrete to symbolic representation. Polypad functions as a virtual manipulative that enables students to experiment with and directly visualize fractions. The use of manipulatives, both physical and virtual has been proven effective in helping students transform abstract concepts into more meaningful understanding (Amelia et al., 2025).

The Android-based interactive e-module proves sufficiently effective in enhancing students' conceptual understanding (Murod et al., 2021). One potential interpretation involves the learning curve students experience when adopting new technologies like Polypad. Compared to prior studies, these findings both reinforce and expand existing research. Previous studies had not systematically integrated Polypad within a structured e-module framework (Rahma et al., 2024; Utomo & Purwati, 2024). The novel finding of this research lies in the systematic integration of Polypad into a digital instructional material structure (e-modul) designed using the ADDIE development model. This study demonstrates that Polypad is not only effective as a standalone supplementary tool, but its potential can be maximized when embedded within a structured learning sequence, complete with instructional content, exercises, and assessments, thereby creating an interactive learning ecosystem.

CONCLUSION

This research has successfully produced a Polypad-assisted Mathematics e-module for teaching fraction concepts. The findings indicate that the developed e-module was deemed highly feasible and practical for implementation in instructional settings. This feasibility assessment represents a synthesis of comprehensive validation results conducted by content experts, media specialists, linguists, and evaluations from practicing teachers in the field.

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Furthermore, this study addresses the objective concerning product effectiveness. The Polypad-assisted Mathematics e-module has proven effective in enhancing students' conceptual understanding of fractions. This success is demonstrated by a significant improvement in students' conceptual comprehension after using the e-module, as measured by comparing pre-test and post-test results. The developed e-module serves as a valid and effective alternative instructional medium, capable of addressing the need to help students comprehend abstract fraction concepts more concretely and visually. The study recommends that teachers optimally utilize this e-module as a learning resource and further develop it to cover broader content areas or adapt it to other instructional topics. However, this research has limitations, particularly regarding its trial scope being confined to a single school. This presents an opportunity for future studies to test the e-module's effectiveness on a larger scale and more diverse populations.

AUTHOR'S NOTE

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