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Implementing Mobile Learning with Differentiated Instruction in Calculus: Student Learning Styles Analysis

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Abstract

This study aims to examine: (1) differences in Calculus learning achievement between students using mobile learning with differentiated instruction (DI) and those using modules, (2) differences in achievement based on students' learning styles, and (3) the interaction between instructional methods and learning styles on learning outcomes. The participants were 112 Informatics Engineering students at Universitas Darussalam Gontor in the 2023/2024 academic year, divided into two groups: 59 students in the experimental group (using mobile learning) and 53 in the control group (using modules). The study was conducted over five sessions on the topic of Absolute Value Equations and Inequalities. A quasi-experimental method with a 2x3 factorial design was used. The research instruments included an achievement test and a learning style questionnaire. Data were analyzed using two-way ANOVA after confirming normality and homogeneity assumptions. The results showed that: (1) mobile learning with DI is more effective than modules, (2) learning styles significantly affect learning achievement, and (3) there is no interaction between instructional method and learning style. These findings suggest that mobile learning with DI can be effectively implemented regardless of students' learning styles and supports the development of inclusive digital learning environments in higher education.

Keywords: mobile learning, differentiated instruction, learning styles

INTRODUCTION

Higher education is undergoing significant transformation in line with technological advancements. One of the key innovations currently at the center of the learning process is using instructional media. Instructional media play a crucial role in supporting the learning process. Modules and mobile learning are two types of instructional media with different characteristics, yet both support the learning process. Modules can be printed or digital, with a well-structured format that includes objectives, materials, and assessments, making them suitable for structured independent learning (Farahin Rachman Laraphaty et al., 2021). In contrast, technology-based mobile learning offers greater flexibility, allowing students to access learning materials instructions, and information related to learning anytime and anywhere (Razilu, 2021). In terms of interactivity, mobile learning is superior as it can incorporate features such as videos, interactive quizzes, and discussion forums, whereas modules are more limited in this regard. Mobile learning serves as a support for independent learning (Elmi et al., 2023).

In this study, researchers developed a mobile learning with differentiated instruction in Calculus instructional media. They designed the learning media using differentiated instruction, tailoring instruction based on students' initial abilities (Triana et al., 2024). The system was developed using the Waterfall approach, encompassing the phases of requirements analysis, system design, implementation, testing, and ongoing maintenance. The team developed the learning media using Android Studio and implemented differentiated instruction. Testing through black-box evaluation, media experts, content experts, and user validation produced high validation scores (90.45%, 92.73%, and 82.50%, respectively), indicating that the application is valid and suitable for learning.

The differentiated instruction (DI) implemented in the application uses instructional strategies within the learning media that are designed based on students' varying levels of prior knowledge, categorized into three levels: high, medium, and low. Although the course learning outcomes remain the same for all students regardless of their proficiency level, the assignments and learning activities differ. Student abilities are stimulated through features such as student activities and post-tests, which are tailored to each student's level of ability.

Differentiated instruction is a contemporary teaching approach where educators modify strategies, content, and assessments to address the varied needs of all learners within a classroom community. In differentiated learning, students are not merely passive recipients of content, but effective learning requires clear materials and appropriate media to support both the delivery and reception of instruction (Prasetyo & Khorimah, 2023). Digital-based differentiated learning is an innovative approach that identifies students' talents and adapts teaching to their diverse learning styles (Hardiansyah et al., 2024). Mobile learning can be successfully combined with differentiated instruction using technology to deliver customized learning experiences tailored to each student's needs and learning preferences. This approach allows for adaptable content, tasks, and assessments that provide suitable support and challenges for every learner.

Learning style is one of the key factors that affect students' potential growth during the learning process. It plays a vital role by reflecting each individual's unique way of thinking, processing information, and comprehending material (Dewi, 2023). Each student has unique differences, leading to variations in learning styles based on personal preferences in learning approaches. A learning style describes how an individual most comfortably receives and processes information. Since students have diverse learning styles, various teaching approaches should be implemented to accommodate these differences (Nurzaki Alhafiz, 2022). Learning styles help students recognize their preferred learning methods, foster a sense of ownership in their education, highlight their individuality, and can make teaching more enjoyable while enhancing instructors' professional skills(Cuizon et al., 2022). A student's learning style is a critical factor in enhancing academic achievement. A misalignment between the student's preferred learning approach and the instructional methods employed by the educator may lead to disengagement, discomfort, and diminished interest in the learning process. Consequently, students' motivation to learn may decrease, and in extreme cases, they might even choose to withdraw from their educational pursuits (Bimastuti, 2021).

Bobbi De Porter and Mike Hernacki (Porter & Hernacki, 2005) identify three primary learning styles: visual, auditory, and kinesthetic. Visual learners absorb information best through observation, focusing on what they see. Their strength lies in strong visual perception. Auditory learners, on the other hand, depend on their sense of hearing and prefer to process information through listening. Kinesthetic learners learn most effectively through physical activity, movement, and touch, as they grasp concepts better when they are actively engaged in hands-on experiences (Restianim et al., 2020).

Research indicates a significant impact of using Android-based mathematics learning media on students' learning outcomes (Ramdani et al., 2023; Tenmau et al., 2023). Prior research examining the impact of e-learning media and learning styles on student performance indicates that the use of e-learning tools can enhance academic achievement, with auditory learners generally outperforming their visual counterparts (Sedik, 2023). On the other hand, the implementation of differentiated instruction has also been widely developed to tailor learning to students' readiness levels and learning styles, both through interactive multimedia (Caballero et al., 2022) and digital worksheets (Fahrizy & Fathurrahman, 2024). However, most existing studies tend to separate the focus between mobile learning and differentiated instruction, or emphasize only one of these aspects. Research that explicitly integrates both approaches simultaneously in the context of higher-level mathematics learning, such as Calculus, remains very limited. Moreover, there is still a lack of studies analyzing the relationship between the implementation of these two approaches and students' learning styles, even though learning styles are a crucial factor in technology-based learning.

This research seeks to examine: (1) the disparity in Calculus achievement among students exposed to mobile learning media compared to those taught using traditional instructional modules, (2) the variations in learning outcomes based on students' individual learning styles, and (3) the interaction effect between instructional media and learning styles on Calculus achievement. This study highlights the dynamic interaction between learning styles and instructional media, acknowledging their substantial impact on the overall effectiveness of the learning process. Students have diverse learning styles, requiring an appropriate approach to ensure optimal understanding of the material. On the other hand, instructional media, such as modules and mobile learning, have distinct characteristics and advantages that can support various learning styles.

Mobile learning and modules used in this study use the differentiated instruction method. Instructions on learning media, both mobile learning and modules, are designed based on differences in students' initial ability levels, categorized into three levels: high, medium, and low. Although all students aim for the same course learning outcomes, the learning tasks and activities vary according to their ability levels. The learning system stimulates student abilities using activity features and posttests tailored to each student's proficiency level. By examining the interaction between these two variables, this research aims to identify the most effective combination for enhancing student learning outcomes and providing new insights for developing adaptive instructional media.

This research addresses that gap by analyzing how mobile learning, when integrated with differentiated instruction strategies, can enhance student engagement and conceptual understanding in Calculus, considering their unique learning styles. The findings are expected to contribute to more inclusive and effective instructional designs, potentially improving student outcomes in mathematics education.

METHODS

This study employs a quasi-experimental method using a 2x3 factorial design with a control group. In this setup, two groups are randomly assigned and administered a posttest to evaluate the differences between the experimental and control groups, as shown in Table 1.

Table 1. Research Design

Learning Media (A)	Learning Style (B)		
	Visual (b_1)	Auditory (b_2)	Kinesthetic (b_3)
Mobile learning (a_1)	ab_{11}	ab_{12}	ab_{13}
Module (a_2)	ab_{21}	ab_{22}	ab_{23}

Note:

ab_{11} : The Calculus learning achievement of students with a visual learning style taught using mobile learning instructional media.

ab_{12} : The Calculus learning achievement of students with a auditory learning style taught using mobile learning instructional media.

ab_{13} : The Calculus learning achievement of students with a kinesthetic learning style taught using mobile learning instructional media.

ab_{21} : The Calculus learning achievement of students with a visual learning style taught using module-based instructional media.

ab_{22} : The Calculus learning achievement of students with a auditory learning style taught using module-based instructional media.

ab_{23} : The Calculus learning achievement of students with a kinesthetics learning style taught using module-based instructional media.

Researchers in this study identified instructional media and students' learning styles as independent variables, while students' Calculus learning achievement was the dependent variable. The instructional media were classified into two types: mobile learning and module-based learning, while learning styles were categorized as visual, auditory, and kinesthetic. The study included two groups: an experimental group and a control group. Researchers implemented mobile learning instructional media for the experimental group and module-based instructional media for the control group. The study involved 112 students from the Informatics Engineering Study Program at the University of Darussalam Gontor, all of whom were enrolled in the Calculus 1 course. Participants were divided into two groups: 59 students were assigned to the experimental group, while 53 constituted the control group. The research was carried out during the first semester of the 2023/2024 academic year and centered on the topic of Absolute Value Equations and Inequalities, delivered over three instructional sessions.

Researchers utilized tests and questionnaires as research instruments. They used the test instrument to measure students' Calculus learning achievement and the questionnaire to identify students' learning styles. The test instrument included an open-ended test with five questions, which they administered at the end of the learning process. The test instrument used in this study was designed to assess students’ computational thinking skills in the context of solving absolute value equations and inequalities. The indicators were developed based on core components of computational thinking, as follows in Table 2.

Table 2. Test question indicators

No.	CT Skill	Indicator
1	Decomposition	Students are able to break down absolute value problems into separate cases based on the definition of absolute value.
2	Pattern Recognition	Students are able to identify patterns in absolute value equations and generalize the solution behavior.
3	Abstraction	Students are able to ignore irrelevant details and focus on the algebraic structure of an absolute value expression.
4	Algorithmic Thinking	Students are able to design a step-by-step procedure to solve absolute value inequalities.
5	Evaluating Efficiency	Students are able to compare two solution methods and evaluate their efficiency.

The questionnaire included written statements aimed at identifying students’ learning styles. To ensure the validity of the test items and learning style indicators, both instruments were reviewed by Mathematics Education lecturers. The classification of learning styles in this study was based on the theory proposed by Bobbi De Porter and Mike Hernacki, which categorizes learning styles into three types: visual, auditory, and kinesthetic (Porter & Hernacki, 2005). They developed learning style indicators according to the characteristics of each learning style, as described by(Latifah, 2023), and presented them in Table 3.

Table 3. Learning Style Indicators

No	Visual Learning Style	Auditory Learning Style	Kinesthetic Learning Style
1.	Thorough and detail-oriented	Easily distracted by noise	Physically oriented and highly active
2.	Struggles with verbal instructions	Learns faster by listening and remembering	Sensitive to expressions and body language
3.	Remembers things more easily through visuals	Enjoys discussions, Q&A, and explaining things in detail	Learns better through practice or simulations
4.	Has difficulty concentrating	Good at oral activities	Moves closer when speaking to others
5.	Understands positions, shapes, numbers, and colors well	Has a strong sensitivity to music	Likes to experiment but tends to be untidy
6.	Not disturbed by noise	Weak in visual activities	Weak in verbal activities

Data were analyzed using a two-way ANOVA test with unequal cell sizes, in accordance with the 2x3 factorial research design. Prior to the analysis, prerequisite tests were conducted, including tests for normality and homogeneity. The normality test was used to verify whether the data followed a normal distribution or originated from a normally distributed population. The Shapiro-Wilk test was employed for this purpose. As a regression-based method, the Shapiro-Wilk test is considered highly effective. To simplify its application, two approximations—based on mean and median order statistics—were introduced, and an optimal, sample size-dependent significance level was adopted to maintain the test's overall error rate in line with the original version (Hernández, 2021). The decision-making process relied on the significance value (Sig.). If Sig. > 0.05, the data followed a normal distribution; if Sig. < 0.05, the data did not follow a normal distribution (Solihin & Sukardi, 2020). The homogeneity test evaluated whether the data groups had homogeneous variances. Levene's test was utilized to evaluate the homogeneity of variance. The decision criterion was based on the significance value (Sig.): a value greater than 0.05 indicated that the data were homogeneous, while a value less than 0.05 suggested a lack of homogeneity (Singgih Santoso, 2016).

RESULTS AND DISCUSSIONS

This study seeks to explore the differences in students' Calculus achievement between those taught using mobile learning and those using module-based instruction, examine how learning styles influence achievement, and analyze the interaction between mobile learning and learning styles in relation to student performance. The research was carried out with students from the Engineering Study Program at the University of Darussalam Gontor who were enrolled in Calculus during the 2023/2024 academic year. Participants were divided into two groups: the experimental group received instruction through mobile learning media, while the control group used traditional module-based materials.

The research data included students' Calculus learning achievement and learning styles. The study categorized learning styles into three types: visual, auditory, and kinesthetic.

Table 4. Presents the Classification of Students Based on Their Learning Styles.

Learning media	Number of student's			Total Number
	Visual	Auditory	Kinesthetic	
Mobile Learning	31	16	12	59
Module	24	15	14	53
Total Number	55	31	26	112

As shown in Table 4, the majority of students preferred the visual learning style, with 55 students, outnumbering those with auditory and kinesthetic preferences. Data on students' Calculus achievement were obtained from test results. Both the experimental and control groups were given the same test, consisting of five open-ended questions. These results were used to compare learning outcomes between students who received instruction through mobile learning media and those who used module-based learning. Table 5 displays a descriptive analysis of Calculus achievement, organized according to students' learning styles.

Table 5. Results of Statistical Analysis of Calculus Learning Achievement Data

Learning media	Students Learning Style	Average	Deviation Standar	N
Mobile Learning	Visual	78,93	10,79	81
	Auditory	65,19	8,7	16
	Kinesthetic	72,81	10,01	12
	Total	73,81	11,58	59
Module	Visual	66,29	13,50	24
	Auditory	65,33	12,06	15
	Kinesthetic	66,57	11,47	14
	Total	66,09	12,36	53
Learning Style	Visual	73,41	13.51	55
	Auditory	65,25	10,28	31
	Kinesthetic	69,11	10,97	26
	Total	70,16	12,51	112

Table 5 reveals that students who received instruction through mobile learning media outperformed those who learned using module-based materials in Calculus achievement. When analyzed by learning style, visual learners achieved the highest average scores compared to their auditory and kinesthetic peers. To assess the significance of these differences, the researchers employed a two-way ANOVA with unequal cell sizes, preceded by prerequisite tests for normality and homogeneity.

The researchers conducted the normality test using the Shapiro-Wilk test at a significance level of 0.05. They performed the normality test for each group of learning media and each group of learning styles—Table 6 and Table 7 present the results of the normality analysis.

Table 6. Results of Normality Analysis for Learning Media Group Data

Variable	Shapiro-Wilk		
	Statistic	df	Sig.
Mobile Learning	0,980	59	0,441
Module	0,970	53	0,205

Table 7. Results of Normality Analysis for Learning Style Group Data

Variable	*Shapiro-Wilk*		
	Statistic	*df*	*Sig.*
Visual	0,978	55	0,411
Auditory	0,977	31	0,735
Kinesthetic	0,975	26	0,764

Tables 6 and 7 show that the Sig. Values for all data groups exceed 0.05. This result indicates that the data in both the learning media and learning style groups follow a normal distribution. The researchers then conducted the next prerequisite test, the homogeneity test, using Levene's test at a significance level of 0.05. Table 8 presents the results of the homogeneity test.

Table 8. Results of the Homogenety Test

F	df1	df2	Sig.
0,997	5	106	0,423

Table 8 presents the homogeneity test results, showing that the Sig. The value is 0.423, which is greater than 0.05. This result made the researchers conclude that the data variance is homogeneous. After meeting the prerequisite assumptions of normality and homogeneity, the researchers proceeded to examine the significance of differences in Calculus learning achievement across instructional media and learning style groups using a two-way ANOVA with unequal cell sizes. This statistical method was chosen due to the unequal number of participants in each group, as indicated in Table 3. They conducted the ANOVA analysis using IBM SPSS Statistics 22. Table 9 summarizes the results of the two-way ANOVA with unequal cell sizes.

Table 9. Results of Two-Way ANOVA with Unequal Cell Sizes

Data Source	JK	df	RK	F	Sig.
Learning Media	906,394	1	906,394	7,025	0,009
Learning style	1072,287	2	536,143	4,155	0,018
Interaction	835,822	2	417,911	3,239	0,043
Error	13676,945	106	129,028		
Total	568716	112			

Table 9 shows that the Sig. Value for the learning media group is 0.009 < 0.05, indicating a significant difference in Calculus learning achievement between students taught using mobile learning media and those taught using module-based learning media. The average Calculus achievement score of students taught with mobile learning media is 73.81, while the average score of students taught with module-based media is 66.09. This result shows that the Calculus learning achievement of students taught using mobile learning media is better than those taught using module-based media.

In Table 9, the significance value (Sig.) for the learning style group is 0.018, which is less than 0.05, indicating a statistically significant difference in Calculus achievement among students with different learning styles. According to Table 5, students with a visual learning style had the highest average score of 73.41, followed by kinesthetic learners with 69.11, and auditory learners with 65.25. This demonstrates that learning style has a significant impact on students' Calculus performance. To explore these differences further, the researchers performed a post hoc analysis using the Scheffé method, with the results detailed in Table 10.

Table 10. Results of Post Hoc Comparison Between Columns

Ho	Sig.
$\mu_1 = \mu_2$	0,008
$\mu_1 = \mu_3$	0,286
$\mu_2 = \mu_3$	0,445

Note:
μ_1 : average Calculus learning achievement of students with a Visual learning style
μ_2 : average Calculus learning achievement of students with an Auditory learning style
μ_3 : average Calculus learning achievement of students with a Kinesthetic learning style

The post hoc analysis presented in Table 10 reveals a significant difference in Calculus achievement between students with visual and auditory learning styles, as indicated by a Sig. value of 0.008, which is less than 0.05. However, no significant difference was found between visual and kinesthetic learners (Sig. = 0.286 > 0.05), nor between auditory and kinesthetic learners (Sig. = 0.445 > 0.05).

In Table 9, the significance value for the interaction effect is 0.043, which is less than 0.05, indicating a statistically significant interaction between learning media and students' learning styles. To further explore this interaction and its impact on Calculus achievement, the researchers performed a post hoc analysis using the Scheffé method, with the findings displayed in Table 11.

Table 11. Results of Post Hoc Comparison Between Cells

No.	Ho	Sig.	No.	Ho	Sig.
1.	$\mu_{11} = \mu_{12}$	0,012	9.	$\mu_{12} = \mu_{23}$	1,000
2.	$\mu_{11} = \mu_{13}$	0,678	10.	$\mu_{13} = \mu_{21}$	0,837
3.	$\mu_{11} = \mu_{21}$	0,008	11.	$\mu_{13} = \mu_{22}$	0,797
4.	$\mu_{11} = \mu_{22}$	0,017	12.	$\mu_{13} = \mu_{23}$	0,909
5.	$\mu_{11} = \mu_{23}$	0,051	13.	$\mu_{21} = \mu_{22}$	1,000
6.	$\mu_{12} = \mu_{13}$	0,772	14.	$\mu_{21} = \mu_{23}$	1,000
7.	$\mu_{12} = \mu_{21}$	1,000	15.	$\mu_{22} = \mu_{23}$	1,000
8.	$\mu_{12} = \mu_{22}$	1,000			`

In Table 11, it can be concluded that:

1. A significant difference exists in Calculus achievement between students with visual and auditory learning styles when taught using mobile learning media.
2. No significant difference is observed in Calculus achievement between students with visual and kinesthetic learning styles when using mobile learning media.
3. There is a significant difference in Calculus achievement between students with a visual learning style who learn via mobile learning media and those who use module-based learning media.
4. A significant difference in Calculus achievement exists between visual learners taught with mobile learning media and auditory learners taught with module-based media.
5. There is a significant difference in Calculus achievement between visual learners using mobile learning media and kinesthetic learners using module-based media..
6. No significant difference is found in Calculus achievement between students with auditory and kinesthetic learning styles when both are taught using mobile learning media.
7. No significant difference was found in Calculus achievement between auditory learners taught with mobile learning media and visual learners taught with module-based media.
8. Calculus achievement did not significantly differ between auditory learners taught via mobile learning and those taught via module-based learning.
9. There was no significant difference in Calculus achievement between auditory learners using mobile learning media and kinesthetic learners using module-based media.
10. No significant difference in Calculus achievement was observed between kinesthetic learners taught with mobile learning media and visual learners taught with module-based media.
11. No significant difference was found in Calculus achievement between kinesthetic learners taught with mobile learning media and auditory learners taught with module-based media.
12. Calculus achievement did not significantly differ between kinesthetic learners taught via mobile learning and those taught via module-based learning.
13. There was no significant difference in Calculus achievement between visual and auditory learners taught using module-based media.
14. No significant difference was observed between visual and kinesthetic learners taught with module-based media.
15. Calculus achievement did not significantly differ between auditory and kinesthetic learners taught using module-based media.

The ANOVA results indicate a significant difference in Calculus achievement between students instructed with mobile learning media and those using module-based media, with the mobile learning group achieving higher average scores. Previous research supports this finding and states that using mobile learning media results in a higher average student score and is more effective than using printed media (Sedik, 2023). Mobile learning is a substitute that allows students to choose their preferred learning model. For example, they can use technology, combine conventional learning with technology (a blended model), or rely entirely on conventional learning methods (Mariati et al., 2021).

Mobile learning is more effective than traditional modules because it supports the three main learning styles: visual, auditory, and kinesthetic, through interactive and engaging features. Dynamic visuals like interactive diagrams help visual learners understand better; narrated lessons and spoken content engage auditory learners; hands-on activities such as quizzes, simulations, and touch-based interactions actively involve kinesthetic learners (Satriani et al., 2024). These features create a more engaging and personalized learning experience compared to the passive, text-heavy approach of modules.

Mobile learning can enhance student-centered learning, support the differentiation of students' learning needs, and enable personalized learning. The implementation of digital-based differentiated learning models demonstrates a high level of effectiveness in enhancing students' science problem-solving skills (Hardiansyah et al., 2024). Mobile learning, particularly Android-based applications, can offer solutions to challenges encountered in the teaching and learning process. Utilizing technology in learning mathematics, particularly in calculus courses, significantly supports both lecturers and students in maximizing learning outcomes (Salsabila, 2024). Mobile devices in facilitating mathematics learning, saving time, and helping achieve better results in mathematics (Jatileni et al., 2024). The use of digital learning materials based on mobile learning also demonstrates high effectivenes (Yaniawati et al., 2023).

Based on the data analysis results, learning styles have a significantly different effect on student achievement. This result aligns with previous studies that stated that learning styles influence academic performance (Darma et al., 2024). Learning styles can affect students' mathematical problem-solving abilities (Syaputra et al., 2022). A more thorough comprehension of students' learning styles can lead to increased engagement and improved academic performance(Hariri et al., 2025). Teachers need to understand students' learning styles to determine teaching methods that align with those styles (Eka et al., 2021).

The findings of this study strengthen the argument that integrating mobile learning and differentiated instruction not only enables more personalized and flexible learning but also significantly enhances learning outcomes when designed in alignment with students' learning styles. This research fills a gap in the literature by combining two pedagogical approaches that have previously been studied mostly in isolation and applying them in the context of higher-level learning, such as Calculus.

CONCLUSION

The results of this study provide valuable insights into the relationship between mobile learning, learning styles, and Calculus achievement, revealing important implications for educational theory and practice. First, the study found that students taught using mobile learning media achieved better Calculus results compared to those taught with module-based learning media. Second, learning style had a significant impact on achievement, with students who had a visual learning style showing the highest average scores. Third, the study revealed that there is no significant interaction between learning media and learning style, suggesting that the effectiveness of learning media (whether mobile learning or module-based) is independent of the student's learning style.

These findings highlight a critical gap in current educational theory: while learning style influences achievement, its impact is conditional upon the type of media used, not the other way around. This challenges the commonly held view that a specific learning style should align with a particular teaching method for optimal results. Instead, the results suggest that mobile learning could be more effective when used with students who have certain learning styles, particularly visual learners, but not necessarily as a universal solution. Therefore, this study suggests the need for an expansion of existing learning theories to consider the dynamic interaction between media types and learning styles, a perspective that has not been adequately explored in prior research.

In light of these results, it is recommended that mobile learning be adopted as an alternative instructional medium to enhance Calculus achievement. Future research could further investigate mobile learning from different perspectives, such as its impact on developing students' computational thinking skills, to broaden our understanding of its potential in improving student outcomes across disciplines.

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