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"Awur Eser" to Explore Number Sense: Hypothetical Learning Trajectory for Integer Material Facilitating Learning Speed

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Abstract: This article aims to explore the concept of "Awur Eser" as a potential learning method to enhance students' number sense, especially in the context of learning integer concepts, and to develop more effective and inclusive strategies for mathematics education. We conducted a literature review to identify students' barriers to understanding integers based on their number sense and learning speed. Then, we conducted a second literature review to design a Hypothetical Learning Trajectory (HLT) for integer learning. Subsequently, we held a Focus Group Discussion (FGD) with mathematics education experts and teachers to discuss and validate the selection of HLT for integer learning. Based on the FGD results, we compiled the final design of HLT for integer learning. This design involves adjustments based on input from experts and teachers, ensuring alignment with students' characteristics and needs. The implementation of HLT hopefully can improve students' conceptual understanding and accelerate the learning process.

Keywords: Number sense, Learning speed, Hypothetical learning trajectory

Introduction

Mathematics education plays a central role in the cognitive development of students. However, many students encounter various barriers in learning mathematics (Smith et al., 2021; Jones, 2020). These barriers can range from a lack of understanding of basic concepts to differences in learning speed (Brown & Miller, 2019). A specific focus on integer concepts is crucial, given that this material is the foundation for further mathematical understanding.

Understanding integers over time is crucial, significantly as a lack of solid comprehension directly impacts the development of students' number sense (Thompson & Smith, 2018). Number sense encompasses the ability to understand and use numbers flexibly, including comprehension of the relationships between numbers, numerical comparisons, and the practical use of numbers in everyday contexts (Johnson, 2019). In general, research related to the numbers has been widely conducted. But students often struggle to translate contexts into mathematics or vice versa, have an imperfect understanding of algebraic expressions, face challenges in applying arithmetic operations in numerical and algebraic expressions, and encounter difficulties in understanding mathematical

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symbols, which is the most commonly observed difficulty (Jupri et al., 2014; Pramesti et al., 2019; Muchoko et al., 2019).

One of the leading causes of barriers to understanding integers is the lack of profound comprehension when students study them (García & Rodriguez, 2020). Varying learning speeds among students poses a challenge, considering each student possesses different levels of understanding and learning capabilities (Huang et al., 2022). In this context, learning integers becomes critical. Developing a learning design that not only facilitates students' learning speed but also enhances their number sense can be an effective solution to overcome these barriers (Brown et al., 2021). An optimal learning design must consider the differences in students' learning speeds while ensuring a deep understanding of integer concepts (Wang & Chen, 2019).

By understanding the complexity of this issue, this article aims to explore the concept of "Awur Eser" as a potential learning method to enhance students' number sense, especially in the context of learning integer concepts. By discussing the potential benefits of this approach, it is anticipated that this article can contribute to developing more effective and inclusive strategies for mathematics education.

Method

This research is part of design research in the preliminary research stage, aiming to understand the context and design an innovative learning approach to enhance students' understanding of integers. The research stage is described in figure 1.

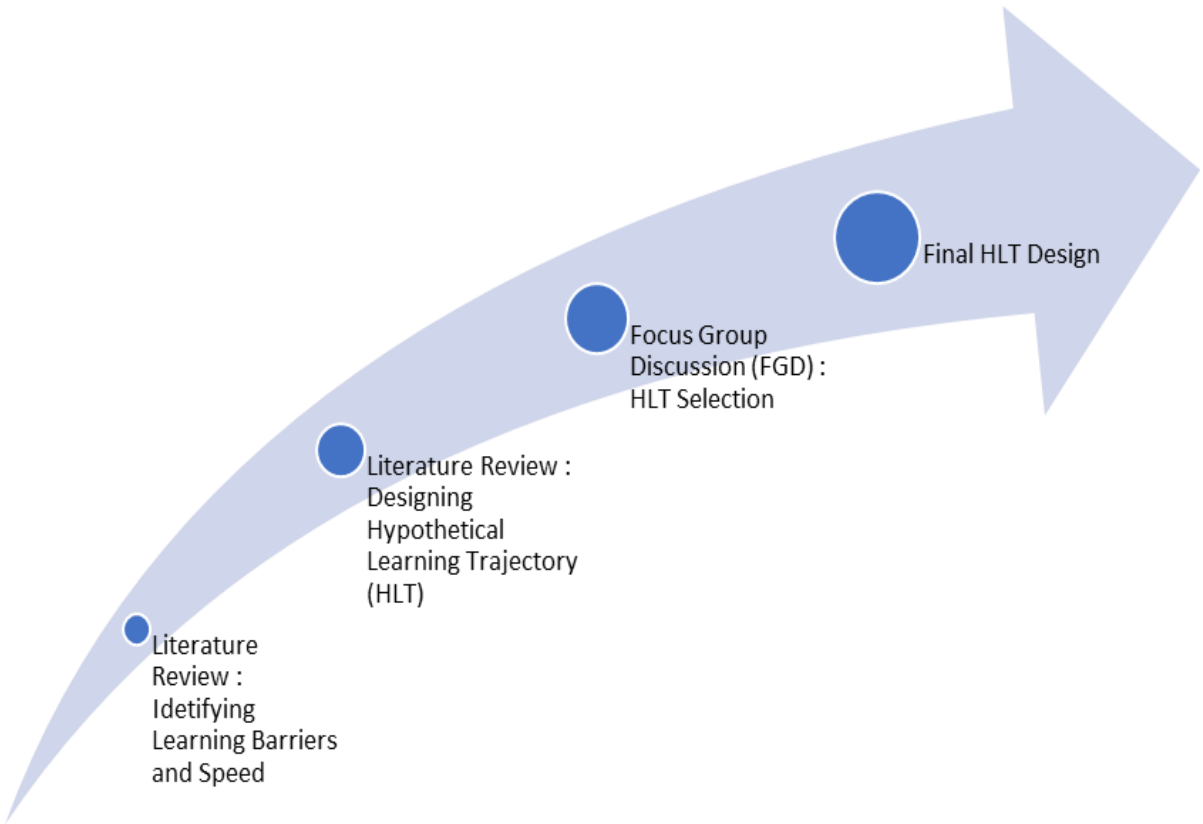


Figure 1. The research stage

Firstly, we conducted a literature review to identify students' barriers to understanding integers based on their number sense and learning speed. Recent studies indicate that a deep understanding of basic integer concepts can influence students' ability to develop a strong number sense (Johnson & Smith, 2023). Then we conducted a second literature review to design a Hypothetical Learning Trajectory (HLT) for integer learning. Understanding how students gradually build integer concepts becomes the focus of HLT design (Brown et al., 2022). Subsequently, we held a Focus Group Discussion (FGD) with mathematics education experts and teachers to discuss and validate the selection of HLT for integer learning.

The FGD results indicate that the active participation of teachers in designing HLT can enhance acceptance and effectiveness of implementation (García & Rodriguez, 2021). Based on the FGD results, we compiled the final design of HLT for integer learning. This design involves adjustments based on input from experts and teachers, ensuring alignment with students' characteristics and needs. Implementing HLT is expected to improve students' conceptual understanding and accelerate the learning process.

Results and Discussion

Literature Review: Identifying Learning Barriers and Speed

The expanded literature review findings affirm that addressing learning barriers in understanding integers requires a multifaceted approach. In addition to emphasizing the significance of understanding basic concepts and learning speed variability, recent research highlights the role of metacognition and the potential benefits of integrating technology. These additional perspectives contribute to a comprehensive understanding of the challenges associated with integer concepts and pave the way for more nuanced and effective instructional strategies.

Lack of Understanding

Jones (2020) identifies that students' lack of understanding of the basic concepts of integers is a primary barrier to building "number sense." The study suggests that an incomplete understanding of basic concepts can hinder students' comprehension of integers. Johnson and Smith's recent research (2023) underscores the role of metacognition in overcoming learning barriers, particularly in integer concepts. The research argues that metacognitive strategies are crucial in helping students navigate challenges and enhance their understanding of integer concepts. Swanson et al. (2022) explore the application of Cognitive Load Theory in integer learning. The research indicates that understanding the cognitive load in processing integer concepts is vital to designing effective instructional strategies. Smith and Johnson (2022) provide insights from neuroscience perspectives on how the brain processes integer concepts. The research emphasizes that understanding the neural mechanisms can inform targeted interventions to overcome learning barriers.

Learning Speed

Brown and Miller's study (2019) emphasizes significant variations in students' learning speed when understanding integer concepts. The research suggests that varied levels of understanding can pose a severe barrier of students' learning process, particularly in the context of integer concepts. Wang and Chen (2019) note that variations in students' learning speeds can complicate the learning process. According to them, diverse learning speeds can hinder creating an inclusive and effective learning environment.

Number Sense

Thompson and Davis (2020) present an assessment-focused study on developing number sense. The study suggests that assessing the nuanced facets of number sense is crucial for understanding and addressing learning barriers in integer concepts. Integer material is fundamental for students to hone their mathematical abilities, particularly their number sense. Researchers attempt to formulate indicators for number sense in algebraic operations through adjustments (Maghfirah, 2019). The indicators used in this study are 1) identifying the sequential properties of numbers and regularities in the number system, 2) determining the nearest estimation in a numerical operation and representing it, 3) identifying the characteristics of numerical operations and their implications on various types of numbers, and 4) assessing the reasonableness of a calculation result.

Other Influence

Kim and Lee (2021) delve into the cultural aspects influencing integer learning. The research highlights that cultural considerations significantly shape students' perspectives and challenges in understanding integer concepts. Chen et al. (2023) investigate the impact of adaptive learning platforms on integer comprehension. The

findings suggest that adaptive platforms can cater to individual learning styles, potentially mitigating barriers in integer understanding.

Literature Review: Designing Hypothetical Learning Trajectory (HLT)

Designing a learning framework that facilitates learning speed and develops students' number sense in integer learning is crucial. Below are some findings elements of the learning design:

Instructional Differentiation

The need for differentiated learning is meant to embrace the diversity in students characteristics. Among them may be learning speed, learning style, students' initial mathematical abilities, hobbies etc. Teachers can focus on the diversity of these characteristics before learning. Facilitating students' characteristics through learning has long been encouraged in Indonesia, as evidenced by initiatives to promote inclusive education (Balkist et al., 2020). Implementation and integration of the Merdeka curriculum also play a role in providing learning based on students' characteristics (Balkist et al., 2022; Sadieda et al., 2022; Muslimin et al., 2022). Internationally, differentiated learning is still practiced and analyzed (Handa, 2019; Morgan, 2013; Balkist et al., 2022). The research focused on students' learning speed which of course needs to be determined before the learning starts. Researches measured learning speed based on three things, namely 1) students' IQ scores; 2) diagnostic test of students' mathematical abilities; 3) interviews with teachers about students' daily lives when studying mathematics.

Realistic Mathematics Education

Realistic Mathematics Education (RME) is a specific mathematics teaching theory developed in the Netherlands since the 1970s. The characteristics of RME are rich and realistic situations, which play an important role in the learning process. This situation serves as a resource to begin the development of mathematical concepts, tools, and procedures and as a context in which students can apply their mathematical knowledge at later stage. Then it gradually becomes more formal, general, and context-specific (Van den Heuvel-Panhuizen & Drijvers, 2020). This is also by the view that mathematics must always be meaningful for students and seen as a human activity, so that problem situations must be experientially real for students (Freudenthal, 1991). So the problem situations presented can be problems that can be encountered both in everyday life and in abstract mathematical problems as long as the problem is meaningful for students. There are five main principles in RME (Treffers, 1987; Bakker, 2004; Jupri, 2008), which the author then reinterprets as Phenomenological exploration, the existence of models and symbols for progressive mathematics, the existence of models and symbols for progressive mathematics, various context problems, models, Independence. The students' constructions and strategies must have meaning for the students and be interactive and related.

Cooperative and Collaborative Learning

Cooperative and collaboration approaches are crucial for creating effective learning environments in mathematics education. These methods enhance students' understanding of mathematical concepts and foster essential social skills. Students develop teamwork and communication skills by working together to solve math problems, leading to deeper learning outcomes (Slavin, 2015; Hattie, 2009; Vygotsky, 1978). Additionally collaborative learning reduces math anxiety among students, as they feel supported by their peers during the learning process. Thus, it is about mastering formulas and building an inclusive and supportive learning community.

Modeling and Visual Representation

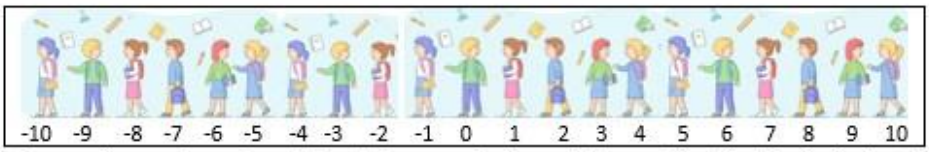
In mathematics education, Integrating modeling and visual representation plays a pivotal role in enhancing students' understanding and problem-solving skills. Visual representations provide concrete illustrations of abstract mathematical concepts, making them more accessible and comprehensible for learners (Hegedus & Moreno-Armella, 2009). Additionally, modeling allows students to apply mathematical concepts to real-world scenarios, fostering deeper conceptual understanding and promoting critical thinking (Lesh & Lehrer, 2003). By

combining these approaches, educators can create dynamic learning environments that engage students and facilitate meaningful learning experiences (NCTM, 2000).

Hypothetical Learning Trajectory (HLT) Design

“Awur Eser" is an abbreviation derived from the Sundanese (One of The tribes in Indonesia), which translates to "aktifitas nawur atanapi dipeser," meaning the activity of paying or being bought. "Nawur" (paying) implies encountering a debt collector (thug) representing negative numbers. On the other hand, "Dipeser" (being bought) implies encountering a buyer representing positive numbers. A student takes on the role of a merchant selling goods from the starting point (point 0). If the student moves towards negative numbers, they encounter a thug demanding money, resulting in a debt..

Table 1. Hypothetical learning trajectory of “awur eser”

Stage of Learning Design
Stage 1 Students are asked to form groups, with each group consisting of a minimum of 22 people. 21 individuals are assigned to represent the integers -10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, arranged side by side.      Those assigned as negative numbers act as debt collectors moving towards the negative direction (indicating trouble ahead). Meanwhile, those assigned as positive numbers act as buyers and hold unit money (indicating buyers ahead in the positive direction). The individual assigned to the number 0 remains stationary, maintaining their initial position. The remaining students act as sellers of goods, moving either left (towards negatives with trouble) or right (towards positives with buyers). **Stage 2: Observing positive, zero, and negative integers.** 1. Observe each of your friends; how many groups of friends are there in the line? 2. On which side are the debt collectors? To reach -7, how many steps do you need to take? How many debt collectors have you encountered? 3. Investigate other scenarios for negative numbers! 4. On which side are the buyers? To reach 5, how many steps do you need to take? How many buyers have you encountered? 5. Find other scenarios for positive numbers! **Stage 3: Observing the positions of integers and comparing them.** 1. Which do you think will generate more money for you, -3 or 2? Why? 2. Which do you think will result in more losses for you, 10 or -5? Why? **Stage 4: Solving operations with integers.** 1. If you are at 6 and have to move towards the debt collectors for 10 steps, where are you now? Write it in a mathematical sentence! 2. If you are at -3 and have to move towards the buyers for 9 steps, where are you now? Write it in a mathematical sentence! 3. If you are at -5 and have to move against the direction of the debt collectors for 10 steps, where are you now? Write it in a mathematical sentence! 4. If you are at 5 and have to move against the direction of the buyers for 10 steps, where are you now? Write it in a mathematical sentence! 5. If you are at -5 and have to move to 7, how many steps do you need to take? Write it in a mathematical sentence! 6. Find similar cases! For example, from 3 to 9, -10 to -4, and so on!

Conversely, moving towards positive numbers, they meet a buyer purchasing goods with money, resulting in earnings. The Sundanese phrase "awur eser" means to scatter and shift, signifying spreading and sharing knowledge with others. This activity is developed from the findings of previous research stages that concluded learning activities for students. "Awur eser" requires collaboration and cooperation among diverse students with varying characteristics (learning speed and mathematical abilities). Therefore, "Awur eser" serves as a facilitator

for differentiated, cooperative, and collaborative learning. Additionally, it presents problems that students need to solve, leading to modeling and visual representation through their movements. Guidance from the teacher, along with different learning assessment processes, is a characteristic of this activity, including varied evaluation formats and narrative teaching

Focus Group Discussion (FGD): HLT Selection

Expert also discussed the development of the Hypothetical Learning Trajectory (HLT) embedded in "Awur eser" in a Focus Group Discussion (FGD). The FGD involved three speakers: a lecturer, a mathematics expert, and a mathematics teacher. The results are shown in Table 1.

Table 2. Hypothetical learning trajectory of "awur eser" results of fgd

Stage of Learning Design	Results of FGD
Stage 1 Students are asked to form groups, with each group consisting of a minimum of 22 people. 21 individuals are assigned to represent the integers -10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, arranged side by side.  -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 Those assigned as negative numbers act as debt collectors moving towards the negative direction (indicating trouble ahead). Meanwhile, those assigned as positive numbers act as buyers and hold unit money (indicating buyers ahead in the positive direction). The individual assigned to the number 0 remains stationary, maintaining their initial position. The remaining students act as sellers of goods, moving either left (towards negatives with trouble) or right (towards positives with buyers).	In stage 1, it is necessary to provide more detailed instructions for students, and perhaps the illustrative representation can be further clarified. Real-life stories about sellers being extorted by thugs and their struggle to find buyers in the surrounding environment can be presented to make the meaning of 'awureser' more tangible, clear, and contextual for students. Additionally, these facts will enrich and enhance students' numeracy literacy skills
Stage 2: Observing positive, zero, and negative integers. 1. Observe each of your friends; how many groups of friends are there in the line? 2. On which side are the debt collectors? To reach -7, how many steps do you need to take? How many debt collectors have you encountered? 3. Investigate other scenarios for negative numbers! 4. On which side are the buyers? To reach 5, how many steps do you need to take? How many buyers have you encountered? 5. Find other scenarios for positive numbers!	The activities in stage 2 are pretty good; however, there might be a need for confirmation of answers and a general review of the material learned. This is also the introduction of an institutionalization phase in the learning process.
Stage 3: Observing the positions of integers and comparing them. 1. Which do you think will generate more money for you, -3 or 2? Why? 2. Which do you think will result in more losses for you, 10 or -5? Why?	The activity in stage 3 is pretty good; however, it might be beneficial to add more probing questions that can enrich the mental actions of students during learning through 'awur eser'.
Stage 4: Solving operations with integers. 1. If you are at 6 and have to move towards the debt collectors for 10 steps, where are you now? Write it in a mathematical sentence! 2. If you are at -3 and have to move towards the buyers for 9 steps, where are you now? Write it in a mathematical sentence! 3. If you are at -5 and have to move against the direction of the debt collectors for 10 steps, where are you now? Write it in a mathematical sentence! 4. If you are at 5 and have to move against the direction of the buyers for 10 steps, where are you now? Write it in a mathematical sentence! 5. If you are at -5 and have to move to 7, how many steps do you need to take? Write it in a mathematical sentence! 6. Find similar cases! For example, from 3 to 9, -10 to -4, and so on!	The activities in stage 4 are pretty good; however, there might be a need for confirmation of answers and a general review of the material learned. This is also the introduction of an institutionalization phase in the learning process.

Discussion

"Awur Eser" is developed from the findings of previous research stages that concluded learning activities for students. "Awur eser" requires collaboration and cooperation among diverse students with varying characteristics (learning speed and mathematical abilities). Therefore, "Awur eser" serves as a facilitator for differentiated, cooperative, and collaborative learning. Additionally, it presents problems that students need to solve, leading to modelling and visual representation through their movements. Guidance from the teacher and different learning assessment processes are a characteristic of this activity, including varied evaluation formats and narrative teaching.

Number sense encompasses the ability to understand and use numbers flexibly, including comprehension of the relationships between numbers, numerical comparisons, and the practical use of numbers in everyday contexts (Johnson, 2019). One of the leading causes of barriers in understanding integers is the lack of profound comprehension when students study them (García & Rodriguez, 2020). Varying learning speeds among students poses a challenge, considering each student possesses different levels of understanding and learning capabilities (Huang et al., 2022). Developing a learning design that not only facilitates students' learning speed but also

enhances their number sense can be an effective solution to overcome these barriers (Brown et al., 2021). An optimal learning design must consider the differences in students' learning speeds while ensuring a deep understanding of integer concepts (Wang & Chen, 2019).

Final HLT Design

Table 3. Final hypothetical learning trajectory and students' response prediction of "awur eser"

Stage of Learning Design	Students' Response Prediction	Teachers' Follow-Up Plan
Stage 1 Students are asked to form groups, with each group consisting of a minimum of 22 people. 21 individuals are assigned to represent the integers -10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, arranged side by side.  -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 Those assigned as negative numbers act as debt collectors moving towards the negative direction (indicating trouble ahead). Meanwhile, those assigned as positive numbers act as buyers and hold unit money (indicating buyers ahead in the positive direction). The individual assigned to the number 0 remains stationary, maintaining their initial position. The remaining students act as sellers of goods, moving either left (towards negatives with trouble) or right (towards positives with buyers).	Students will be interested and immediately enthusiastic about participating in "awur eser" activities. Students may not be interestedbut still participate in "awur eser" activities.	The teacher motivates the studentsto engage in activities.
Stage 2: Observing positive, zero, and negative integers. 1. Observe each of your friends; how many groups of friends are there in the line? 2. On which side are the debt collectors? To reach -7, how many steps do you need to take? How many debt collectors have you encountered? 3. Investigate other scenarios for negative numbers! 4. On which side are the buyers? To reach 5, how many steps do you need to take? How many buyers have you encountered? 5. Find other scenarios for positive numbers!	Students can comprehend the material participate in the "awur eser" activity. Students still need to fully understood the positions of integers.	Students who have not fully understood the positions of integers can change roles to become sellers so that they will move step by step while understanding each position of theintegers.
Stage 3: Observing the positions of integers and comparing them. 1. Which do you think will generate more money for you, -3 or 2? Why? 2. Which do you think will result in more losses for you, 10 or -5? Why?	Students can comprehend the material participate in the "awur eser" activity. Students have yet to fully grasp which integer is greater or smaller.	Students who have not fully grasped which integer is greater or smaller can change roles to become sellers so that they will move step by step while understanding which position is most advantageous for them as sellers.
Stage 4: Solving operations with integers. 1. If you are at 6 and have to move towards the debt collectors for 10 steps, where are you now? Write it in a mathematical sentence! 2. If you are at -3 and have to move towards the buyers for 9 steps, where are you now? Write it in a mathematical sentence! 3. If you are at -5 and have to move against the direction of the debt collectors for 10 steps, where are you now? Write it in a mathematical sentence! 4. If you are at 5 and have to move against the direction of the buyers for 10 steps, where are you now? Write it in a mathematical sentence! 5. If you are at -5 and have to move to 7, how many steps do you need to take? Write it in a mathematical sentence! 6. Find similar cases! For example, from 3 to 9, -10 to -4, and so on!	Students can comprehend the material participate in the "awur eser" activity. Students still need to fully understand integer operations.	For students who have yet to fully understood integer operations, they can be assisted by their peers while continuously exchanging roles.

Conclusion

"Awur Eser" serves as a facilitator for differentiated, cooperative, and collaborative learning. Additionally, it presents problems that students need to solve, leading to modelling and visual representation through their movements. Guidance from the teacher and different learning assessment processes are a characteristic of this activity, including varied evaluation formats and narrative teaching.

Recommendations

"Awur Eser" needs to practice in teaching experience from the stage of design research. So the effectiveness and the students' response could be confirmed and improved even more.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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