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Contemporary Didactic Methodologies in the Teaching of Mathematics in Higher Education: A Systematic Literature Review (2020–2025)

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Abstract

This study analyzes contemporary didactic methodologies applied to the teaching of mathematics in higher education within the Spanish-speaking context. Using a systematic literature review, peer-reviewed studies published between 2020 and 2025 were identified and assessed, focusing on innovative approaches such as problem-based learning, cooperative learning, gamification, flipped classroom, AI-supported instruction, and socio-emotional education. Strict inclusion criteria were applied to ensure quality, considering only full-text articles written in Spanish. The findings indicate that active methodologies significantly improve student motivation, critical thinking, autonomy, and conceptual understanding of mathematics. The incorporation of technological tools, including Python and AI-based platforms, enhances personalized learning, while socio-emotional strategies help reduce math anxiety and strengthen interpersonal competencies. Nonetheless, challenges remain, including the digital divide, resistance to pedagogical change, and the need for specialized teacher training. The study concludes that the convergence of active strategies, emerging technologies, and humanistic approaches offers a transformative opportunity for mathematics education in higher education. Realizing this potential requires supportive educational policies that promote equitable resource access, continuous professional development, and curricular adaptation aligned with 21st-century demands. Further longitudinal and context-specific studies are recommended to assess the long-term effectiveness of these methodologies.

Keywords: Mathematics Education; Didactic Methodologies; Higher Education; Active Learning; Educational Technology

INTRODUCTION

In this context, it becomes evident that the methodologies traditionally employed by mathematics teachers have proven to be limited and insufficient for fostering the development of meaningful competencies in students. This situation highlights the need to explore, from a critical and updated perspective, the methodological strategies that are emerging as subjects of study and innovation within the Spanish-speaking educational community. This work is framed within a systematic literature review, aiming to identify these methodologies, as well as the characteristics, perceptions, and outcomes associated with their implementation. In this regard, the research question guiding the study is: Which methodologies are transforming the paradigm of mathematics teaching, traditionally perceived as difficult, mechanical, and based on memorization?

The general objective of this study is to identify and systematize the contemporary didactic methodologies that have been implemented in mathematics teaching over the past five years within the Spanish-speaking context, highlighting their main characteristics, pedagogical approaches, perceptions of educational stakeholders, and the results documented in recent scientific literature.

Literature Review

The teaching of mathematics in higher education has undergone a significant transformation through the incorporation of active methodologies, digital strategies, and student-centered approaches. These proposals not only address current challenges in learning this discipline but also promote a profound change in how students engage with mathematical content, fostering their participation, motivation, and autonomy.

Project-Based Learning (PBL) is an active methodology in which students develop solutions to real-world problems through extended projects, integrating mathematical knowledge with practical contexts (Meza-Holguín et al., 2024). According to the study, this strategy fosters autonomy, creativity, and interdisciplinary application of concepts, as demonstrated in its implementation in mathematics, where students improved their ability to model real-life situations (e.g., resource optimization in agriculture). PBL also promotes critical thinking by requiring analysis, planning, and constant evaluation of results.

In the same vein, Aguilar Enríquez et al. (2020) propose gamification as a strategy to improve mathematics learning in higher education, where more than 70% of students fail to reach the basic level according to PISA assessments. Their study showed that gamification increased student acceptance by 33.5% compared to traditional methods, validated with a reliability coefficient of 0.7 using Cronbach's alpha. The authors highlight that this methodology, supported by ICT, fosters skills such as observation, analysis, and collaborative work, although it requires clear guidelines and teacher training for effective implementation.

Likewise, cooperative learning, also framed within active methodologies, emphasizes positive interdependence and individual responsibility within small teams (Meza-Holguín et al., 2024). In mathematics, this methodology has been shown to increase the retention of complex concepts (e.g., algebra or geometry) through group discussions and peer tutoring. Students not only improve their academic performance but also develop key social skills such as communication and conflict resolution.

All these strategies share fundamental principles of active learning, although they differ in their approaches. While PBL focuses on concrete products, cooperative learning emphasizes collaborative processes, and gamification introduces playful and technological elements that encourage student engagement. The combination of these methodologies has proven to be especially effective in the field of mathematics, where deep understanding and problem-solving require both teamwork and practical application.

In line with the above, Problem-Based Learning (also abbreviated as PBL, but with a different focus than project-based learning) represents another active methodology that fosters critical thinking and problem-solving through collaborative work in real-world scenarios (Meza-Holguín et al., 2024). This strategy positions the student as the protagonist of their learning, while the teacher acts as a facilitator, guiding the process of inquiry and analysis. Studies such as that by Meza-Holguín et al. (2024) demonstrate its effectiveness in mathematics, where students not only improve their analytical skills but also develop competencies to apply knowledge in practical contexts. It is worth noting that this methodology has shown greater retention of concepts and improved ability to tackle complex problems, although its success depends on careful planning and the selection of relevant problems that motivate students to actively engage in their learning process.

In this same line of pedagogical innovation, the flipped classroom emerges as a strategy that reorganizes learning spaces by moving direct instruction outside the classroom (through digital resources) and using in-person time for collaborative and personalized activities (Durán & Vigueras, 2023). In the Ecuadorian context, where mathematics is often perceived as a difficult and demotivating subject, this methodology has proven effective in improving academic performance and encouraging a more active student role. According to the authors, the “smart” flipped classroom integrates digital technologies (such as Classroom, Zoom, or Genialy) with active methodologies (PBL, gamification) and comprehensive teacher support, enabling students to develop autonomy and socio-emotional skills while building mathematical knowledge.

Complementing these proposals, virtual mathematics instruction has recently become a key methodology in higher education, especially after the pandemic (Giler-Velásquez, 2021). This approach combines digital platforms (Moodle, Classroom), interactive tools (GeoGebra, MATLAB), and strategies such as problem-based learning adapted to virtual environments. Studies in Ecuador highlight its potential to offer flexibility and democratized access, although challenges such as the digital divide and the need for greater teacher training in digital pedagogies are also identified. This modality represents a viable alternative for contexts with limited in-person instruction, maintaining academic rigor through adapted instructional design and personalized support (Giler-Velásquez, 2021).

In this context of educational transformation, artificial intelligence (AI) is emerging as a key component that further enhances active methodologies in virtual environments. AI is revolutionizing mathematics education by offering personalized learning and adaptive feedback. As noted by Román Cañizares (2024), tools such as intelligent tutors and AI-based platforms (e.g., GeoGebra with machine learning algorithms) improve academic performance by adjusting content to the individual needs of students. Studies cited in the PRISMA review show that these technologies increase motivation and understanding of abstract concepts, although challenges such as the digital divide and the need for teacher training in digital pedagogies persist. This innovation represents a major advancement for post-pandemic mathematics education by combining adaptability and scalability. However, Román Cañizares (2024) warns that its effectiveness depends on student-centered instructional design and future research that evaluates long-term impacts in diverse educational contexts.

In this same line, research in the Chilean context highlights that active methodologies combined with AI are revolutionizing mathematics education in higher education. According to Silva Acuña et al. (2024), tools such as intelligent tutoring systems and adaptive platforms optimize feedback and problem-solving, aligning with pedagogical approaches like PBL and the flipped classroom. This synergy supports personalized learning and promotes more active student participation, resulting in greater educational efficiency. However, the authors also warn that for these innovations to be sustainable, key challenges must be addressed, such as teacher training and improvements in technological infrastructure. The study, based on a PRISMA systematic review, concludes that AI enhances active methodologies by automating assessments and providing interactive resources, allowing teachers to focus on higher-impact pedagogical strategies. Nevertheless, Silva Acuña et al. (2024) emphasize that its success depends on educational policies that integrate principles of digital ethics and ensure equitable access, in order to prevent these technologies from widening existing socioeconomic gaps in mathematics learning.

Lastly, among these transformative strategies, socio-emotional education also emerges as an essential pedagogical pathway to improve mathematics learning by addressing emotional factors such as anxiety and self-confidence (Quiñónez et al., 2024). Reviewed studies show that techniques such as emotional self-regulation and the creation of collaborative environments reduce fear of making mistakes, fostering a growth mindset in students. This approach not only increases academic performance but also develops interpersonal skills such as empathy and teamwork, which are essential for solving mathematical problems collectively. The research highlights that linking mathematical content to everyday situations and prioritizing effort over immediate results enhances motivation and meaningful understanding. However, its successful implementation requires both teacher training in socio-emotional strategies and curricular adaptation that allows for the coherent integration of these approaches. Thus, socio-emotional education positions itself as a pillar for more inclusive and human-centered mathematics teaching.

In conclusion, active methodologies, the integration of emerging technologies such as artificial intelligence, and the socio-emotional approach represent a pedagogical convergence that is redefining the teaching of mathematics in higher education. Their coordinated implementation can contribute to a more comprehensive, equitable, and meaningful education, provided it is supported by strong educational policies, continuous teacher training, and adequate resources.

METHODS

Strategies for finding literature

For this research, a systematic bibliographic search was conducted with the aim of identifying the various methodologies currently being investigated and considered of relevant interest in the educational field. The review focused exclusively on academic sources and scientific articles published in specialized journals, considering only those documents written in Spanish with full and open access to their content.

Inclusion criteria

All the selected articles make a substantial contribution to the objective of this research, following a bibliographic review focused on studies about mathematics teaching in higher education, with particular emphasis on the didactic methodologies used. To ensure the quality and relevance of the sources, clearly defined selection criteria were established. One of the main criteria was the recency of the publications, considering only those articles published within the last five years, that is, between 2020 and 2025. This time frame responds to the need to gather recent evidence aligned with contemporary pedagogical transformations.

Likewise, language was defined as a relevant criterion, so only articles written in Spanish were included, allowing for contextual coherence with the Spanish-speaking focus of this review. Regarding the type of source, only indexed documents published in peer-reviewed scientific journals were considered, excluding non-peer-reviewed works, theses, or other preliminary or non-academic documents. Another key criterion was thematic relevance: only articles that explicitly and substantively addressed a teaching methodology applied to mathematics were considered, discarding those that dealt with the topic in a tangential or superficial manner.

To identify the documents, combinations of keywords such as "teaching methodologies in higher education mathematics" were used, along with synonyms and related terms. The initial relevance assessment was based on reading the title and abstract of each article, and subsequently, those that clearly developed a methodological proposal accompanied by significant results or substantial pedagogical contributions were selected. For each source deemed relevant, complete references were recorded, including author(s), year of publication, and other necessary data for detailed analysis.

Identification of literature

During the reference search, specialized academic databases such as Google Scholar, Redalyc, Dialnet, SciELO, and LatinIndex were consulted, ensuring that all sources met the criteria of the Catálogo 2.0 as a minimum quality requirement. Among these platforms, Google Scholar stood out for its broad multidisciplinary coverage, while Redalyc and SciELO provided access to open-access scientific literature with an emphasis on the Latin American context.

This process allowed for the integration of both recent research and classical contributions, ensuring a balanced and well-founded literature review.

Screening

During the screening process, following the initial search in the selected databases, a total of 25 potentially relevant sources were identified. Based on a detailed review of titles and abstracts, and applying the previously established inclusion criteria, 10 articles were selected for their thematic relevance and significant contribution to the study's objective. These studies were documented and organized for subsequent full-text analysis, as well as for data extraction and evaluation of findings related to teaching methodologies in higher education mathematics.

Eligibility and Quality Assessment

After completing the initial screening process, the selected articles were read in full to verify their eligibility according to the established criteria. This evaluation confirmed that the selected studies explicitly and well-foundedly addressed a teaching methodology applied to mathematics in higher education contexts. Documents that, despite apparent thematic relevance in the title or abstract, did not clearly develop a concrete methodological proposal, lacked pedagogical support, or focused on other educational levels were excluded.

Additionally, a general assessment of the methodological quality of the included articles was conducted. This evaluation considered elements such as clarity in research design, coherence between objectives and reported results, detailed description of samples or application contexts, and the type of analysis performed. Only those studies that, in addition to being relevant to the research objective, presented a minimally acceptable level of scientific rigor and provided substantial findings on the implementation, effects, or perceptions associated with the studied teaching methodologies were retained for final analysis.

RESULTS

Table 1. Summary of Recent Studies on Innovative Methodologies in Mathematics Teaching in Higher Education

Author(s)	Methodology Analysis	Key Features	Reported Benefits and Students' Perception	Challenges and limitations
Meza-Holguín et al. (2024)	Integrated Active Learning Approach (IALA) — This approach incorporates several active methodologies (Problem-Based Learning, Project-Based Learning, and Cooperative Learning) into a unified framework referred to as the "Integrated Active Learning Approach (IALA)." It combines practical experiences, problem-solving, and peer	Encourages direct student participation. Fosters critical thinking and problem-solving. Involves projects, teamwork, and discussions. Integrates digital tools and manipulative materials. Applies concepts to real-world situations. Based on principles such as constructivism, metacognition, and meaningful learning.	Significant improvement in academic performance in mathematics. Increased student motivation and participation. Development of social skills (empathy, communication). Teachers perceive greater engagement and deeper understanding of concepts.	Resistance to change from teachers and students. Requires more planning time and resources. Difficulty in assessing non-cognitive skills. Gaps in access to technology in vulnerable contexts.

Author(s)	Methodology Analysis	Key Features	Reported Benefits and Students' Perception	Challenges and limitations
	collaboration to foster critical thinking.			
Vera Velázquez et al. (2021)	Problem-Based Learning (PBL): A student-centered methodology that promotes active learning through the resolution of real-world problems connected to their academic and professional environment. It fosters critical thinking, autonomy, and collaborative work.	Student-centered approach. Use of problems linked to professional context (e.g., agricultural engineering). Integration of multidisciplinary knowledge. Assessment based on processes, products, and content. Promotes skills such as critical thinking, teamwork, and autonomy	92.3% of students positively evaluated the PBL strategies. 89.3% considered the use of real-world problems beneficial to their training. Increased motivation and knowledge retention. Improvement in solving mathematical problems related to their field.	Institutional resistance to methodological change. Lack of teacher training in PBL. Limited time for full development of activities. Initial difficulties with basic content required for calculus.
PinargoteZambrano et al. (2024)	Didactic Technological Integration with Python: This proposal, referred to as "Programming-Based Mathematics Teaching," uses the Python programming language as a didactic tool to teach algebraic concepts. It enables the development of logical-mathematical skills, computational thinking, and process visualization.	Use of Python and Google Colab to teach first- and second-degree equations. Emphasis on practical and interdisciplinary learning. Application of libraries such as NumPy and SymPy. Course structured in stations with progressive activities. Focus on logical thinking, problem-solving, and motivation.	94% of students expressed appreciation for the teaching methodology. 90% want increased use of interactive tools and more digital resources. The proposal was validated by experts with a 100% approval rating. Evident increase in motivation, understanding, and preference for practical assessments.	The proposal has not yet been formally implemented in the classroom. Possible bias in the sample of surveyed students. Initial lack of familiarity with Python among most students (only 12% had used it). Requires teacher training for effective implementation. Technological gap: 66% had not previously used digital resources.
Durán Muñoz, M. L., & Vigueras Moreno, J. A. (2022).	Smart Flipped Classroom (Flipped Classroom 3.0)	A methodological proposal that combines the flipped classroom model with comprehensive student support—academic, emotional, and socio-emotional. It involves intensive use of ICT and a	Increased student motivation through active roles. Personalized learning according to individual pacing. Improved teacher-student	Dependence on technological resources (internet access, devices). Teacher resistance to changing traditional methods. Lack of empirical

Author(s)	Methodology Analysis	Key Features	Reported Benefits and Students' Perception	Challenges and limitations
		stage-based planning structure (preparation, development, support, and holistic evaluation). This approach promotes autonomous, active, and collaborative learning.	interaction. Theoretical validation by experts, though lacking quantitative implementation data.	implementation (theoretical study). Requires teacher training in ICT and flipped pedagogy.
Giler-Velásquez, L. E. (2021)	Virtual Teaching with ICT (EVA Platforms, Math Software, and Social Media) Combined with Problem-Based Learning (PBL):	100% virtual classes. Use of digital tools (GeoGebra, MATLAB). Practical approach using real-world problems.	Students develop autonomy and digital competencies. Positive perception toward interactive tools. Reduction in logistical costs.	Digital divide (lack of access to technology). Difficulty in conducting reliable assessments. Lack of physical interaction. Resistance to change among teachers and students. Risk of student dropout.
Román, G. (2024).	Adaptive Learning Based on AI: This methodology uses AI algorithms to personalize educational content according to the individual needs of students. It provides immediate feedback and adjusts the difficulty level in real time, enhancing the learning experience through tailored instruction.	Personalized learning through AI. Use of intelligent tutoring systems and instant feedback. Integration of virtual environments (VLEs) and multimedia resources. Focus on educational inclusion and adaptation to learning styles.	Significant improvement in academic performance. Increased student participation and motivation. Deep understanding of mathematical concepts through interactive tools.	Digital divide (lack of access to technology/internet). Need for teacher training in AI. Lack of longitudinal studies on long-term effects. Risk of excessive dependence on automated tools.
Silva, M., Correa, R., & McGuire, P. (2024).	Integrated Active Methodologies with AI (includes PBL, Collaborative Learning, and Flipped Classroom): This approach combines active learning strategies—such as Problem-Based Learning,	Integration of AI with active methodologies (PBL, collaborative learning, flipped classroom). Use of intelligent tutoring systems (ITS) and interactive simulations. Student-centered approach and personalized learning.	Integration of AI with active methodologies (PBL, collaborative learning, flipped classroom). Use of intelligent tutoring systems (ITS) and interactive simulations. Student-centered approach and personalized learning.	Digital divide and unequal access to technology. Need for teacher training in artificial intelligence. Ethical challenges (e.g., data privacy). Lack of longitudinal studies on long-term impact.

Author(s)	Methodology Analysis	Key Features	Reported Benefits and Students' Perception	Challenges and limitations
	Collaborative Learning, and the Flipped Classroom—with AI tools to personalize learning, provide adaptive feedback, and facilitate interactive exploration of mathematical concepts.			
Quiñónez, R., et al. (2024).	Socio-emotional education integrated into mathematics learning. It is an approach focused on emotional development, self-regulation, empathy, and the creation of trusting environments to improve students' readiness and performance in mathematics.	Strategy that promotes emotional self-regulation, reduction of math anxiety, collaborative work, empathy, growth mindset, and emotional connection with the content. It integrates mindfulness, focused attention, and positive reinforcement.	Significant improvement in readiness to face mathematical challenges, increased confidence and motivation, better academic performance, reduced math anxiety, and development of social and emotional skills.	Requires teacher training in socio-emotional competencies; may be difficult to integrate without a coherent institutional approach; demands curricular adaptation and additional planning time.
Aguilar Enríquez et al. (2020)	Gamification with ICT (a playful and technological approach to teaching mathematics and statistics). Description: Use of tools such as Blippar (augmented reality), Minecraft Education, and ThingLink to encourage participation, teamwork, and problem-solving through game-based dynamics.	Alternative to traditional methods in higher education. Integration of ICT and game elements (levels, rewards, collaboration). Focus on logical-mathematical and abstract thinking skills. Use of interactive platforms (LMS) for synchronous/asynchronous learning.	33.5% higher acceptance compared to traditional methods. 93.1% of students showed increased interest in mathematics/statistics. Improved participation and teamwork. 84.8% of students had good connectivity for online classes.	High preparation time required for teachers. Requires teacher training in ICT and gamified activity design. Technological gap: 15.2% of students have poor internet connectivity. Difficulty in gamifying abstract content.

DISCUSSION

The systematic review highlights a progressive transformation in mathematics education in higher education within the Spanish-speaking context, driven by the adoption of active methodologies, the integration of emerging technologies such as artificial intelligence (AI), and the growing recognition of the role of emotions in learning. These innovations not only aim to address traditional pedagogical challenges—such as rote memorization and the disconnect between theory and practice—but also seek to enhance student motivation, conceptual understanding, and academic performance in a subject historically perceived as difficult (Meza-Holguín et al., 2024; Quiñónez et al., 2024).

Among the most significant findings is the positive impact of methodologies such as problem-based learning (PBL) and integrated active learning, which foster real-world problem solving, collaborative work, and critical thinking. These strategies have proven to increase knowledge retention, improve the perceived usefulness of content, and develop transferable skills for professional contexts, as evidenced by Vera Velázquez et al. (2021) in the field of agricultural engineering. Similarly, Meza-Holguín et al. (2024) report a significant improvement in mathematical understanding when PBL, project-based learning, and cooperative learning are combined in an integrated approach.

The incorporation of emerging technologies, particularly Python programming and artificial intelligence, represents a disruptive innovation in the educational field. Studies such as Pinargote-Zambrano et al. (2024) show that teaching mathematics through programming tools not only supports the development of logical thinking but also increases student motivation and preference for interactive methods. Likewise, Román Cañizares (2024) and Silva Acuña et al. (2024) demonstrate that AI, by offering adaptive feedback and personalized content, improves academic performance and promotes more active participation. However, critical challenges are also highlighted, such as the digital divide, the need for specific teacher training, and attention to ethical principles in data use.

The proposal of a "smart" flipped classroom, which reorganizes the use of face-to-face and digital time, emerges as a viable alternative to enhance autonomous learning and meaningful classroom interaction. Although still limited in empirical implementation, this methodology promises to improve motivation and adapt to different learning paces (Durán & Vigueras, 2023). Similarly, post-pandemic virtual teaching has gained relevance by facilitating access and flexibility, although it presents limitations related to connectivity, social interaction, and reliable assessment (Giler-Velásquez, 2021).

A distinctive aspect of this review is the inclusion of socio-emotional education as a key component to improve performance in mathematics. As highlighted by Quiñónez et al. (2024), emotional self-regulation, empathy, and affective support reduce math anxiety, increase self-confidence, and foster deeper learning. This approach represents a humanizing shift in the teaching of exact sciences and underscores the importance of training teachers not only in technical skills but also in emotional competencies.

Despite the reported benefits, the effective implementation of these methodologies faces institutional, technological, and cultural barriers. Resistance to change from both teachers and students, lack of time and resources, and the absence of specific training continue to limit the widespread adoption of these strategies (Meza-Holguín et al., 2024; Vera Velázquez et al., 2021). Moreover, many innovative proposals still lack longitudinal validation or studies in diverse contexts, which prevents generalizing their effects.

This review supports the need for a transition from traditional models toward active, technological, and socio-emotional pedagogies that recognize students as active agents in their learning. In line with constructivist and metacognitive approaches, the reviewed methodologies promote more meaningful, contextualized, and equitable education. However, consolidating these advances requires a comprehensive educational policy that articulates ongoing teacher training, universal technological access, and a curriculum redesign focused on deep learning.

Future research should explore the longitudinal impact of these methodologies in different socioeconomic contexts, as well as their potential to reduce educational inequalities. It is also relevant to study how the combination of active strategies with artificial intelligence and socio-emotional approaches can generate synergies that further enhance mathematics learning. Finally, it is essential to investigate teacher training models that enable critical and contextualized appropriation of these pedagogical innovations.

CONCLUSION

The results of this systematic review reveal a significant pedagogical transformation in mathematics education in higher education within the Spanish-speaking context. Active methodologies, such as problem-based learning, cooperative learning, and the flipped classroom, have shown a positive impact on student motivation, conceptual understanding, and the development of critical and social skills. These strategies, by focusing on active student participation and real-world problem solving, represent a progressive departure from traditional approaches centered on unidirectional content transmission.

Likewise, the integration of emerging technologies, such as artificial intelligence and Python programming, has expanded the didactic possibilities of mathematics teaching, promoting personalized learning and adaptation to different student rhythms and styles. These innovations have shown improvements in academic performance and attitudes toward the subject, although persistent challenges remain, such as the digital divide, resistance to methodological change, and the need for specific teacher training.

Another relevant finding is the incorporation of the socio-emotional approach in mathematics teaching, which has proven essential for addressing factors such as anxiety, self-confidence, and learning readiness. This perspective fosters a more inclusive and human environment, facilitating meaningful knowledge construction and the holistic development of students.

Overall, the evidence gathered supports the need for educational reform that not only promotes innovative methodologies but also ensures structural and formative conditions for their effective implementation. This involves designing institutional policies that guarantee equitable access to technology, continuous teacher training in active and digital approaches, and curricular adjustments that coherently integrate these new pedagogical paradigms.

Ultimately, the convergence of active methodologies, emerging technologies, and humanistic approaches offers a promising path to transform mathematics education in higher education. However, this transformation requires a critical and contextualized perspective that acknowledges both the potential of these proposals and the structural challenges that must be overcome to ensure quality, inclusive, and relevant mathematics education for the demands of the 21st century.

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