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How EtnoEduction is Essential and Linked to the Science Learning in the 21st Century Paradigm?

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ABSTRAK

Meningkatkan kualitas pendidikan sains di sekolah dasar tidak hanya penting untuk menumbuhkan pemahaman sains yang lebih baik, namun juga untuk membangun landasan yang kuat bagi pemikiran dan tindakan ilmiah di masa depan. Tinjauan sistematis ini bertujuan untuk mengeksplorasi dan menganalisis berbagai metode dan strategi pembelajaran sains yang efektif di sekolah dasar pada abad ke-21. Tinjauan sistematis ini dirancang berdasarkan kriteria yang relevan dari Item Pelaporan Pilihan untuk Tinjauan Sistematis dan Meta-Analisis (PRISMA). Data bersumber dari pemanfaatan database elektronik seperti PubMed, ERIC, Scopus, dan Google Scholar. Kata kunci pencarian yang digunakan antara lain "pembelajaran sains efektif", "sains di sekolah dasar", dan "abad 21". Semua makalah ditinjau dan penilaian kualitas dilakukan. Lima belas studi akhirnya dipilih. Data diekstraksi, diorganisasikan dan dianalisis menggunakan sintesis naratif. Ada beberapa faktor yang mempengaruhi efektifnya pendidikan sains di abad ke-21, antara lain penggabungan teknologi digital, unsur budaya, pembelajaran kontekstual, pendekatan adaptif, dan metode berbasis kompetensi. Strategi yang cocok untuk mendukung pendidikan sains ini antara lain pembelajaran berbasis inkuiri, pembelajaran berbasis proyek, pembelajaran kooperatif, pembelajaran berbasis eksperimen, dan pembelajaran berbasis permainan. Akibatnya, siswa mendapatkan manfaat besar dari pendidikan etno-sains yang disampaikan melalui aplikasi pembelajaran digital yang berakar pada konteks budaya lokal

ABSTRAK

Improving the quality of science education in elementary schools is not only crucial for fostering better understanding of science, but also for building a strong foundation for future scientific thinking and actions. This systematic review aims to explore and analyze various effective methods and strategies of science learning in elementary schools in the 21st century. This systematic review was designed based on relevant criteria from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The data were sourced from the utilization of electronic databases such as PubMed, ERIC, Scopus, and Google Scholar. The search keywords employed included "effective science learning", "science in elementary schools", and "21 century". All papers were reviewed and quality assessment was performed. Fifteen studies were finally selected. Data were extracted, organized and analysed using a narrative synthesis. There are several factors influencing effective science education in the 21st century, including the incorporation of digital technology, cultural elements, contextual learning, adaptive approaches, and competency-based methods. Suitable strategies to support this science education include inquiry-based learning, project-based learning, cooperative learning, experiment-based learning, and game-based learning. Consequently, students greatly benefit from ethno-science education delivered through digital learning applications rooted in local cultural contexts.

1. INTRODUCTION

Science learning in elementary schools (SD) plays a crucial role in preparing the next generation to face the challenges of the 21st century. In an era where technology and knowledge are rapidly advancing, there is a heightened urgency to establish a strong scientific foundation from an early age (Hau et al., 2020;

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Kartimi et al., 2021). Effective science learning not only focuses on teaching basic scientific concepts but also aims to develop critical, creative, and collaborative thinking skills. These skills are not only essential for understanding science but also for preparing students to tackle complex problems they may encounter in the future (Lai & Hong, 2015; Sefriani & Sepriana, 2022).

Furthermore, the integration of Information and Communication Technology (ICT) in elementary school science education is becoming increasingly crucial. The use of digital tools can enrich students' learning experiences, enabling them to explore scientific concepts more deeply and interactively (Bagon et al., 2018; Ratheeswari, 2018). Learning approaches that emphasize active and project-based learning also help enhance students' learning motivation and develop their ability to apply scientific knowledge in real-world contexts. Education in elementary schools focuses not only on absorbing information but also on building a sustainable knowledge foundation. Through this approach, students are not only taught scientific concepts but also given opportunities to hone their critical and analytical thinking skills (Amir, 2020; Tabroni et al., 2021). Consequently, they not only understand natural phenomena but also develop the thinking skills necessary to tackle future challenges.

Student-centered science learning plays a key role in fostering deep curiosity. By providing students with opportunities to take an active role in exploration and experimentation, they can develop a deeper understanding of scientific concepts. This approach also teaches students to become independent learners, enabling them to explore and discover creative solutions to complex problems (Fearnley & Amora, 2020; Sefriani & Sepriana, 2022). Science learning that supports an experimental approach is not just about understanding theory, but also about applying knowledge in practical contexts. By participating in experiments and practical activities, students not only see scientific concepts in texts but also experience and understand them in real life. This not only enhances their understanding of the subject matter but also prepares them to be innovators capable of facing future changes and complexities (Shaalan, 2018; Yamin et al.,2020).

Thus, improving the quality of science education in elementary schools is not only crucial for fostering better understanding of science, but also for building a strong foundation for future scientific thinking and actions (Labouta et al., 2018; Made et al., 2022). Through this research, it is expected that practical strategies and recommendations can be identified for curriculum development and teaching practices that promote effective and relevant science learning aligned with contemporary demands.

In this context, this research aims to explore and analyze various effective methods and strategies of science learning in elementary schools in the 21st century. Through this approach, it is hoped that strategies enhancing understanding of scientific concepts and preparing students to become lifelong independent and innovative learners can be identified. Additionally, this study aims to provide concrete recommendations for the development of curriculum and improved teaching practices in the future, aligned with the ever-changing demands of the times. By exploring the potentials and challenges in elementary school science education, this research is expected to make a significant contribution to advancing science education at the primary level, supporting the goals of sustainable educational development, and preparing the younger generation to become competitive global leaders in the future.

2. METHOD

This systematic review is designed based on relevant criteria from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021). PRISMA provides stringent guidelines to ensure that the review process is conducted systematically, transparently, and replicable. Criteria for Inclusion including: 1.) Studies focusing on effective science learning in elementary schools in the 21st century era. 2.) Articles published in recognized, peer-reviewed journals. 3.) Research encompassing teaching methods, effectiveness, and evaluation of these skills. Criteria for Exclusion: 1.) Studies not focused on the development of effective science learning in elementary schools in the 21st century era. 2.) Non-scientific articles, such as editorials, opinions, and non-peer-reviewed reports. 3.) Studies lacking empirical data or adequate analysis.

Literature search strategies involve using electronic databases such as PubMed, ERIC, Scopus, and Google Scholar. Keywords used in the search include "effective science learning" "science in elementary schools," and "21 century learning". The search was conducted without time restrictions to gain a comprehensive understanding of historical developments and current trends. The initial search yielded a total of 1.200 relevant articles. Following identification, identified articles were screened based on their titles and abstracts to eliminate irrelevant or duplicate articles. This screening ensured that only articles meeting the inclusion criteria proceeded to the next stage. After the initial screening, 350 articles were identified. Articles passing the screening stage were then fully assessed by reading the full texts. At this

stage, articles not meeting the inclusion criteria or meeting the exclusion criteria were removed from the list. After eligibility assessment, 50 articles were identified. The remaining articles were then evaluated for their quality using critical appraisal tools such as the Critical Appraisal Skills Programme (CASP) and Joanna Briggs Institute (JBI) checklist. This assessment included internal validity, data reliability, and relevance of findings. Articles failing to meet the established quality standards were excluded from the final list. Following quality appraisal, 15 articles remained. The data screening process is illustrated in Figure 1.

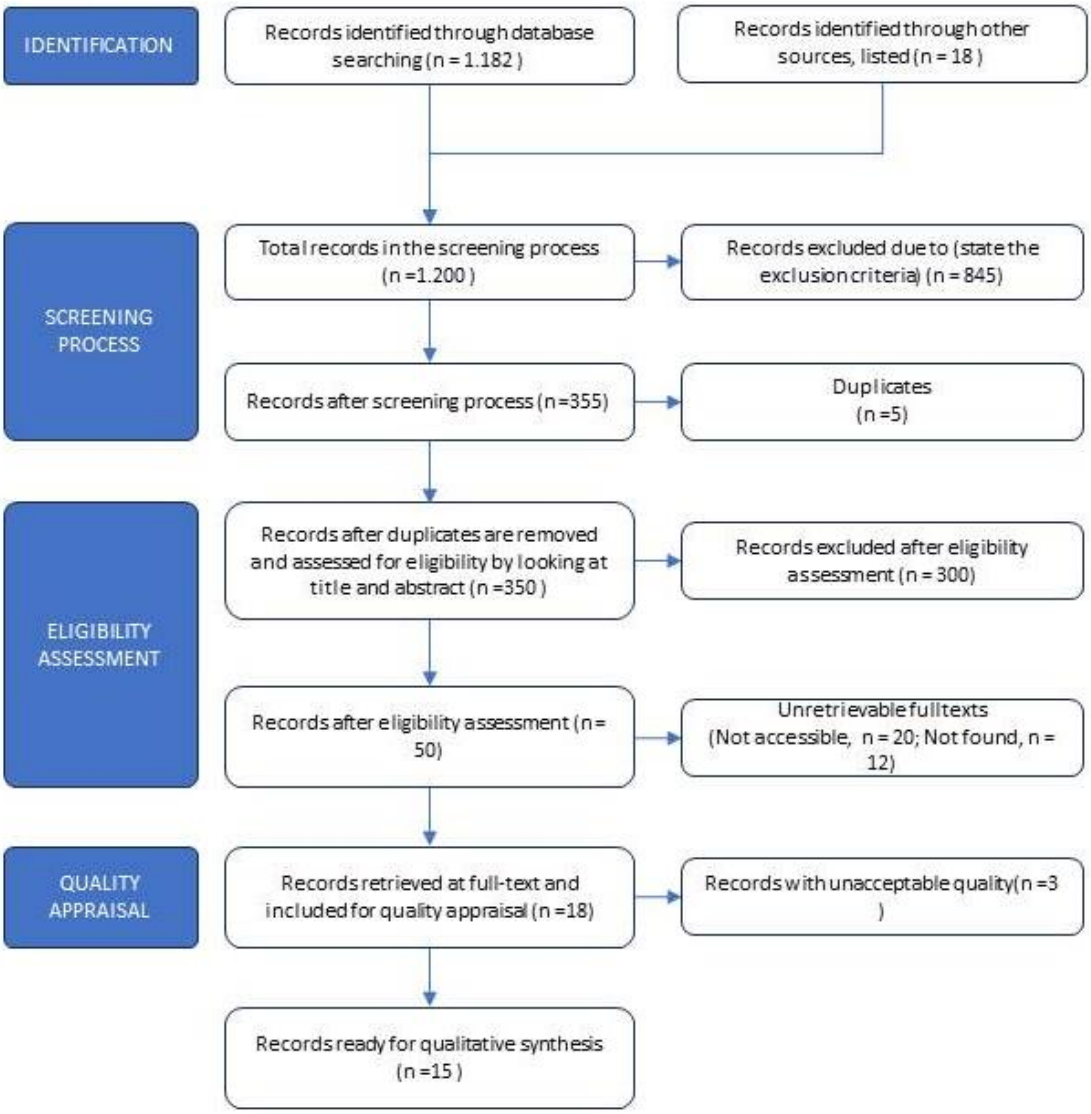

Figure 1. The Data Screening Process

Data were extracted from each included study using a standardized data extraction form that encompassed information on the authors, year of publication, research objectives, methods, key findings, and recommendations. The extracted data were then synthesized narratively to present a comprehensive overview of the existing literature, identify patterns, and provide insights for practical and policy implications.

3. RESULT AND DISCUSSION

Results

Effective Science Learning in the 21st Century

Based on the synthesis results, researchers identified two categories: effective science learning in the 21st century and learning strategies to improve science in elementary schools. The findings are illustrated through the framework in Figure 2 and further elaborated in the subsequent subsection.

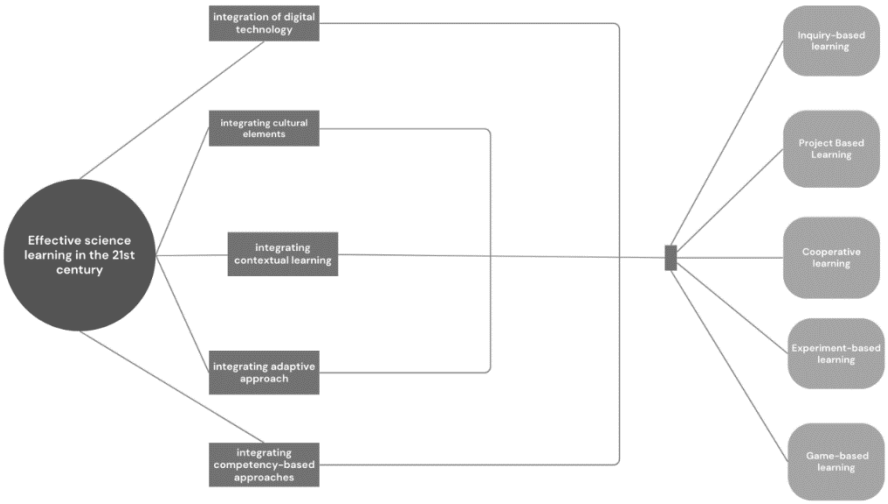

Figure 2. Research Findings Framework

Effective science learning in the 21st century heavily relies on the integration of digital technology in the learning process. Utilizing digital devices such as tablets, computers, and educational software enables teachers to create interactive and engaging learning environments for students (Dewanti et al., 2021; Sulasmi, 2022). Previous research indicates that digital technology not only facilitates access to diverse and rich information sources but also supports the implementation of more personalized and adaptive learning methods tailored to individual student needs (Granić & Marangunić, 2019). By employing simulation applications and visualization tools, complex scientific concepts can be explained in a more understandable manner. Furthermore, other studies highlight that digital-based learning allows students to conduct virtual experiments that may be difficult or even impossible to perform in a physical classroom (Blumberg & Fisch, 2013; Zen et al., 2022). This not only enriches students' learning experiences but also develops critical skills and problem-solving abilities essential in this digital era. As a result, digital-based science learning not only enhances students' understanding of the subject matter but also prepares them to face the challenges of an increasingly connected and technology-driven world.

Effective science learning in the 21st century requires an innovative approach that is culturally relevant to students. Previous research findings indicate that integrating cultural elements into science education, known as ethno-science approach, can enhance students' understanding of concepts and engagement (Ginzburg & Barak, 2023; Vartiainen et al., 2016). This approach utilizes local and traditional knowledge within communities and connects them with modern scientific concepts. For instance, in biology education, using traditional medicinal plants as teaching materials can provide a deeper understanding of biodiversity and its benefits (Rukiyati Sugiyo & L. Andriani Purwastuti, 2017; Surtikanti et al., 2017). Furthermore, ethno-science helps students see the relevance of science in their daily lives, fostering higher curiosity and learning motivation. Thus, this culturally-based approach not only enriches learning experiences but also develops students' critical and creative thinking skills, which are essential competencies in the 21st century.

Effective science learning in the 21st century demands innovative and relevant approaches to real-life situations, one of which is contextual learning. Based on previous research findings, contextual learning has shown significant improvements in students' understanding and engagement (Vaportzis et al., 2017). This approach emphasizes the connection of subject matter to everyday life contexts, enabling students to see the relevance and practical application of the concepts they learn. It aligns with constructivist theory, which posits that knowledge is built through experience and interaction with the environment (Alkhudiry, 2022; Xu & Shi, 2018). Contextual learning also develops critical thinking skills and problem-solving abilities, crucial in this information age. By incorporating real-life situations into the learning process, students are more motivated and have opportunities to apply their knowledge in various different scenarios. These findings underscore the importance of integrating real-life contexts into science curricula to create more meaningful and effective learning experiences in the 21st century.

Effective science learning in the 21st century requires an adaptive approach, as highlighted by various previous studies. In this context, adaptive learning refers to the curriculum's and teaching methods' ability to adjust to the individual needs, abilities, and learning styles of students. Research by previous study indicates that an adaptive approach enables teachers to provide materials that align with each student's

level of understanding and skills, thereby maximizing their learning potential (Taufiq et al., 2019). Furthermore, other research found that adaptive educational technologies, such as computer-based learning systems that adjust in real-time to students' performance, can significantly enhance learning outcomes (Granić & Marangunić, 2019; Wu & Chen, 2020). In this digital era, the ability to tailor learning to the dynamics and advancements of technology is increasingly crucial. Therefore, adaptive-based science learning offers flexibility and personalization that not only enhance student engagement but also cultivate critical skills necessary to tackle 21st-century challenges.

Effective science learning in the 21st century increasingly emphasizes the importance of competency-based approaches. Previous research findings indicate that this approach can facilitate the development of skills relevant to contemporary demands (Tise et al., 2023). Competency-based learning not only focuses on knowledge transfer but also on fostering critical thinking, problem-solving, collaboration, and creativity skills. This aligns with the need for graduates who are prepared to face global challenges and rapid technological changes. Other research suggests that competency-based approaches can enhance student engagement and learning outcomes, as students are more actively involved in the learning process (Prasetyono et al., 2021; Wanchana et al., 2020). Moreover, this approach allows for more authentic and sustainable assessment, where student progress can be measured based on specific competency achievements. Therefore, integrating competency-based learning into the 21st-century science curriculum represents a strategic step toward preparing competent and adaptable younger generations for the future.

Learning Strategies to Improve Science in Elementary Schools

Various previous studies have shown that inquiry-based learning strategies are highly effective in enhancing science learning in elementary schools. This strategy actively engages students in the learning process, encouraging them to ask questions, formulate hypotheses, and conduct experiments to discover their own answers. Through this approach, students not only memorize scientific facts but also develop critical thinking skills and problem-solving abilities. For example, a study by previous study found that students engaged in inquiry-based learning demonstrated deeper conceptual understanding and were able to apply their knowledge in new contexts (Gray, 2017). Furthermore, other research supports these findings by stating that inquiry-based learning strategies significantly improve students' science learning outcomes compared to traditional teaching methods (Hong et al., 2021). Thus, implementing inquiry-based learning strategies in elementary schools not only enhances students' understanding of scientific concepts but also equips them with the skills necessary for success in the 21st century.

Project-Based Learning (PBL) has proven to be an effective strategy in enhancing science mastery in elementary schools. Based on various previous studies, PBL can encourage students to actively engage in the learning process through relevant and contextual projects. This method allows students to integrate theoretical knowledge with practical applications, thereby enhancing their understanding of scientific concepts (Barth et al., 2019; Dewi et al., 2019). Additionally, PBL supports the development of 21st-century skills such as critical thinking, creativity, and collaboration. Previous study indicated that students involved in PBL showed significant improvements in science learning outcomes compared to conventional methods (Slough & Milam, 2013). Another research revealed that through PBL, students not only learn scientific content but also essential scientific reasoning skills necessary for solving real-world problems (Aksela.M. & HaatainenO, 2019). Thus, the implementation of PBL in elementary schools emerges as a promising learning strategy to prepare students to face educational and life challenges in the future.

Cooperative learning has been proven to be an effective strategy in enhancing science education in elementary schools. According to various studies, cooperative learning not only improves students' understanding of scientific concepts but also develops their social and communication skills (Bui & Fagan, 2013; Wijayanti & Pratomo, 2019). This method encourages students to work in small groups, where they can support each other and share knowledge. Other research indicates that students engaged in cooperative learning show significant improvements in science learning outcomes compared to those who learn individually (Jalinus et al., 2019). Furthermore, other study found that cooperative learning enhances students' intrinsic motivation and increases their interest in scientific subjects (Arphattananon, 2021; Imran et al., 2011). This approach also enables students to engage in deep discussions and collaboratively solve problems, thereby strengthening their understanding of scientific concepts. Therefore, implementing cooperative learning strategies in elementary schools can be crucial in enhancing the quality of science education and preparing students for academic challenges in the future.

Based on previous research findings, effective learning strategies to enhance science education in elementary schools involve utilizing an experimental learning approach (Afriana et al., 2016; Gilmanova, 2018). This approach has proven effective as it allows students to learn through direct experience, applying

scientific principles, and developing their critical thinking skills. Through conducting experiments, students not only grasp theoretical knowledge but also experience scientific concepts in practical contexts. This not only enhances their understanding of the subject matter but also fosters curiosity and improves their analytical and evaluative skills (Tytler & Prain, 2022; Wahyuni et al., 2017). Additionally, this approach facilitates more interactive and enjoyable teaching, encouraging active student participation in the learning process.

Previous research indicates that game-based learning strategies are effective in enhancing elementary school students' understanding of scientific concepts (Dam et al., 2019). In this context, the use of games as a learning tool has been proven to increase student engagement and reinforce information retention. Specifically designed games can create an interactive and enjoyable learning environment, allowing students to actively participate in exploration and experimentation. Moreover, the competitive aspects of games can stimulate intrinsic motivation among students, thereby deepening their understanding of complex scientific concepts (Farihah et al., 2021; Hwang et al., 2022). Thus, implementing game-based learning strategies not only facilitates active learning but also enhances the effectiveness of science teaching at the elementary level.

Discussion

Based on the analysis, there are some factors that impact the effective science learning in the 21st century such as, integration of digital technology, integrating cultural elements, integrating contextual learning, integrating adaptive approach and integrating competency-based approaches. The strategies that suitable applied in support this science learning is inquiry-based learning, project based learning, cooperative learning, experiment-based learning, and game-based learning. Therefore, based on this problem, students really need ethnoscience learning packaged in the form of digital learning applications based on local culture.

The digital ethnoscience learning application is expected to integrate contextual learning with an adaptive approach. This approach allows the application to customize the learning experience based on the needs and characteristics of individual students. By utilizing local content or ethnosciences, the application not only presents information contextually in accordance with local wisdom but also adapts the learning approach according to each student's learning abilities (Dewi et al., 2019; Hikmawati et al., 2021). This enables students to engage more deeply in the learning process, enhances learning motivation, and strengthens the connection between abstract scientific concepts and the realities they experience daily. Thus, the digital ethnoscience learning application serves not only as an informative learning tool but also as an adaptive and relevant tool within the students' learning contexts.

The Digital Ethnoscience Learning Application not only presents content that integrates local knowledge with science through digital technology, but also provides various activities that support modern learning strategies. These include inquiry-based learning, where students are encouraged to ask questions, investigate, and discover answers on their own through exploration within the application (Dewi et al., 2019; Puspasari et al., 2019). Additionally, the application facilitates project-based learning, where students can work on collaborative projects to solve given challenges or problems, as well as cooperative learning, which promotes teamwork and peer-to-peer learning among students (Hanif et al., 2019; Sari & Angreni, 2018; Sefriani & Sepriana, 2022).

The Digital Ethnoscience Learning Application not only presents content that integrates local knowledge with science through digital technology, but also provides various activities that support modern learning strategies. These include inquiry-based learning, where students are encouraged to ask questions, investigate, and discover answers on their own through exploration within the application. Additionally, the application facilitates project-based learning, where students can work on collaborative projects to solve given challenges or problems, as well as cooperative learning, which promotes teamwork and peer-to-peer learning among students.

This research employs Systematic Literature Review (SLR) to ensure that the collected and analyzed data originate from reliable sources that have undergone rigorous evaluation processes. SLR enables researchers to access and assess numerous relevant studies, providing a more comprehensive perspective on the discussed topic. By analyzing various studies, SLR can identify key trends, research gaps, and offer evidence-based recommendations for educational practices and policies. This study provides deep insights into the importance of effective science learning in the 21st century, and how these skills can be applied in the context of elementary education. However, not all relevant studies may be accessible, especially those published in journals with limited access or outside the databases used. Studies included in SLR may exhibit variability in methodology and research quality, which can influence the reliability of findings. It is recommended for future research to continue the results of this research by designing digital

ethno-science learning application. Additionally further research is recommend conducting direct field empirical research in primary schools to observe and measure the effectiveness of science learning process. This research could take the form of case studies, experiments, or surveys involving both teachers and students.

4. CONCLUSION

There are several factors influencing effective science education in the 21st century, including the incorporation of digital technology, cultural elements, contextual learning, adaptive approaches, and competency-based methods. Suitable strategies to support this science education include inquiry-based learning, project-based learning, cooperative learning, experiment-based learning, and game-based learning. Consequently, students greatly benefit from ethno-science education delivered through digital learning applications rooted in local cultural contexts.

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