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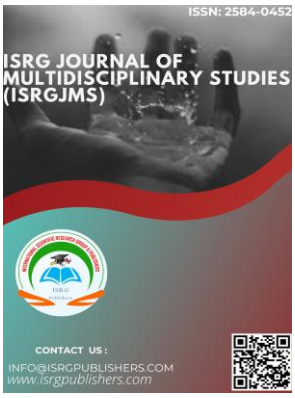

Realistic Mathematichs Education in Deep Learning Literature Review: Strengthening Critical Thinking and Problem Solving

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Abstract

Mathematics learning in primary and secondary schools still faces major challenges in the form of low critical thinking skills and student problem-solving due to conventional approaches that are memorized and less contextual. This study aims to comprehensively analyze the integration of Realistic Mathematics Education (RME) in the framework of Deep Learning as an innovative strategy to strengthen students' critical thinking and problem-solving skills. This study uses a systematic literature review method with the PRISMA approach. Data was obtained from 15 scientific journal articles published by 20242026 taken from the Google Scholar, Sinta, Garuda, and accredited national journals databases. The analysis was carried out through narrative synthesis and thematic analysis to identify synergies between the two approaches. The results of the review show that the integration of RME and Deep Learning produces a significant synergistic effect. RME provides real context and local culture as a foundation, while Deep Learning adds adaptivity, real-time feedback, visualization, and deep reflection. This combination consistently improves concept understanding, critical thinking, logical thinking, and problem-solving skills at various levels of education (elementary to high school). The integration of RME in Deep Learning has proven to be an adaptive, contextual, and meaningful learning model, in line with the Independent Curriculum. This hybrid approach is recommended to be widely applied to improve the quality of mathematics education in Indonesia.

Keywords: *Realistic Mathematics Education; Deep Learning; Critical Thinking; Troubleshooting; Math Learning*

INTRODUCTION

Mathematics learning at the primary and secondary school levels still faces complex challenges in the 21st century. Students often perceive mathematics as an abstract, elusive, and irrelevant subject to everyday life. This leads to a low level of students' critical thinking and problem-solving skills, which are essential competencies to face global demands (Ratnasari et al., 2025). Conventional learning approaches that are mechanistic and based on memorization have not been able to build a deep conceptual

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understanding, so students have difficulty connecting mathematical concepts with real context (Patmaniar et al., 2025).

This problem is further exacerbated by the low numeracy literacy and mathematical connection ability of students, especially in elementary and junior high schools. The main issues include the lack of use of cultural and daily life contexts in learning, limited technological facilities, and the lack of adaptive and interactive learning strategies. As a result, students tend to only master mathematical procedures without meaningful comprehension, which hinders the development of higher-level thinking skills such as analysis, evaluation, and synthesis (Wardani et al., 2025; Manggarrani et al., 2024). On the other hand, the Independent Curriculum emphasizes contextual and student-centered learning, so an innovative approach that integrates real context with deep learning technology is needed.

Various previous studies have shown the potential of Realistic Mathematics Education (RME) and Deep Learning approaches separately. RME has been shown to be effective in improving problem-solving abilities through the use of real-world contexts and the development of student worksheets (Manggarrani et al., 2024). Another study found that the implementation of RME significantly improved the mathematical connection ability of junior high school students (Wardani et al., 2025) as well as problem-solving skills in elementary school students (Riyanti et al., 2025). Meanwhile, the Deep Learning approach has a positive impact on mathematical critical thinking skills through conceptual understanding, reflection, and real-time personal feedback (Ratnasari et al., 2025; Patmaniar et al., 2025). Technology-based media such as GeoGebra also supports deep learning with dynamic visualization of geometry concepts, thereby improving students' understanding interactively (Sati et al., 2024).

Nonetheless, literature reviews that specifically integrate RME with Deep Learning to strengthen critical thinking and problem-solving are still limited. Some studies only discuss one approach or focus on specific aspects such as numeracy literacy and game-based learning (Marlinda et al., 2025; Hamidah et al., 2025). Therefore, this literature review aims to comprehensively analyze the integration of Realistic Mathematics Education in the framework of Deep Learning as an innovative strategy in mathematics learning. Thus, it is expected to provide practical recommendations for educators to create adaptive, contextual, and meaningful learning to improve the quality of mathematics education in Indonesia.

THEORETICAL FOUNDATION

The theoretical basis of this research is based on two main approaches to mathematics learning, namely Realistic Mathematics Education (RME) and Deep Learning (deep learning), which reinforce each other in building students' critical thinking and problem-solving skills. Both approaches were chosen because they have a strong philosophical and empirical foundation to address the low conceptual understanding of mathematics in primary and secondary schools.

1. Realistic Mathematics Education (RME)

Realistic Mathematics Education (RME) is a theory of mathematics learning developed in the Netherlands based on Hans Freudenthal's view that mathematics should be seen as *a human activity* and not just a finished product that is ready to be memorized (Freudenthal, 1973). According to Gravemeijer (1994), RME has three main principles of instructional design: (1) *guided reinvention*, (2) *didactical phenomenology*, and (3) *self-developed models* or *emergent modeling*. These principles emphasize that students learn mathematics through meaningful real-world contexts, so that abstract concepts can be built gradually from concrete to formal situations (van den Heuvel-Panhuizen & Drijvers, in press).

Some empirical research supports the effectiveness of RME. Manggarrani et al. (2024) found that RME-based LKS significantly improved the problem-solving skills of junior high school students through the use of real-world scenarios. In line with that, Wardani et al. (2025) proved that RME is superior to conventional learning in optimizing the mathematical connection ability of grade VII students. Riyanti et al. (2025) also reported a significant influence of RME on the problem-solving ability of 3rd grade elementary school students in the measurement material ($p = 0.000$). Widad and Hadi (2025) in their literature review concluded that RME is able to increase learning motivation and deep understanding because it connects mathematical concepts with daily life.

2. Deep Learning Approach in Learning

The term *Deep Learning* in the context of education refers to an in-depth learning approach that emphasizes conceptual understanding, reflection, and cognitive, affective, and metacognitive involvement of students, in contrast to the *surface learning* approach. This concept was first proposed by Marton and Säljö (1976) who distinguish two approaches to learning: deep approach (searching for meaning, connecting with previous knowledge, and thinking critically) and surface approach (only memorizing without deep understanding). Biggs (1987) developed a 3P (*Presage-Process-Product*) model which explains that the deep learning approach produces high-quality learning outcomes because students actively build knowledge meaningfully.

In mathematics learning, the deep learning approach has been shown to be effective in improving critical thinking and problem-solving. Ratnasari et al. (2025) through a quasi-experimental design found that students who received deep learning experienced a significant increase in mathematical critical thinking skills compared to the control group. Patmaniar et al. (2025) show that deep learning allows for the visualization of abstract concepts and real-time feedback, thus creating adaptive and interactive learning. Marlinda et al. (2025) in a literature review concluded that project-based deep learning strategies and interactive digital media improve numeracy literacy according to the Independent Curriculum. Hayati (2025) added that deep learning provides task difficulty adaptation and real-time feedback, thereby increasing students' thinking flexibility.

3. Critical Thinking and Mathematical Problem Solving

Critical thinking is the ability to analyze, evaluate, and synthesize information logically and systematically (Ratnasari et al., 2025). In mathematics, this ability is closely related to problem solving. Polya (1945) put forward four stages of problem-solving: understanding the problem, planning the strategy, executing the strategy, and evaluating the results. Schoenfeld (1985) expands on this framework by emphasizing the role of metacognitive knowledge and student beliefs in the problem-solving process.

Recent research shows that the integration of RME and deep learning is able to strengthen both capabilities. Hamidah et al. (2025) through a game-based approach based on local culture

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found an increase in mathematical literacy and student engagement. Ritonga et al. (2025) prove that RME based on Mandailing culture combined with deep learning significantly improves the logical thinking of high school students. Maharani et al. (2025) added that mindfulness-based deep learning supports holistic understanding of concepts in elementary school.

4. RME and Deep Learning Integration

The integration of RME as a contextual approach with deep learning as an in-depth approach creates strong synergies. RME provides real context as a starting point (*horizontal mathematization*), while deep learning encourages deep reflection and concept connection (*vertical mathematization*) (Gravemeijer, 1994; Marton & Säljö, 1976). Several studies have begun to explore this integration, including through numeracy puzzle media (Midiantini et al., 2026), hybrid game-based learning (Hamidah et al., 2025), and culture-based contextual strategies (Ritonga et al., 2025). However, a comprehensive literature review of the integration of these two approaches to strengthen critical thinking and problem-solving is still limited, making it the main focus of this study.

Thus, this theoretical foundation provides a solid conceptual foundation for the literature review to analyze how RME in the framework of deep learning can be an innovative strategy in mathematics learning in Indonesia.

RESEARCH METHODS

This study is a systematic literature review (SLR) with a qualitative approach. This method was chosen because the research aims to analyze, synthesize, and integrate findings from various empirical studies related to the integration of Realistic Mathematics Education (RME) in the framework of Deep Learning to strengthen students' critical thinking and problem-solving skills.

This research is qualitative descriptive with a systematic literature review design. The SLR approach is carried out following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency, replicability, and objectivity of the article selection process.

Primary data came from 15 scientific journal articles published between 20242026. These articles were obtained from open and indexed databases such as Google Scholar, Sinta, Garuda, and accredited national journals. All articles have gone through a peer-review process and are relevant to the research theme.

Data collection was carried out through the literature search stage with the keywords: Realistic Mathematics Education, Deep Learning, deep learning, mathematical critical thinking, mathematical problem solving, RME and Deep Learning, and its variations in Indonesian and English. Screening based on inclusion and exclusion criteria:

- **Inclusion criteria**: peer-reviewed article, year of publication 20242026, focus on RME and/or Deep Learning in elementary/junior high/high school mathematics learning, discussing critical thinking and/or problem-solving, full-text available.
- **Exclusion criteria**: articles are not scientific journals, duplicate, irrelevant, or only discuss one approach without integration.

Data analysis was carried out with two main techniques: Narrative synthesis to present a summary of the findings of each article, Thematic analysis to identify the main themes: RME principles, characteristics of Deep Learning, impact on critical thinking, impact on problem solving, and synergy of the two approaches.

RESULTS AND DISCUSSION

Literature searches on Google Scholar, Sinta, Garuda, and accredited national journals as databases yielded mixed results. In the search for articles, the keywords used are Deep Learning and Realistic mathematic education. The results in each database using the same keywords obtained a different number of related articles. In the keyword Deep Learning, From the search results, articles are filtered again according to the inclusion and exclusion criteria, so that a list of articles used is obtained, and presented in Table 1.

Table 1 RME and Deep Learning Article Search List Results

No.	Researcher (Year)	Journal Name (Year, Vol, No, Page)	Article Title
1	Patmaniar et al. (2025)	Abdimas Langkane (2025, Vol. 5, No. 1, p. 63)	Deep Learning in Mathematics Learning
2	Laras Sati, Rangga Firdaus & Herpratiwi (2024)	DIDACTICS (2024, Vol. 4, No. 4, pp. 404-414)	The Effectiveness of Using GeoGebra Software in Improving Understanding of Geometry Concepts in Students in Elementary School
3	Ratnasari, Nikmah Nurvicalesti & Ami Sulistia Wati (2025)	Algorithms: Journal of Mathematics, Natural Sciences, Earth and Space (2025, Vol. 3, No. 4)	Implementation of Deep Learning on Students' Mathematical Critical Thinking Skills
4	Anggita Manggarrani, Nafida Hetty Marhaeni & Ageng Triyono (2024)	EDUTREND: Journal of Emerging Issues and Trends in Education (2024, Vol. 1, No. 2)	Design of Realistic Mathematics Education Based Student Worksheets to Improve Students Mathematical Problem-Solving Skills
5	Yusifa Ratna Wardani, Nelly Fitriani & Risma Amelia (2025)	Journal of Innovative Mathematics Learning (2025, Vol. 8, No. 5, pp. 657-674)	Optimizing the Mathematical Connection Ability of Junior High School Students in Grade VII through the Implementation of the Realistic Mathematics Education Approach
6	- Stuart Stuart (2025)	caXra: Journal of Policy Research and Basic Education Science (2025, Vol. 05,	Deep Learning Approach in Improving Numeracy Literacy in Elementary Schools: Literature Review

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No.	Researcher (Year)	Journal Name (Year, Vol, No, Page)	Article Title
		No. 02, pp. 541-554)	
7	Riyanti, Rayi Siti Fitriani & Acep Ruswan (2025)	caXra: Journal of Policy Research and Basic Education Science (2025, Vol. 05, No. 02, pp. 729-738)	The Influence of the Realistic Mathematics Education Model on the Mathematical Problem-Solving Ability of Grade 3 Elementary School Students
8	Ida Hamidah, Zulkardi, Ratul Ilma Indra Putri & Surya Amami Pramuditya (2025)	Journal on Mathematics Education (2025, Vol. 16, No. 4, pp. 1407-1430)	Developing and Evaluating a Hybrid Game-Based Learning Environment for Teacher Facilitation in Mathematical Literacy
9	Haffadah Dwi Widad & Muhamad Sofian Hadi (2025)	JIIP (Scientific Journal of Educational Sciences) (2025, Vol. 8, No. 2, pp. 2309-2315)	Realistic Mathematics Education, Problem-Solving Skills, and Mathematics Learning in Elementary Schools
10	Ria Norfika Yuliandari & Nurul Izhan Pepridel Yulanda (2025)	Pendas: Scientific Journal of Basic Education (2025, Vol. 10, No. 03, p. 406)	Contextual-Based Deep Learning Strategies to Improve Practical Intelligence in Mathematics Learning
11	Rahmi Hayati (2025)	Indonesian Educator Journal (2025, Vol. 6, No. 1, p. 29)	The Role of Deep Learning in Improving Students' Problem-Solving Skills
12	Aprillia Anggi Midiantini, Suyoto & Rintis Rizkia Pangestika (2026)	e-DuMath Journal (2026, Vol. 12, No. 1, pp. 216-228)	The Influence of Deep Learning Assisted by Numeracy Puzzles on Problem-Solving Skills
13	Dahroni, Zul Andry Saputra, Hendar Restiani, Margareta Ayu & Rina Hidayati Pratiwi (2025)	Algebra: Journal of Educational, Mathematical and Earth Sciences (2025, Vol. 1, No. 3)	Comparison of the Effectiveness of Deep Learning and Differentiation on Junior High School Students' Mathematical Problem-Solving and Reasoning Skills
14	Lily Maharani, Arie Rakhmat Riyadi & Neni Maulida (2025)	Pendas: Scientific Journal of Basic Education (2025, Vol. 10, No. 2, p. 125)	Deep Learning in Mathematics Learning in Elementary School
15	- Idris Ritonga et al. (2025)	Riemann: Research of Mathematics and Mathematics Education (2025, Vol. 7, Issue 2, pp. 111-120)	The Effectiveness of Realistic Mathematics Learning Based on Mandailing Culture with a Deep Learning Approach In Improving Logical Thinking Skills

The article on the data above is then examined to discuss and relationship between RME and Deep Learning, the results of the study are presented in Table 2.

Table. 2 Results of the discussion and relationship between RME and Deep Learning

No.	Author	Title	Main Discussion	Relationship to Themes (RME + Deep Learning)
1	Patmaniar, Muhammad Ilyas, Marufi, Syamsu Alam, Taufiq, Nisraeni, Fitriani A.	Deep Learning in Mathematics Learning	Community Service Activities (PkM) introduced concepts, applications, and the potential of deep learning for visualization of abstract concepts and real-time personal feedback to junior high school Mathematics MGMP teachers. Results: improved concept understanding, learning motivation, and adaptive-interactive learning.	Deep learning (AI) as a supporting tool for RME to strengthen deep understanding and problem-solving through real-world visualization.
2	Laras Sati, Rangga Firdaus & Herpratiwi	The Effectiveness of Using GeoGebra Software in Improving Understanding of Geometry Concepts in	Literature review: GeoGebra improves the understanding of geometry (flat shapes, angles, symmetry,	GeoGebra as a supporting media for RME-based deep learning in building a concrete understanding of geometry

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No.	Author	Title	Main Discussion	Relationship to Themes (RME + Deep Learning)
		Students in Elementary School	transformations) through dynamic and interactive visualization. Challenge: teacher skills and technology facilities.	concepts and improving problem solving.
3	Ratnasari, Nikmah Nurvicalesti, Ami Sulistia Wati	Implementation of Deep Learning on Students' Mathematical Critical Thinking Skills	Quasi-experiment (pretest-posttest control group): the deep learning approach significantly improved the mathematical critical thinking skills of grade VIII students compared to conventional learning.	Deep learning directly strengthens critical thinking as the core of RME for mathematical problem-solving.
4	Anggita Manggarrani , Nafida Hetty Marhaeni, Ageng Triyono	Design of Realistic Mathematics Education Based Student Worksheets to Improve Students Mathematical Problem-Solving Skills	Research Design (iterative): RME-based worksheets with real-world context improve the problem-solving skills of junior high school students.	RME as the foundation of deep learning for the development of meaningful LKS and improved problem-solving.
5	Yusifa Ratna Wardani, Nelly Fitriani, Risma Amelia	Optimizing the Mathematical Connection Ability of Junior High School Students in Grade VII through the Implementation of the Realistic Mathematics Education Approach	Mixed method: RME is superior to conventional learning in improving the mathematical connection skills of grade VII students.	RME is a concrete form of deep learning that strengthens the connection of concepts → critical thinking and problem-solving.
6	Sherly Marlinda, Taofik, Julius Sagita	Deep Learning Approach in Improving Numeracy	Literature review (1,800 articles, 6 selected):	Contextual-based deep learning is the main strategy

No.	Author	Title	Main Discussion	Relationship to Themes (RME + Deep Learning)
		Literacy in Elementary Schools: Literature Review	project-based learning, interactive digital media, and active participation of students improve concept understanding, motivation, and critical thinking according to the Independent Curriculum.	for numeracy literacy that is in line with RME principles.
7	Riyanti, Rayi Siti Fitriani, Acep Ruswan	The Influence of the Realistic Mathematics Education Model on the Mathematical Problem-Solving Ability of Grade 3 Elementary School Students	Quasi-experiment: RME had a significant effect (p=0.000) on the problem-solving ability of grade 3 elementary school students (length and weight measurement material).	RME directly improves problem-solving as a form of deep learning at the elementary level.
8	Ida Hamidah, Zulkardi, Ratul Ilma Indra Putri, Surya Amami Pramuditya	Developing and Evaluating a Hybrid Game-Based Learning Environment for Teacher Facilitation in Mathematical Literacy	Design research + evaluation of Guskey: a hybrid game-based environment (RPG based on religious tourism in Cirebon) improves mathematics literacy and student engagement.	Hybrid game-based as an implementation of RME-based deep learning with the context of local culture.
9	Haffadah Dwi Widad, Muhamad Sofian Hadi	Realistic Mathematics Education, Problem-Solving Skills, and Mathematics Learning in Elementary	Literature study: RME connects mathematical concepts with everyday life thereby improving problem-	RME as a core approach to deep learning to strengthen problem-solving in elementary schools.

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No.	Author	Title	Main Discussion	Relationship to Themes (RME + Deep Learning)
		Schools	solving, motivation, and deep understanding.	
10	Ria Norfika Yuliandari, Nurul Izhan Pepridel Yulanda	Contextual-Based Deep Learning Strategies to Improve Practical Intelligence in Mathematics Learning	Literature review: the mathematical foundations of deep learning (linear algebra, calculus, optimization) + latent context representation result in adaptive and contextual learning.	Contextual-based deep learning as an RME reinforcement for practical intelligence and problem solving.
11	Rahmi Hayati	The Role of Deep Learning in Improving Students' Problem-Solving Skills	Qualitative (observations, interviews, documents): deep learning provides real-time feedback, difficulty adaptation, and increases motivation and flexibility of thinking.	Deep learning technology as a support for RME in the development of problem-solving skills.
12	Aprillia Anggi Midiantini, Suyoto, Rintis Rizkia Pangestika	The Influence of Deep Learning Assisted by Numeracy Puzzles on Problem-Solving Skills	Pre-experiment (one group pretest-posttest): deep learning + numeracy puzzles increased the problem solving score of grade I elementary school from 81.79 to 97.89 ($p < 0.001$).	Deep learning assisted by concrete media (puzzles) is in line with the principles of RME for solving numeracy problems.
13	Dahroni, Zul Andry Saputra, Hendar Restiani, Margareta Ayu, Rina Hidayati Pratiwi	Comparison of the Effectiveness of Deep Learning and Differentiation on Junior High School Students' Mathematical	Quasi-experimental: deep learning is more effective than differentiation in improving the mathematical reasoning and	Deep learning excels in depth of thinking over differentiation; integration of both is recommended for RME.
		Problem-Solving and Reasoning Skills	problem-solving of junior high school students.	
14	Lily Maharani, Arie Rakhmat Riyadi, Neni Maulida	Deep Learning in Mathematics Learning in Elementary School	Literature review (10 articles): deep learning + mindfulness improves concept understanding, critical thinking, creative, and analytical in elementary school.	Deep learning is mindfulness-based as a holistic approach that strengthens RME at the basic level.
15	Including Idris Ritonga et al.	The Effectiveness of Realistic Mathematics Learning Based on Mandailing Culture with a Deep Learning Approach In Improving Logical Thinking Skills	Development research (ADDIE): RME based on Mandailing culture + deep learning significantly improves the logical thinking of high school students.	Direct integration of RME (local cultural context) with deep learning to strengthen logical thinking and problem-solving.

This study analyzes 15 scientific articles published 20242026 relevant to the integration of Realistic Mathematics Education (RME) in the framework of Deep Learning to strengthen students' critical thinking and problem-solving skills.

Ten articles (No. 4, 5, 7, 9, 15, and others) consistently show that RME is able to connect mathematical concepts with real-world contexts and local cultures. This approach has been proven to improve problem-solving skills (Riyanti et al., 2025; Manggarrani et al., 2024) and mathematical connections (Wardani et al., 2025). When combined with deep learning, RME becomes more powerful because it provides concrete context as a starting point (horizontal mathematization).

Eight articles emphasize the role of deep learning in creating adaptive, interactive, and reflective learning. This approach provides real-time feedback, visualization of abstract concepts, and difficulty adaptation (Patmaniar et al., 2025; Livingston, 2025; Ratnasari et al., 2025). The results of the experiment showed a significant increase in critical thinking skills (Ratnasari et al., 2025) and problem-solving (Midiantini et al., 2026; Dahroni et al., 2025).

All 15 articles support that the integration of the two approaches produces synergistic effects. RME provides meaningful context,

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while deep learning guarantees deep understanding, reflection, and adaptivity. The most powerful example of integration is seen in the use of concrete media (puzzles, GeoGebra, game-based, local culture) which results in significant improvements in critical thinking, logical thinking, and problem-solving skills at various levels of education (elementary to high school).

CONCLUSION

Based on a literature review of 15 scientific articles, it can be concluded that the integration *of Realistic Mathematics Education* (RME) in the *framework of Deep Learning* is a very effective learning strategy to strengthen students' critical thinking and problem-solving skills. RME provides a contextual and meaningful foundation, while deep learning adds an adaptive, reflective, and immersive technological dimension. The combination of the two is able to overcome the weaknesses of conventional learning that are memorized and abstract.

Key findings show consistent and significant improvements in:

- Understanding of mathematical concepts,
- Critical thinking and logical thinking skills,
- Problem-solving skills,
- Student motivation and engagement.

Therefore, this study recommends that educators and curriculum developers adopt the RME-Deep Learning hybrid learning model, especially by utilizing contextual media (local culture, game-based, numeracy puzzles, and visualization software). This approach is very much in line with the spirit of the Independent Curriculum which emphasizes project-based, contextual, and student-centered learning.

Further research is suggested to test this integration model through large-scale experimental design, development of ready-to-use learning modules, as well as long-term evaluation of students' knowledge retention and skill transfer.

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