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An Overview of Decentralized Cooperative Learning Strategies (Dec-LS) in Enhancing Student Proficiency in Solving Quadratic Equations

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Abstract. This literature study examined how Decentralized Cooperative Learning Strategies (DeC-LS) can enhance students' ability to solve quadratic equations. DeC-LS encourages collaborative learning, where students work together in small groups, take charge of their education, and share information to solve Mathematics problems. The review suggests that DeC-LS enhances student involvement, problem-solving abilities, and conceptual comprehension, making it an effective method for studying complex mathematical concepts. However, barriers to the successful implementation of DeC-LS include issues with classroom management, technological limitations, cultural resistance to nontraditional methods, and a lack of professional development for teachers. The evaluation advocates for the provision of sufficient resources, educator training, and institutional backing to facilitate the adoption of more student-centered, interactive pedagogical approaches. Confronting these problems will cultivate more inclusive and effective educational settings, hence improving student performance in mathematics, especially in the resolution of quadratic equations.

Keywords: Decentralized cooperative learning strategies; Mathematical problems; Proficiency; Quadratic equations; Technological barriers.

1.0 Introduction

Understanding the notion of Mathematics presents a significant challenge for many learners nowadays, particularly in comprehending quadratic equations. Based on the DepEd K-12 Curriculum Guide, subsequently updated to the Essential Learning Competencies (MELCs), ninth-grade students must be capable of solving quadratic equations in a single variable by methods such as extracting square roots, factoring, completing the square, and employing the quadratic formula. Students often encounter numerous challenges when studying the topic, which can significantly impact their comprehension and mastery of the material. Most students experience difficulties with the diverse techniques for solving quadratic equations, including factoring, completing the square, and using the quadratic formula, all of which require a profound understanding of algebraic manipulation and procedural methodologies. This underscores the importance of a robust mathematical foundation and ongoing, structured learning to support student achievement in more challenging subjects.

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Fateh et al. (2024) assert that students who participate in small-group interactions, exchanging knowledge and responsibilities, are more likely to achieve learning objectives. Subsequent research has consistently demonstrated that students participating in group interactions experience improved academic performance and acquire numerous cognitive and social benefits (Wang & Hofkens, 2020). This method adheres to the tenets of cooperative learning, wherein students engage in collaborative efforts within small groups to exchange knowledge, responsibilities, and strategies. Silalahi and Hutauruk (2020) suggest that collaborative learning is based on the premise that students learn best when they actively discuss ideas and work together on schoolwork. Qureshi et al. (2023) support this idea by demonstrating that in cooperative learning settings, students assume specific responsibilities, share resources, and collaborate to solve problems. This helps students learn the topic more effectively and develop essential skills, such as communicating with others, collaborating as a team, and solving problems.

The Decentralized Cooperative Learning Strategy (DeC-LS) is an instructional method that prioritizes collaborative learning via small-group interactions. This tactic enables students to develop expertise in a particular subject or skill, allowing them to instruct and clarify their understanding to classmates. Prediger et al. (2021) demonstrate that teaching enhances students' understanding of the material by prompting them to think critically and explain their knowledge in a more organized manner. This idea encourages students to work together and take charge of their education, which differs from traditional, teacher-centered methods (Bhardwaj et al., 2025). This method encourages students to become more interested in the subject and helps them think critically and solve problems by collaborating to tackle challenging issues (Xu et al., 2023). The decentralized characteristic facilitates a more adaptable, peer-oriented learning atmosphere in which each student engages and cultivates vital soft skills, including collaboration and communication, in conjunction with knowledge acquisition (Mancilla & Frey, 2020).

It is becoming increasingly clear that schools today need more creative ways to teach that engage students, encourage collaboration, and foster academic success (Revenko et al., 2024). Traditional teaching approaches, which focus on passive learning, often fail to meet the needs of a diverse group of students who require more engaging and interesting learning experiences (Zitha et al., 2023). This means that children may struggle to understand abstract arithmetic concepts, such as quadratic equations. Because of this, teachers strive to find better ways to keep students interested and help them grasp the material. Lugosi and Uribe (2022) suggest that active learning strategies, which engage students in the learning process, facilitate their understanding and retention of mathematical topics.

Although First World countries employ various technologies and teaching methods to make learning more engaging and meaningful for students, it is evident that there remains a need to integrate differentiated instruction and activities that can enhance or create new learning experiences for students (Castro, 2019). Recent studies emphasize the growing need for innovative instructional strategies that actively engage students in Mathematics, particularly in understanding complex topics such as quadratic equations, which many learners find difficult due to their procedural complexity and abstract nature (Alam & Mohanty, 2024).

While cooperative learning has been proven effective in enhancing student engagement and problem-solving abilities (Tadesse et al., 2024), there remains a significant gap in the literature concerning the specific application and impact of Decentralized Cooperative Learning Strategies (DeC-LS) on students' ability to solve quadratic equations. Sannigrahi et al. (2025) suggest that decentralized and peer-led models foster more profound understanding and active participation. However, empirical studies focused on DeC-LS in secondary Mathematics, especially within the K-12 context in developing countries like the Philippines, are limited. With this, the researchers suggest using the decentralized cooperative learning approach (DeC-LS) as a way to facilitate a deeper understanding of the quadratic equation debate. This kind of method will help kids think critically and get along better with their classmates.

This review aims to assess Decentralized Cooperative Learning Strategies (DeC-LS) for improving student competence in solving quadratic equations. The study specifically aims to analyze the elements of DeC-LS, evaluate its impact on student engagement and comprehension of quadratic equations, and identify the problems

and advantages associated with its adoption in mathematics education. The review will examine how DeC-LS creates a space where students can work together to comprehend and solve mathematical challenges. This will demonstrate the importance of working together and helping each other in cooperative learning, as well as how these interactions aid students in mastering quadratic equations. Research has consistently shown that cooperative learning enhances students' ability to solve problems. This is because students often understand mathematical concepts better when they talk about and work together (Fadzil & Osman, 2025). By compiling relevant information, the review aims to provide important insights into the potential benefits of this strategy in today's schools.

1.1 Theoretical Framework of Decentralized Cooperative Learning Strategies (DeC-LS)

Numerous academics have developed and delineated diverse definitions and components of cooperative learning. Abramczyk and Jurkowski (2020) define cooperative learning as an instructional strategy in which students collaborate in teams to achieve a shared objective, characterized by positive interdependence, enhanced interaction, individual accountability, effective utilization of collaborative skills, and group processing.

This review is based on the theory of cooperative learning, which is founded on Lev Vygotsky's concept of the Zone of Proximal Development. The educational benefits of cooperative learning groups are contingent upon the caliber of student conversations, which encompass arguing, elucidating concepts to peers, and integrating and expanding upon each other's ideas (Silva et al., 2023). Cooperative learning, as articulated by Johnson and Johnson (2021), is a systematic method wherein the educator actively participates in the learning process by ensuring that each group member is responsible for a designated task. This worker is responsible for assisting others in learning their respective tasks.

Research on cooperative learning strategies has been conducted from two primary theoretical perspectives: development and motivation (Yang, 2023). The developmental approach posits that task-oriented interaction among students improves learning by generating cognitive tensions and presenting pupils with superior-quality thinking. Conversely, motivational theories of cooperative learning suggest that incentivizing groups based on the individual learning of all members fosters peer norms and sanctions that promote achievement-oriented endeavors and active peer assistance (Almasri, 2021). These interactions with peers are believed to facilitate pupils' cognitive reorganization (Ciharova et al., 2021). Engaging in mutual explanations and discussions can enhance comprehension, identify misconceptions, and reinforce the linkages between new information and prior knowledge (Chen et al., 2020).

The study indicates that Decentralized Cooperative Learning Strategies (DeC-LS) is a synthesis of multiple proven cooperative learning strategies, each providing distinct components that enhance collaborative, student-centered learning. Cooperative learning is a crucial element of DeC-LS, as this approach prioritizes group work in which students collaborate to achieve shared educational objectives. It encourages peer-to-peer interaction, shared responsibility, and mutual help, which improves learning outcomes by allowing students to explain their ideas to one another, ask questions, and provide feedback (Balasubramanian, 2023). Ruijuan et al. (2023) also support the claim that active, collaborative learning environments increase engagement and motivation, which, in turn, lead to better academic performance.

Furthermore, the Jigsaw method, a recognized cooperative learning tool, as indicated in the research of Shakerian et al. (2020), underpins this strategy. In this approach, students are first organized into small groups, with each member assigned to study a distinct aspect of the topic (Vives et al., 2024). In mastering the designated topic, pupils are reorganized into new groups, wherein each expert instructs the remaining members about the subject (Namaziandost et al., 2020). It enables each student to take responsibility for their education while benefiting from the expertise of others. DeC-LS integrates components of peer instruction, where students elucidate topics to one another. This strategy is beneficial in complex subjects like mathematics because it allows students to engage in back-and-forth discussions to clarify confusion, reinforce their understanding, and correct any misconceptions (Litster et al., 2020). DeC-LS also includes student-centered learning methods, which put students at the heart of the learning process. The instructor is in charge of groups and makes sure that pupils have the tools and help they need (Panggabean et al., 2024). This approach pushes students to be independent, think critically, and motivate themselves, which helps them take ownership of their education.

Figure 1 above shows how several teaching methods can be combined into a single framework for Decentralized Cooperative Learning Strategies (DeC-LS). The diagram illustrates how multiple methods intersect and overlap, creating a more open and participatory learning environment. DeC-LS is a mix of peer teaching, cooperative learning, the Jigsaw method, and student-centered learning. Each of these strategies contributes something different but valuable to the main idea of DeC-LS. These combination strategies work together to boost teamwork, understanding, and academic performance, especially in complex subjects like maths. This technique empowers students to take an active role in their education by creating a learning environment that is both interactive and supportive.

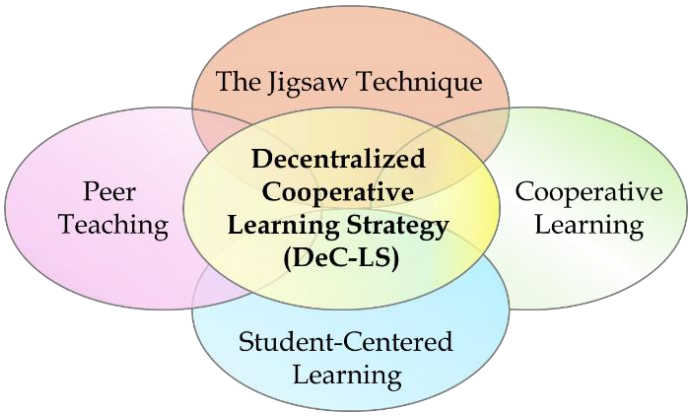

Figure 1. *Strategies for Decentralized Cooperative Learning (DeC-LS)*

1.2 The Role of Decentralized Cooperative Learning Strategies (DeC-LS) Enhancing Proficiency in Solving Quadratic Equations

In Mathematics Education, sequences of learning that progressively grow in difficulty with each subsequent review of a topic are closely linked to the iterative connection between conceptual comprehension and procedural proficiency. A significant challenge during the middle years of secondary education in Australia is to enhance students' conceptual understanding of non-linear functions, particularly quadratic equations (Reid et al., 2020). Wilkie (2024) observed that pupils endeavored to resolve quadratic equations expediently, frequently neglecting their structural and conceptual significance. Students struggle with factoring quadratic equations when they are presented in unusual forms and structures.

Therefore, educators should provide diverse types of quadratic equations in multiple forms rather than solely in the traditional format. Baybayon and Lapinid (2024) corroborated the findings, indicating that Mexican pupils have inadequate performance in quadratic equations, which does not improve following comprehensive teaching. Additionally, some authors have highlighted that one contributing cause is the excessive focus on specific solving strategies, such as factorization, stemming from inadequate skills in fractional and radical arithmetic (Reid et al., 2024). They suggested that augmented reality (AR) may serve as a valuable supplementary educational tool for subjects that benefit from contextual learning experiences in the future.

Many schools in the Association of Southeast Asian Nations (ASEAN) region also struggle to teach quadratic equations. For example, Baybayon and Lapinid (2024) state that students in Malaysia often make mistakes when solving quadratic equations because they cannot break the problem down into smaller parts. This means that students will struggle to grasp math topics if they do not know how to break down and simplify math problems into simpler forms. The study by Ly and Takuya (2023) in Cambodia also supported this theory. It found that most Cambodian students consistently made the same mistakes when completing word problems involving quadratic equations. The results showed that most students had poor reading comprehension (36.2%), poor error processing skills (19.94%), and poor encoding skills (29.44%). In addition, pupils made 12.7% of transformative mistakes and 2.15% of reading mistakes. This means that there are many reasons why pupils struggle to comprehend how to solve quadratic problems effectively. Not being aware of these things could make it harder for students to learn the material.

Additionally, Vietnamese students often struggle with quadratic equations, particularly when procedural and conceptual knowledge are combined. This is because they lack sufficient basic algebra knowledge, they do not receive enough opportunities to solve real-world problems, and traditional teaching methods focus more on memorizing facts than on understanding concepts. Studies show that these problems worsen when there are not enough interactive and student-centered learning spaces, which are crucial for understanding complex arithmetic concepts (Loc et al., 2020). To solve these problems, we need to employ more engaging and hands-on teaching methods that help students understand quadratic equations and how to apply them effectively.

In Metro Manila, on the other hand, children often question how the maths they learn in school applies to their daily lives. They typically struggle to understand how quadratic equations are applied in the real world, which makes the material appear abstract and unimportant. This lack of context can lead people to become less interested in learning and less motivated (Berlinghoff & Gouvêa, 2020). Similarly, Baybayon and Lapinid (2024) noted that many Filipino students struggled to comprehend the fundamental concepts behind quadratic equations, including the meanings of roots, factors, and the quadratic formula, as well as their applications. This could be because they do not fully understand earlier algebraic ideas. With that, they advised using an inquiry-based approach to teach children how to solve quadratic equations. This is because it enables children to explore, ask questions, and improve their understanding via study and discovery.

In Cebu, Macachor and Morados (2024) found that, although students recognized some rules for solving quadratic equations, they did not consider whether their methods were mathematically valid. By identifying these mistakes early on, teachers can devise proactive strategies to address and rectify them before they worsen and negatively impact overall student performance. The proposed learning strategy, Decentralized Cooperative Learning Strategies (DeC-LS), can help students understand and solve quadratic equations by encouraging collaboration, peer support, and active participation. This is because students often struggle with conceptual understanding, make procedural mistakes, and fail to see how the problems relate to the real world.

Decentralized Cooperative Learning Strategies (DieC-LS) are gaining increasing attention as effective methods to help students improve their math skills, particularly in solving quadratic equations. These tactics encourage students to work together, share responsibilities, and learn from one another, which aligns with the constructivist approach to teaching mathematics. Johnson and Johnson (2021) state that cooperative learning helps students perform better than traditional approaches, primarily when they work together to tackle challenging arithmetic problems, such as quadratic equations.

Recent research, informed by Vygotsky's sociocultural theory, also supports the idea that working with peers facilitates cognitive growth (Alkhudiry, 2022). Nguyen and Kulm's (2020) research demonstrated that decentralized learning models, in which students take charge of group work, significantly enhance students' ability to solve problems and reason algebraically. Lee et al. (2023) also emphasized that incorporating student-led discussions and group accountability into algebra lessons significantly enhanced students' ability to retain and understand the material. Most recently, Cruz and Salazar (2025) demonstrated that decentralized cooperative setups lead to measurable improvements in students' ability to solve quadratic equations, attributed to increased engagement and learner autonomy. All of these results suggest that DeC-LS is crucial in helping individuals improve their ability to solve quadratic equations through active cooperation and shared cognitive effort.

1.3 Benefits of Decentralized Cooperative Learning Strategies in Mathematics Education

People are interested in Decentralized Cooperative Learning Strategies (DeC-LS) because they may help students become more engaged and perform better in maths class. This technique emphasizes connecting with peers and being actively involved, fostering a learning environment where students take responsibility for their education while engaging with their peers (Balasubramanian, 2023). This strategy helps with communication, critical thinking, and problem-solving, which are all important for learning math concepts like how to solve quadratic equations. Zitha et al. (2023) suggest that cooperative learning enhances student performance and comprehension by enabling them to share their thoughts and plans.

Recent studies show that using cooperative structures in Decentralized settings may help students talk to one another, think critically, and learn on their own. Cooperative learning, according to Johnson and Johnson (2021), encourages positive interdependence and personal responsibility, which helps people do well on math tasks. Sujatha and Vinayakan (2022) also found that students in decentralized cooperative groups performed better in remembering and applying math topics than students in traditional classes. Nguyen and Kulm (2020) conducted a quasi-experimental study that demonstrated significant improvements in student performance and attitudes toward mathematics in classrooms employing student-centered, collaborative learning. Tran and Lewis (2021) also conducted a meta-analysis that showed decentralized learning environments help math students perform better in school and improve their social and emotional abilities. Finally, Patel et al. (2023) found that digital technologies that promote decentralized cooperative learning can make students even more independent and help them work together in maths. These results demonstrate how DeC-LS can transform the way people learn mathematics by making it more accessible and valuable.

1.4 Challenges and Limitations of Implementing Decentralized Cooperative Learning Strategies (DeC-LS)

Even though Decentralized Cooperative Learning Strategies (DeC-LS) can help students become more independent and work together, implementing them in practice is not without its problems and limitations. One significant issue is that students often fail to attend and take responsibility, resulting in some group members not contributing equally (Arsenis et al., 2022). Additionally, teachers may struggle to manage and track numerous small-group activities in the classroom, which can hinder their ability to effectively run decentralized learning environments (Singh et al., 2024).

Because group work is decentralized, teachers must pay attention to more than one group at a time, which makes it challenging to provide all pupils with the help and direction they need (Abramczyk & Jurkowski, 2020). Additionally, this increased demand for teachers' attention can make it more challenging to monitor students' progress, clarify misunderstandings promptly, and ensure that all students are actively engaged (Trabelsi et al., 2023). This restriction could make DeC-LS less effective overall, as some students may not receive the feedback or help they need, which could slow down their learning.

A study by Siregar et al. (2024) supports this finding, demonstrating that cooperative learning practices can increase students' interest and improve their understanding. However, teachers often struggle to monitor group progress and address individual needs promptly. Attardi et al. (2022) observed that teachers tended to pay more attention to louder or more academically successful students, which meant that they missed opportunities to help other children who needed it more. Due to this, some groups of pupils may not receive sufficient instruction, which could result in disparities in learning outcomes. These problems are exacerbated in larger classrooms, as the teacher may not be able to provide each group with the same level of attention, which limits the potential benefits of collaborative learning (Yang et al., 2023). This highlights the importance of teachers receiving sufficient training and having effective methods to manage their classrooms, enabling them to address the challenges of decentralized cooperative learning.

Technological problems, especially in areas where resources are limited, make DeC-LS even more challenging to scale up and implement effectively. This implies that in many schools, a lack of technology or inadequate technology infrastructure can make it very difficult for these methods to work effectively and grow. For example, students cannot work together online or utilize digital learning platforms that facilitate decentralized learning when schools lack the necessary digital tools and resources (Singh et al., 2021). Students cannot fully participate in cooperative learning activities that involve working with peers and collaborating with others if they lack access to dependable internet, devices, or the necessary software (Rahardja et al., 2021). Because of this, the technique is challenging to implement, which reduces its potential impact on how engaged and learned students learn.

Hennessy et al. (2022) also found that teachers in low-resource schools generally struggle to utilize technology in cooperative learning due to issues with infrastructure and financial constraints. Oliveira et al. (2021) also demonstrated that when schools lack sufficient technology, teachers resort to outdated teaching methods, which hinders students' ability to learn together and engage with one another. Additionally, the situation is exacerbated by the fact that teachers often lack sufficient training in technology, which means they may not possess the necessary skills or confidence to effectively utilize digital technologies in their lessons (Maphosa, 2021). This

highlights the importance of closing technology gaps and providing teachers and students in resource-poor areas with the necessary support to make DeC-LS effective.

In more conservative school systems, decentralized solutions are also challenging to implement due to cultural and institutional resistance to non-traditional teaching approaches. In these kinds of settings, teachers may be hesitant to adopt new methods like DeC-LS because they are unfamiliar with them or feel uncomfortable with them (Goh & Sigala, 2020). Additionally, institutional regulations and standardized curricula may not permit the flexibility required to utilize decentralized techniques, which would further entrench existing practices (Virvidaki et al., 2024). Because of this, both teachers and administrators typically resist the move to more innovative, collaborative learning environments, which makes it challenging for DeC-LS to be implemented in these systems.

Bangara (2022) found that educational innovations aiming to make learning more student-centered often encounter challenges in settings where conventional cultural norms and institutional frameworks prioritize rote memorization, high-stakes testing, and teacher-led instruction. Often, teachers and administrators are hesitant to adopt these novel methods, as they appear to disrupt the traditional educational process (Ruijuan et al., 2023). Litster et al. (2020) also found that teachers in conservative schools typically do not want to try new teaching methods because they are concerned about potential drawbacks, such as poorer test scores or difficulties managing the classroom. This cultural and institutional resistance makes it significantly more challenging to implement changes and utilize solutions like DeC-LS, which rely on flexible and collaborative learning environments (Mhlongo et al., 2023). To overcome this opposition, we need to change the culture and encourage institutions to support this effort, including providing teachers with professional development and revising the curriculum to promote the use of more interactive and student-centered methods.

Lastly, a lack of sufficient professional development and support for teachers is a significant problem that highlights the importance of reforming the system to encourage innovative teaching methods (Dewey et al., 2023). Without the proper professional development, teachers may not fully comprehend the ideas and methods behind cooperative learning initiatives, which can make it more challenging for them to implement them effectively (Cojorn & Sonsupap, 2024). Individuals who lack sufficient training may not feel confident and may be hesitant to try new teaching methods. Additionally, teachers may struggle with managing group dynamics, facilitating peer learning, and implementing student-centered methods in their classrooms, all of which are crucial for the success of DeC-LS (Georgopoulou, 2024). Therefore, it is essential to provide teachers with ongoing professional development opportunities that equip them with the necessary skills and knowledge to utilize these strategies effectively.

Maphosa (2021) also observed that professional development is crucial for successfully implementing new teaching methods, particularly in helping teachers understand and feel confident in using these approaches. Bangara (2022) stated that instructors are more likely to effectively utilize new tactics when they receive good training and ongoing support. This leads to better outcomes for students. However, in many school systems, there are insufficient professional development opportunities for teachers, or they are not tailored to their unique needs (Cojorn & Sonsupap, 2024). Because of this, teachers might revert to old ways of doing things, as they are more accustomed to and comfortable with them.

2.0 Conclusion

In conclusion, Decentralized Cooperative Learning Strategies (DeC-LS) is a good way to assist students in improving their ability to solve challenging arithmetic problems, including quadratic equations. The literature review reveals that cooperative learning offers numerous benefits, including increased student engagement, enhanced understanding of concepts, and improved problem-solving skills. DeC-LS helps students take charge of their learning, communicate with one another in a way that makes sense, and engage in meaningful interactions that support their academic growth by fostering a collaborative learning environment. Additionally, studies have demonstrated that decentralized learning models, where students work in small groups and are responsible for their learning, can enhance their ability to remember and understand math concepts, such as quadratic equations, particularly in schools with limited resources or traditional approaches.

However, some problems need to be addressed in order for DeC-LS to function effectively. The literature also addresses specific issues, including classroom management challenges, inadequate technology, cultural resistance

to new approaches, and insufficient professional development for teachers. These difficulties underscore the need for substantial adjustments that enable schools to adopt innovative teaching methods. The goal of this study is to provide a clear understanding of how effectively DeC-LS supports teachers in teaching mathematics, particularly in solving quadratic equations. It also emphasizes the importance of overcoming these challenges to realize the potential of decentralized cooperative learning fully. Schools invest in professional development for teachers to enhance their understanding and application of Decentralized Cooperative Learning Strategies (DeC-LS). This ensures that teachers are prepared to facilitate group work and support students in learning together. Additionally, systemic improvements addressing technology restrictions and cultural objections can help DeC-LS become more popular. This will make classrooms more engaging and interesting, which will help students improve at solving quadratic problems.

3.0 Contributions of Authors

The authors contributed equally to each section of the work. They were involved in the conceptualization, review, and final approval of this research review.

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5.0 Conflict of Interests

The authors declare no conflict of interest regarding the publication of this paper.

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