

Functional thinking in Kolb learning style: A causal-comparative study

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Abstrak Penelitian ini bertujuan untuk mengetahui perbedaan berpikir fungsional siswa dengan gaya belajar divergen, konvergen, asimilator dan akomodator. Penelitian causal-comparative ini melibatkan 137 sampel siswa yang diambil secara acak dari 214 siswa kelas 8 Madrasah Tsanawiyah Negeri (MTsN) 3 Mataram, Lombok, Indonesia. Data berpikir fungsional siswa dikumpulkan melalui tiga jenis tugas, yang terdiri dari dua tugas pola linier dan satu tugas pola non-linier. Data gaya belajar diperoleh dari Kolb learning style inventory (KLSI), yang terdiri dari dua belas item pernyataan. Analisis deskriptif mengungkapkan bahwa distribusi gaya belajar Kolb siswa adalah sebagai berikut: 29.93% gaya belajar divergen, 24.82% gaya belajar konvergen, 17.52% gaya belajar asimilator, dan 27.74% gaya belajar akomodator. Pada skala 0-100, rata-rata berpikir fungsional siswa adalah 67.90, sedangkan rata-rata berpikir fungsional siswa dengan gaya belajar divergen, konvergen, asimilator, dan akomodator secara berturut-turut adalah 73, 64.5, 69.9, dan 64.2. Hasil ANOVA menunjukkan nilai uji F sebesar 10.297 dengan signifikansi 0.0, artinya terdapat perbedaan yang signifikan kemampuan berpikir fungsional keempat kelompok siswa tersebut. Lebih jauh, kelompok siswa dengan gaya belajar divergen menunjukkan rerata tertinggi ($m = 73$) dibandingkan dengan ketiga kelompok lainnya. Hasil penelitian ini dapat dijadikan sebagai acuan dalam mendesain pembelajaran matematika berdasarkan gaya belajar siswa.

Kata kunci *Berpikir fungsional, Gaya belajar Kolb, Causal comparative*

Abstract This study aims to elucidate variations in students' functional thinking across divergent, convergent, assimilator, and accommodator learning styles. A causal-comparative study involving 137 student samples was conducted randomly from 214 students enrolled in grade 8 of junior high schools (MTsN 3) in Mataram, Lombok, Indonesia. Data collection for students' functional thinking utilized three types of tasks, comprising two linear pattern tasks and one non-linear pattern task. Students' learning style data were obtained from the Kolb learning style inventory (KLSI), comprising 12 statement items. Descriptive analysis revealed that the distribution of students' Kolb learning styles was as follows: 29.93% divergent learning styles, 24.82% convergent learning styles, 17.52% assimilator learning styles, and 27.74% accommodator learning styles. On a scale of 0-100, the average functional thinking of students was 67.90, while the average functional thinking of students with divergent learning styles was 73, convergent 64.5, assimilator 69.9, and accommodator 64.2. The ANOVA test results yielded an F test value of 10.297 with a significant value of 0.0, indicating significant differences in students' functional thinking among students with divergent, convergent, assimilator, and accommodator learning styles. Furthermore, the students with divergent learning styles exhibited the highest mean ($m = 73$) compared to the other groups. The research outcomes can serve as a basis for mathematics learning design based on students' learning styles.

Keywords *Functional thinking, Kolb learning style, Causal comparative*

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Introduction

Mathematics has long been considered as a universal language of logic, order, and reasoning. Its role extends beyond solving equations to shaping the way individuals think, problem-solve, and interpret the world. However, despite its universality, the methods by which students learn mathematics can vary widely (Autida, 2024; Farman, 2023). This diversity in learning styles, e.g., the individual preferences and approaches students use to acquire and process information, is a critical aspect of learning that educators must consider (Newton & Miah, 2017; Rustamovna, 2019)

Learning styles are broadly defined as the preferred ways in which individuals gather, process, and retain information (DePorter & Hernacki, 2000; Willingham et al., 2015). Students' learning styles correlates with their attitude, communication abilities, and academic achievement in mathematics (Aydın, 2016; Fatkhiyyah et al., 2019; Villajuan, 2019; Ganesen et al., 2020; Orhun, 2007; Sujadi et al., 2019; Akinyode & Khan, 2016). Kolb's learning styles (KLS) are a powerful framework for understanding how students learn and process information, particularly in the context of mathematics learning and problem solving (Knisley, 2003; Muro & Terry, 2014; Rokhima et al., 2019). The framework identifies four styles: Diverging (visual and collaborative learners), Assimilating (theoretical and logical thinkers), Converging (practical problem-solvers), and Accommodating (hands-on, intuitive learners). Each of these learning styles plays a significant role in shaping how students interact with mathematical content. As for instance, a diverging learner may excel when presented with graphs, charts, and diagrams, while assimilating learner might benefit more from verbal explanations or discussions (Idkhan & Idris, 2021; Dwiyanto & Kurniasih, 2024; Anwar et al., 2023). Accommodating learner, on the other hand, may find mathematical concepts easier to grasp through hands-on activities and real-world applications.

While learning styles determine how students best acquire and process information, functional thinking skill requires the application of that information in systematic and logical ways. At its core, functional thinking involves understanding and analyzing relationships between variables, often expressed in the form of functions (Frey et al., 2022). NCTM (2000) prioritizes fostering functional thinking by promoting an understanding of patterns, relationships, and the concept of functions. Meanwhile, the latest Indonesian curriculum outlines learning outcomes for grades 3 and 4 (Phase B) that focus on recognizing patterns in objects and numbers, which serve as a foundation for developing functional thinking (BSKAP, 2024). This type of thinking is foundational to higher-level mathematical concepts, particularly algebra and calculus (Krüger, 2019).

Students' functional thinking can be assessed by examining their ability to generalize relationships between quantities, which can be classified into three types: recursive patterns, covariational reasoning, and correspondence relationships (Confrey & Smith, 1991; Smith, 2008). Recursive patterns involve identifying variations within a sequence of values. Covariational reasoning focuses on analyzing how changes in one variable influence changes in another. Correspondence relationships, on the other hand, require students to generalize and express the overall relationship between variables. These categories collectively provide a framework for understanding how students develop and apply functional reasoning in mathematical contexts (Digel & Roth, 2020; Stephens et al., 2012).

Drawing on Piaget's theory of cognitive development, students who have reached the formal operational stage are more capable of engaging in the abstract reasoning required to generalize relationships between quantities (Shayer, 1979). Nevertheless, even kindergarten-aged children can recognize simple patterns (Blanton & Kaput, 2004; Syawahid et al., 2020; Tanışlı, 2011; Warren et al., 2006). As students are progressing into higher education level, e.g., elementary or high schools, their cognitive abilities advance, as evidenced by the emergence of various categories of functional thinking skills (Stephens et al., 2017). Although students often encounter challenges in developing their functional thinking (Lannin, 2005; Huntley et al., 2007; Bush & Karp, 2013; Jupri et al., 2014; Sari et al., 2018; Yuniati et al., 2019; Suryowati, 2021; Syawahid, 2022; Syawahid et al., 2024; Utami et al., 2023), the learning environments that incorporate collaborative activities, hands-on experiences, and the integration of digital technology may offer effective solutions to this issue (Günster & Weigand, 2020; Wei et al., 2023; Pittalis et al., 2024). Moreover, a study suggests that the variety of mathematical tasks, including pattern tasks, operation tasks, one-to-one tasks, and pre-functional tasks; that are assigned to students may also influence the development of their functional thinking skills (Ding et al, 2023).

Considering the variability in students' learning styles, it raises an issue of how mathematics learning programs can be tailored to align with individual preferences, thereby effectively supporting the development of their functional thinking abilities. In this context, much of the existing literature predominantly focuses on the development, implementation, and evaluation of didactical approaches aimed at enhancing students' functional thinking, without taking into account the heterogeneity of their learning styles (see for example Wei et al., 2024; Pittalis et al., 2024). Additional efforts should be directed towards considering this psychological aspect. A recent qualitative study has conducted an initial exploration of the functional thinking abilities exhibited by student groups with varying learning styles during mathematical problem-solving (Syawahid & Sucipto, 2023). It highlights the importance of educational practices that support both students' learning preferences and the enhancement of their functional thinking. In this paper, we extend prior research by undertaking a quantitative investigation of potential differences in students' functional thinking skills according to KLS. Specifically, this study will seek the answer to the question: "Are there significant differences in functional thinking skills among students with diverging, assimilating, converging, and accommodating learning styles?".

The paper is organized as follows. First, we present theoretical overview of functional thinking and Kolb learning styles. Then, we elaborate the methodology used throughout the study including sample and population, research instruments, and statistical analysis. Next, we display the results and accordingly discuss the overall impact of research findings on teaching and learning mathematics. Finally, we draw a conclusion on students' functional thinking differences based on their learning styles.

Theoretical review

Functional thinking

Functional thinking is a component of algebraic reasoning (Blanton & Kaput, 2005; Kaput, 2008). It is a reasoning process that constructs and generalizes patterns and relationships utilizing various linguistic tools and representations (Blanton, 2008). It explores the generalizations of relationships or functions. Functional thinking can also be interpreted as generalizing the relationships between two quantities (or more) in a covariant manner, expressing those

relationships in words, tables, graphs, or mathematical symbols, and manipulating different representations to analyze function behavior (Blanton & Kaput, 2011).

Smith (2008) defines functional thinking as representative thinking that focuses on the relationship between two (or more) different sums. This type of thinking leads to the generalization of a particular relationship (individual event) to that relationship. According to Stephens et al. (2017), functional thinking is a process of constructing, describing, and interacting with and about functions.

Functional thinking comprises three distinct types: recursive patterning, covariational thinking, and correspondence relationship (Confrey & Smith, 1991; Smith, 2008). Recursive patterning describes changes in one quantity's value. Covariational thinking critiques how two quantities change simultaneously and explicitly represents those changes. Correspondence relations describe relationships between variables through algebraic rules or expressions. Pittalis et al. (2020) has established a correlation between recursive patterning, covariational thinking, and correspondence relationships within students' functional thinking.

Figure 1 illustrates an example of a functional thinking task. In recursive patterning, the students determine the number of leaves on the following day by asserting that each day, the leaves increase by 3 ($day\#4 = day\#3 + 3 = 10 + 3 = 13$). In covariation thinking, students determine the number of leaves on the next day by stating that when the day increases by 1, the number of leaves increases by 3. In a correspondence relationship, students determine the number of leaves on the next day by multiplying the day by 3 and adding by 1 ($the\ number\ of\ leaves = 3 \times the\ day + 1$).

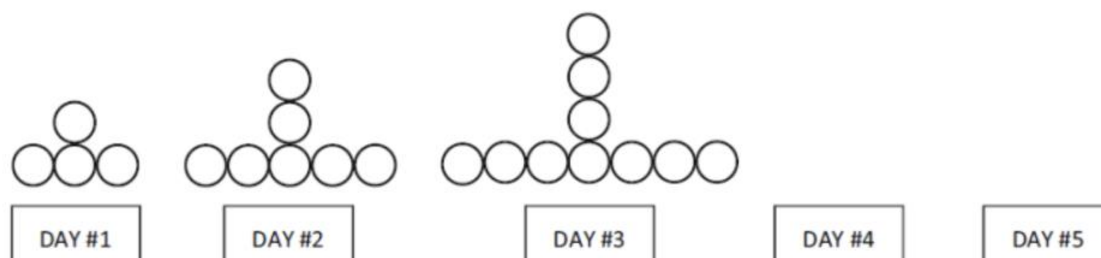


Figure 1. Illustration of functional thinking: Relationship between the number of leaves and the number of days

In their 2008 publication, Smith proposed six activities that facilitate functional thinking: (1) engaging in diverse physical activities; (2) identifying two or more quantities that exhibit variation in activity and focusing attention on the correlation between two variables; (3) recording the correspondence values of quantities using tabulations, graphs, or symbols; (4) identifying patterns within such records; (5) coordinating the identified patterns with the actions associated with the activity; and (6) utilizing these coordinates to construct representations of the pattern of relationships. To establish functional thinking it is necessarily for students to: (a) generalize the relationship between two quantities, (b) represent and justify the relationship between two quantities in various ways, such as through verbal descriptions, variable notation, tabulations, and graphs, and (c) effectively generalize representations to comprehend and predict behavioral functions (Blanton et al., 2015).

According to the National Council of Teachers of Mathematics (NCTM, 2000), students in grades 3-5 should possess the ability to (a) describe, extend, and generalize geometric and

numeric patterns, and (b) represent and analyze patterns and functions using verbal descriptions, tables, and graphs. Stacey (1989) distinguishes between near and far generalizations. Near generalization involves identifying the next pattern that can be reached through counting, drawing, or creating a table. Conversely, far generalization requires understanding general rules. Amit and Neria (2008) further categorize generalizations into near generalization, far generalization, and formal generalization. Formal generalization entails explicitly representing a generalization in a formal manner, aiming towards algebraic concepts. Mouhayar and Jurdak (2016) classify numerical and figural reasoning in pattern generalization. Numerical generalization involves relating the values of terms in a quantity (number) from a given pattern. Figural reasoning involves relating the changes in figures from a given pattern. In this study, the students' functional thinking was identified through their responses to numerical and figural pattern generalization tasks. Each task comprised near generalization, far generalization, and formal generalization.

Kolb learning style

A learning style refers to an individual's propensity for acquiring and organizing information (DePorter & Hernacki, 2000). As elucidated by Kolb (1984), a learning style encompasses an individual's inclination to comprehend the significance of experiences and the transformative processes involved. DePorter and Hernacki (1999) posits that a learning style encompasses a diverse range of methods for absorbing, organizing, and processing information. Sugihartono (2007) defines a learning style as a specific sequence of behaviors exhibited by an individual in acquiring new information, developing novel skills, and subsequently storing these acquired knowledge and skills.

Kolb (1984) distinguished four distinct learning preferences in students, as depicted in Figure 2, concrete experience (CE), reflective observation (RO), conceptual abstract conceptualization (AC), and active experimentation (AE). In the concrete experience state, students draw upon their personal experiences and emphasize practical applications. They demonstrate a heightened level of receptivity and engagement in novel experiences.

In the abstract conceptual state, the students are engaged in logical analysis, systematic and conceptual mastery from diverse perspectives, and form opinions based on their thoughts and feelings. In the active experience state, the students employ actions (doing) such as persistence in tasks and demonstrate a firm attitude towards taking risks. They possess the ability to influence others through their attitudes.

Among the four trends, Kolb (1984) categorized students' learning styles into four distinct types: divergers, assimilators, convergers, and accommodators. The diverger learning style is a fusion of the tendencies of CE and RO. This learning style integrates both feeling and observation. The advantages of diverger students are that they perceive real-world scenarios from diverse perspectives, possess imaginative capabilities, enjoy tasks that require generating ideas, appreciate gathering information, and are passionate about literature, culture, history, and other social sciences (Altun, 2019). The assimilator learning style is a combination of AC and RO tendencies. This learning style combines thought and observation. The advantages of assimilator students are that they comprehend, respond, and organize information in a concise and logical manner, akin to working with abstract concepts and theoretical inclinations. Students with the assimilator type exhibit an interest in science and mathematics (Altun, 2019).

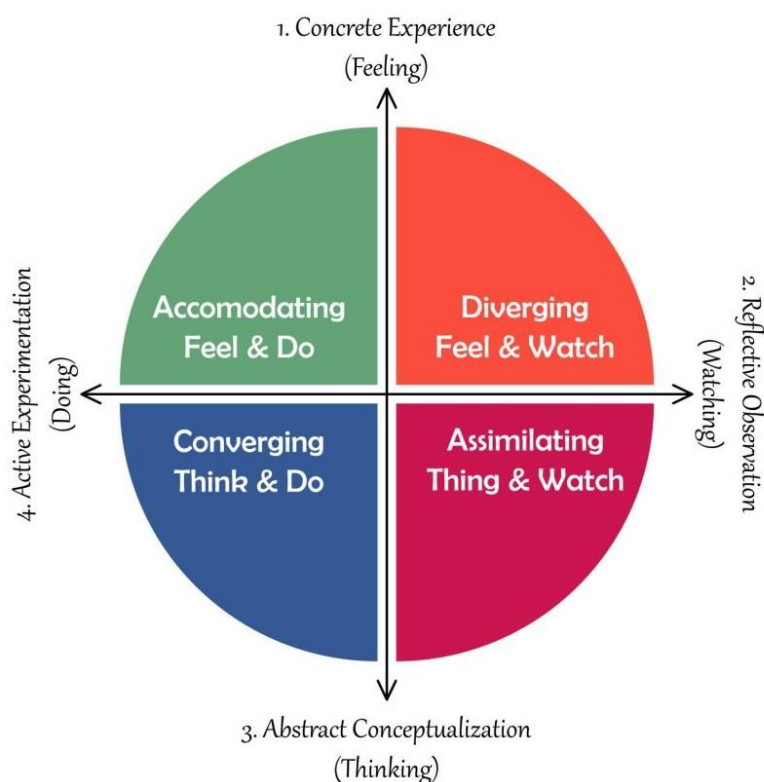


Figure 2. Kolb learning style

The converger learning style is a combination of the AC and RO tendencies. This learning style integrates the capacity for thought and action. Individuals with a converger learning style possess strong problem-solving and decision-making abilities and are particularly drawn to practical technical tasks (Altun, 2019)

In contrast, the accommodator learning style is a combination of the tendencies of CE and AE. This learning style combines the capacity for feeling and action. Students with an accommodator learning style approach problem-solving by considering input and employing trial and error. They tend to disregard theories that conflict with empirical evidence. Additionally, they exhibit a strong affinity for business and engineering courses (Altun, 2019).

Methods

This study employs a quantitative methodology with a causal-comparative design. A causal-comparative design is implemented to ascertain the cause or consequences of pre-existing differences between or among groups of individuals (Fraenkel et al., 2012). This design was selected due to the absence of direct treatment administered to the samples. The researchers compared students' existing functional thinking proficiencies without prior intervention. This research is conducted at the Islamic State of Junior High School in Mataram, which comprises a student body primarily drawn from grade 8 and a total enrolment of 214 students. The selection of grade 8 was based on previously established learning on number patterns. A total of 137 students were selected as samples using a simple randomization sampling technique.

Data collection was conducted through a combination of questionnaire and test methodologies. The questionnaire methodology was used to gather information on students' learning preferences, while the test methodology was utilized to assess students' functional

thinking abilities. A questionnaire comprising 12 statement items was utilized to obtain data on students' learning styles. The questionnaire was derived from Kolb's Learning Style Inventory (KLSI) version 2.0 (Loo, 1999).

The functional thinking test employed in this study was adapted from (Amit & Neria, 2008; Lepak et al., 2018) and (Amit & Neria, 2008). The test comprised three distinct types of tasks, as depicted in Figure 3. Each task type included two linear pattern problems and one non-linear pattern problem. Each problem type consisted of four question items that assessed the individual's capacity for near generalization, distant generalization, formal generalization, and inverse generalization.

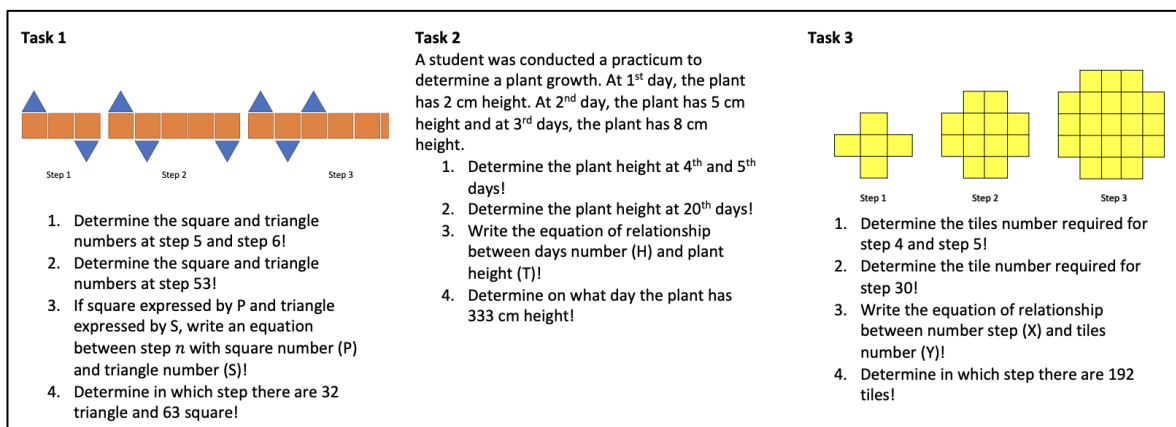


Figure 3. Functional thinking test

Data analysis was conducted employing descriptive data analysis techniques, prerequisite tests, and hypothesis testing. Descriptive data analysis encompasses both category descriptive and descriptive statistics. Category data description categorizes functional thinking into five scales: excellent, good, fair, poor, and very poor (as depicted in Table 1).

Table 1. Functional thinking category

No	Score interval	Category
1	$X \geq 75$	Excellent
2	$58,3 \leq X < 75$	Good
3	$41,6 \leq X < 58,3$	Fair
4	$25 \leq X < 41,6$	Poor
5	$X < 25$	Very Poor

Descriptive statistics involves calculating average data, maximum and minimum values, and data variance. The prerequisite tests employed are the normality test and the homogeneity test. The normality test utilizes the Kolmogorov-Smirnov and Shapiro-Wilk tests, while the homogeneity test employs the Levene test. For hypothesis testing in this study, a one-way ANOVA was conducted, with the significance value of the F test serving as the criterion. The interpretations of this criterion are as follows: (a) if the significance value is less than 0.05, the hypothesis is accepted, indicating a difference in functional thinking among students with divergent, convergent, assimilator, and accommodator learning styles; (b) if the significance value is greater than or equal to 0.05, the hypothesis is rejected, suggesting no difference in functional thinking among students with these learning styles (Cohen et al., 2007).

Findings

Descriptive of students' FT based on KLS

Based on the results of the KLSI assessment, the study has identified four distinct learning styles among the 137 students: divergent (41 students), convergent (34 students), assimilator (24 students), and accommodator (38 students) (Figure 4). Notably, the divergent learning style was the most preferred, followed by the accommodator, assimilator, and convergent styles in decreasing proportions. This finding suggests that students predominantly engage in learning modalities that emphasize reflective and imaginative skills rather than task-oriented or technically solution-focused approaches characteristic of the convergent learning style.

In contrast to the findings reported by Ganesen et al. (2020), who asserted that the convergent learning style is the most prominent among middle school learners, the current study's results indicate a preference for divergent learning styles. Several academic and contextual variables may contribute to these discrepancies. The cultural milieu and educational environment of the participants in this study's sample may have fostered critical and creative cognitive skills, which are commonly associated with divergent learning styles. In contrast, Ganesen et al. (2020) conducted their research on a cohort of students with a strong emphasis on problem-solving and practical orientation, potentially rendering the convergent learning style more prevalent. Additionally, variations in curricular frameworks and methodologies employed for data collection could also explain the observed differences between these investigations.

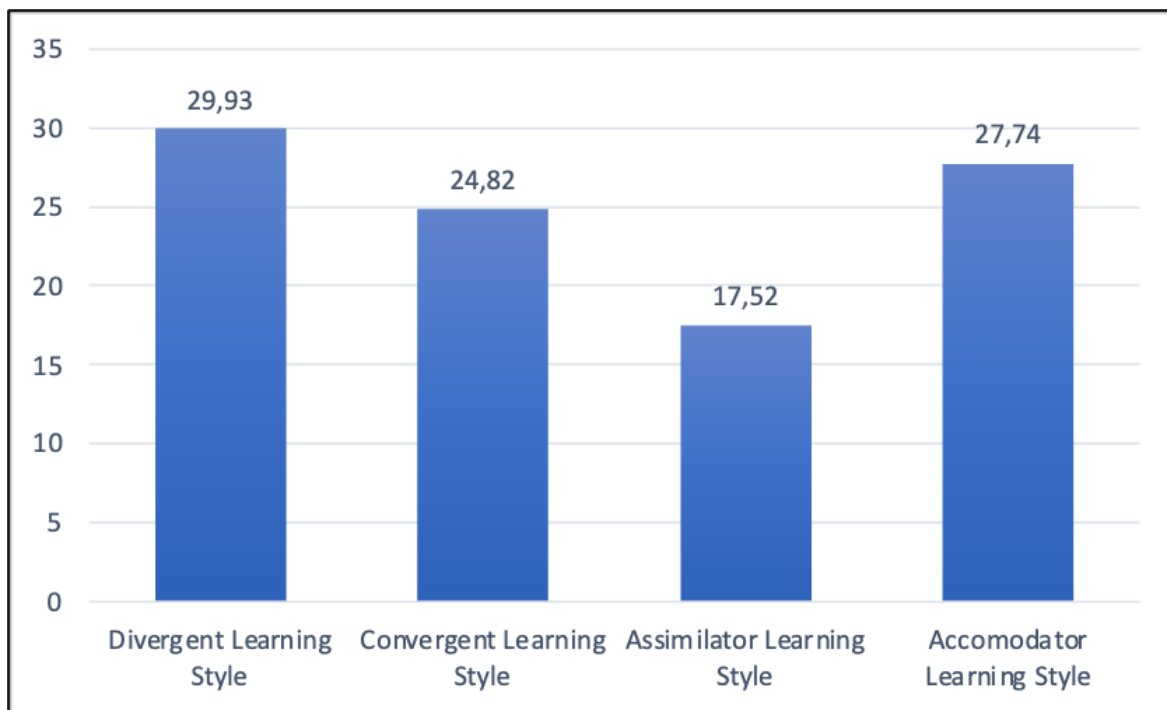


Figure 4. Percentage of students' Kolb learning style

The findings of the descriptive analysis of students' functional thinking are presented in Figure 5. The students' functional thinking predominantly falls within the "good" category, followed by "excellent" and then "fair" category. Over half of the sample in this study exhibits functional thinking with interval scores ranging from 58.3 to 75. Furthermore, there are no students whose functional thinking falls into both the poor and very poor categories meaning

that the students chosen in this study can demonstrate their functional thinking skills in a good manner.

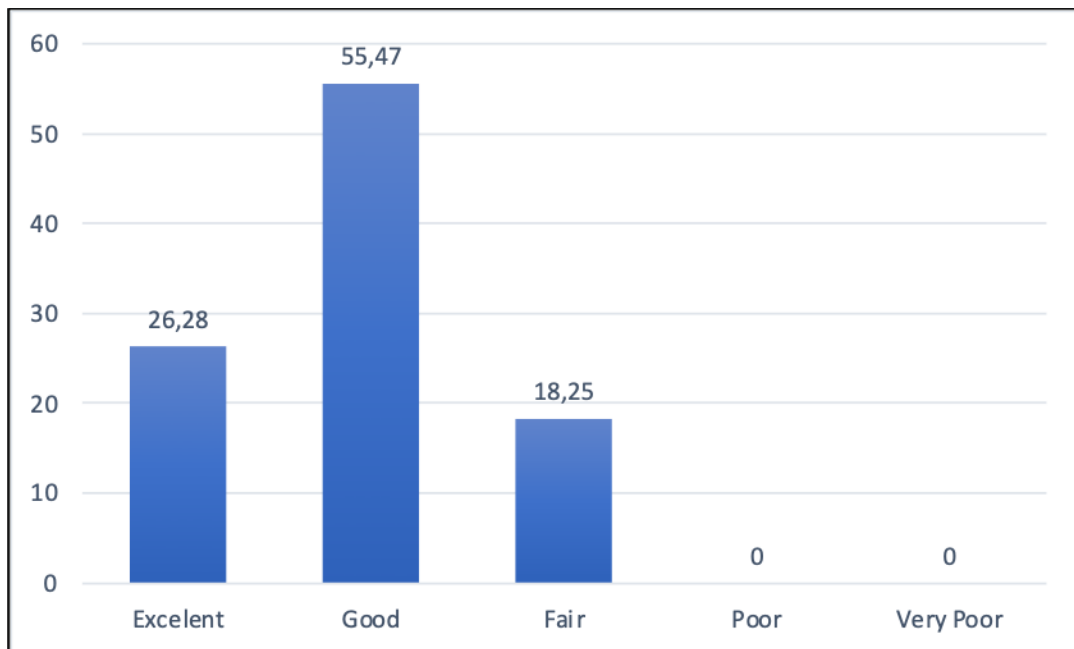


Figure 5. Percentage of students' functional thinking category

The analysis of categorical distribution of students' functional thinking reveals that most students are categorized within the “good” classification, which significantly exceeds the numerical representation of both the “excellent” and “fair” classifications. This observation suggests that a substantial proportion of students have already developed robust functional thinking competencies, encompassing the capacity to comprehend relationships, identify patterns, and, to a certain degree, effectively represent functions. The prevalence of the “good” category indicates that the pedagogical approaches employed have proven to be sufficiently effective in fostering fundamental to intermediate functional thinking skills. However, a limited number of students have attained the “excellent” tier, which signifies a more profound comprehension of abstract reasoning and the generalization of patterns (Stephens et al., 2017).

Furthermore, the conspicuous absence of students categorized as poor and very poor is a noteworthy positive indicator. This phenomenon demonstrates that all students have successfully achieved the necessary minimum standards for functional thinking, with no substantial deficiencies evident in their mastery of these fundamental skills. The scarcity of students in the lower classifications further emphasizes the effectiveness of the instructional methodologies employed in facilitating equitable access to foundational functional concepts for the entire student body. Consequently, while there is potential for an increase in the representation of students within the excellent category, these outcomes reflect an inclusive educational environment that effectively supports all students in attaining satisfactory skill proficiency levels.

These findings provide a positive outlook on students' functional thinking abilities while simultaneously emphasizing the need for the development of more effective strategies to support students in the “good” and “fair” categories in enhancing their skills to the “excellent” level.

Figure 6 provides a statistical summary of students' functional thinking abilities. The range of scores spans from 46 to 82, with a standard deviation of 82.17. The substantial variance indicates a wide range of students' functional thinking abilities, encompassing both excellent and fair categories. Additionally, the mean score of 67.9 falls within the range of good functional thinking.

Based on the descriptive statistical analysis presented in Figure 6, the mean functional thinking ability of the student population is 67.9, accompanied by a variance of 82.17. The lowest recorded score is 46, and the highest is 82. This mean-value suggests that, overall, the functional thinking capabilities of the students are categorized within a moderate range. In fostering functional thinking, this evaluation reveals that a considerable portion of students demonstrate adequate foundational competence; however, significant potential exists for improvement to achieve a more advanced level of understanding.

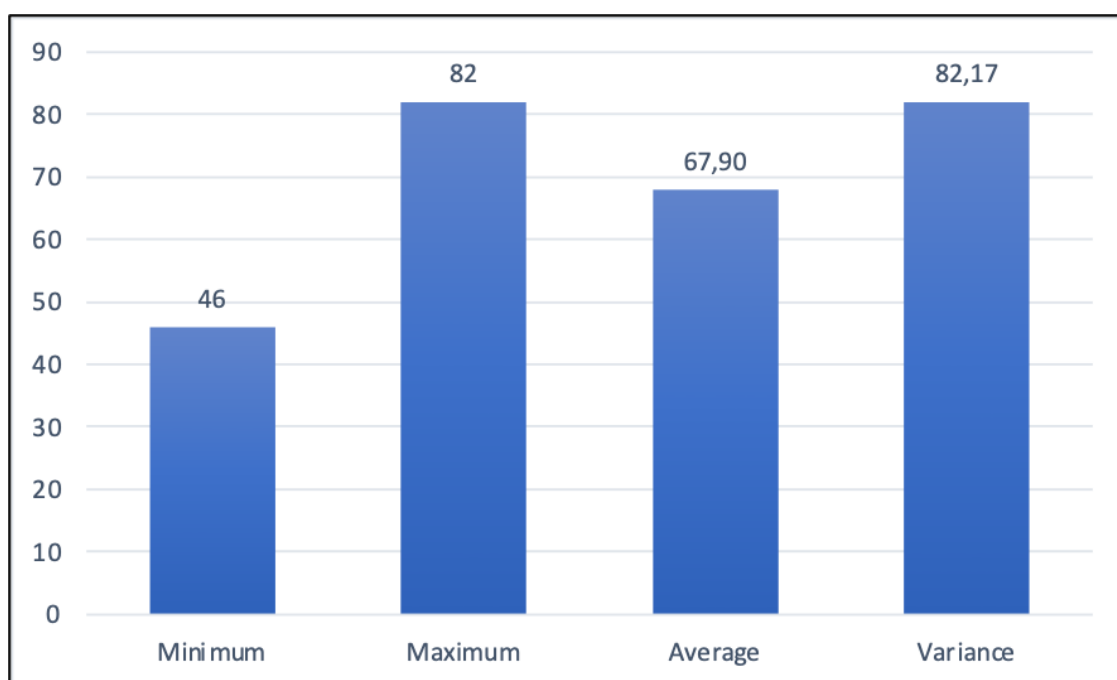


Figure 6. Statistical description of students' functional thinking

The substantial variability in scores, spanning from a minimum of 46 to a maximum of 82, underscores significant disparities in the students' capabilities. This observation suggests the existence of a subpopulation of students who encounter difficulties with functional thinking, while others demonstrate a comparatively high level of proficiency. These disparities emphasize the imperative for differentiated pedagogical approaches, which would provide supplementary support for students with lower competencies and present greater challenges for those with higher abilities to further develop their potential.

The variance of 82.17 further supports the conclusion that the functional thinking abilities of students exhibit considerable diversity. The wide distribution of scores indicates that standardized instructional approaches may be insufficient in addressing the diverse needs of the entire student population. Customized techniques, such as experiential learning centered around projects or teaching that aligns with real-world experiences, can effectively address the varying capabilities among students (Blanton et al., 2015; Warren et al., 2006).

In summary, the data indicate that while students' average functional thinking ability is satisfactory, the pronounced individual variations necessitate focused attention. More flexible and targeted instructional methodologies can facilitate the enhancement of students' functional thinking while ensuring equitable opportunities for all learners to realize their full potential (Lichti & Roth, 2018; Wilkie, 2015).

Figure 7 shows that the Divergent group achieves the highest mean score (73), followed by the Assimilator (69.9), Convergent (64.5), and Accommodator (64.2) groups. This observation suggests that the Divergent learning style is more conducive to the enhancement of functional thinking capabilities compared to the other learning styles. Conversely, the Accommodator and Convergent groups exhibit the lowest mean scores, indicating that direct and pragmatic pedagogical approaches may be less effective in this context.

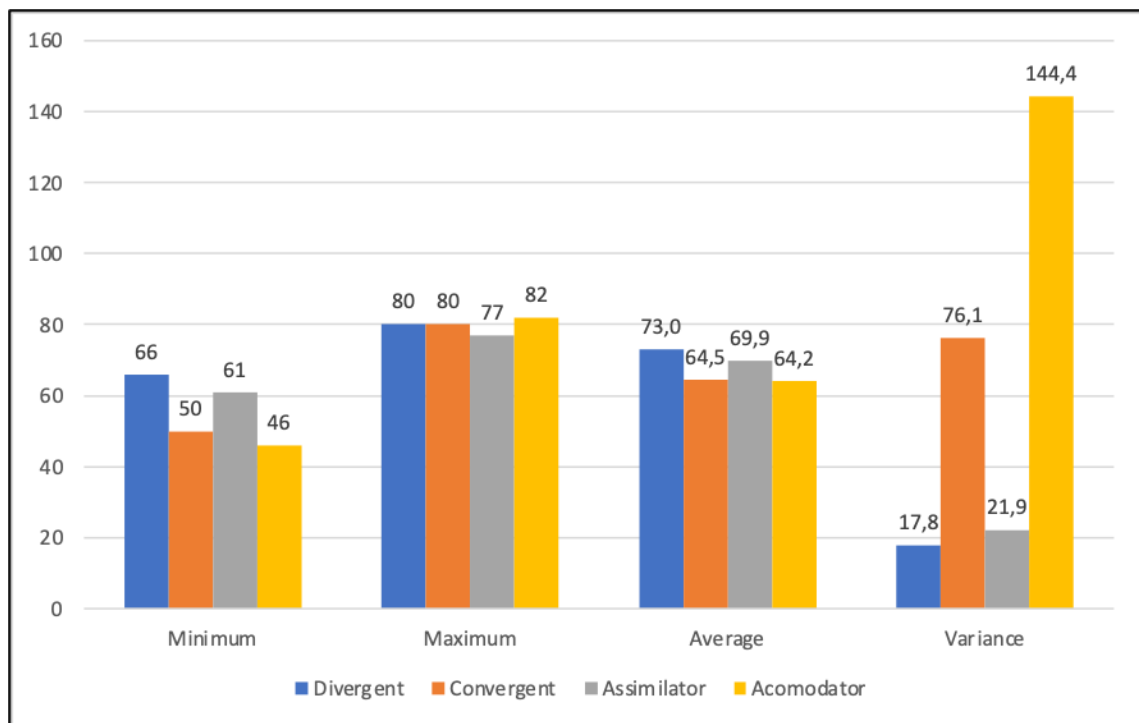


Figure 7. Statistical descriptif of students' functional thinking based on their Kolb learning style

A review of the score distribution (minimum and maximum) reveals that the Accommodator group presents the most extensive range (36), indicating substantial differences in the skill levels of individuals within this segment. In contrast, the Divergent group exhibits the most limited range (14), suggesting a significant level of homogeneity. The substantial range identified within the Accommodator group may imply that this learning style lacks a systematic framework for the ongoing development of functional thinking. Furthermore, the Accommodator cohort exhibits the greatest degree of variability (144.4), followed in proximity by the Convergent (76.1), Assimilator (21.9), and Divergent (17.8) cohorts. The significant variance observed within the Accommodator and Convergent groups underscores considerable heterogeneity in student competencies among these cohorts, while the diminished variance noted in the Divergent group indicates an enhanced level of uniformity in functional thinking capabilities.

Considering the preceding analysis, the findings demonstrate that the Divergent learning style is more effective and consistent in facilitating the development of functional thinking

compared to alternative styles. This aligns with the study conducted by Purwasih et al. (2024), which indicated that students with divergent learning styles possess the ability to generalize patterns across three stages: representation, mathematical object, and interpretations. Furthermore, students with divergent learning styles demonstrate proficiency in problem-solving, planning, and execution (Anwar et al., 2023). While the Assimilator group also exhibits commendable performance, it is less pronounced than that of the Divergent group. Conversely, the Accommodator and Convergent groups encounter challenges characterized by lower mean scores and increased heterogeneity. These outcomes underscore the necessity for specialized instructional methodologies, particularly tailored for the Accommodator and Convergent groups, to address the diverse needs of students and enhance their functional thinking abilities.

Analysis of Prerequisite Test

The prerequisite test analysis conducted in this study was the normality test of the data using the Kolmogorov-Smirnov test (Table 2) and the homogeneity test using Levene (Table 3). Table 2 indicates that the Kolmogorov-Smirnov test’s significance values for each learning style’s functional thinking data are greater than 0.05 (5%), suggesting that the data is distributed normally. Table 3 obtained data of significance values for Levene’s test less than 0.05, indicating that the functional thinking data for the four learning styles were not homogeneous. Despite the non-homogeneity, the one-way ANOVA test was conducted, and the Games-Howell post hoc test was continued (Mishra et al., 2019).

Table 2. Normality test

Learning Style	Kolmogorov-Smirnov			Prerequisites for the Normality Test	Conclusion
	Statistic	df	Sig		
Divergent	0.101	41	0.2	0.2 > 0.05	Normal Distribution
Convergent	0.096	34	0.2	0.2 > 0.05	Normal Distribution
Assimilator	0.092	24	0.2	0.2 > 0.05	Normal Distribution
Accommodator	0.118	38	0.2	0.2 > 0.05	Normal Distribution

Table 3. Homogeneity test

		Levene Test				Prerequisites for the Homogeneity Test	Conclusion
		Statistic	df1	df 2	Sig		
Based on Mean	23.703	3	133	0.00	0.00 < 0.05	Variances are not homogeneous	
Based on Median	22.824	3	133	0.2	0.00 < 0.05	Variances are not homogeneous	
Based on the Median with adjusted df	22.824	3	92.497	0.2	0.00 < 0.05	Variances are not homogeneous	
Based on trimmed mean	23.672	3	133	0.2	0.00 < 0.05	Variances are not homogeneous	

Analysis of Hypothesis Test

The data analysis employed for the hypothesis test in this study is the one-way ANOVA test. As presented in Table 4, an F value of 10.297 was obtained, accompanied by a significance value of 0.000. Given that the significance level falls below 0.05, it is evident that there exist distinctions in the functional thinking of students categorized into divergence, convergence, assimilation, and accommodation learning styles.

Table 4. One-way ANOVA test

	ANOVA Test			Requisites for ANOVA Test	Conclusion
	Mean Square	F	Sig		
Between Group	702.079	10.297	0.00	0.00 < 0.05	There are differences mean

Based on the empirical data presented in Table 5 (Games-Howell's Post-Hoc test), significant disparities exist in the functional thinking capabilities of students as a function of Kolb's learning styles: Divergent, Convergent, Assimilator, and Accommodator. The post-hoc analysis yields substantial insights regarding the mean differences among various learning style cohorts, characterized by quantifiable significance levels. Specifically, the average functional thinking proficiency of students with a Divergent learning style is substantially superior to that of their Convergent counterparts, with a mean differential of 8.554. The significance level of 0.000 indicates that this difference holds statistical significance ($p < 0.05$). This observation suggests that students adopting a Divergent learning style, characterized by reflective observation, exhibit a pronounced advantage in functional thinking relative to those with a Convergent style that prioritizes practicality and direct application.

Furthermore, students exhibiting a Divergent learning style also demonstrate superior functional thinking abilities compared to those with an Assimilator style, with a mean difference quantified at 3.108. The significance value (0.049) corroborates the existence of a statistically significant divergence ($p < 0.05$), albeit the magnitude is less pronounced in comparison to the Convergent style. This finding illustrates that the Divergent learning style confers moderate advantages in developing functional thinking when contrasted with the Assimilator style, predicated on analysis and conceptual structuring.

The most significant disparity in functional thinking capabilities between students with Divergent and Accommodator learning styles is evident, with a mean difference of 8.866. The significance value of 0.000 indicates that this inconsistency is notably significant ($p < 0.05$). Students identified with an Accommodator style, which prioritizes concrete experiences and active experimentation, appear to encounter more substantial challenges in developing functional thinking compared to their Divergent counterparts.

Furthermore, students with a Convergent learning style exhibit lower functional thinking capabilities compared to those with an Assimilator style. This difference is statistically significant, with a mean difference of -5.446 and a significance figure of 0.017. This observation implies that the Assimilator style's analytical and conceptual orientation is more conducive to enhancing functional thinking when contrasted with the practical orientation of the Convergent style.

No statistically significant difference was observed between students with Convergent and Accommodator learning styles regarding their functional thinking capabilities. The analysis

revealed a mean difference of 0.313 with a significance value of 0.999, indicating that these two learning styles exhibit comparable levels of functional thinking proficiency. These findings suggest that students with Convergent and Accommodator learning styles are likely to encounter similar challenges in developing their functional thinking skills, underscoring the necessity of instructional strategies tailored to address the specific difficulties encountered by both groups.

Finally, the mean difference in functional thinking capabilities between students with Assimilator and Accommodator styles is quantified at 5.759, with a significance value of 0.050, indicating a statistically significant difference ($p = 0.05$). Students who adopt the Assimilator style demonstrate superior functional thinking capabilities compared to their Accommodator counterparts. This finding implies that the analytical framework underpinning the Assimilator style is more effectively conducive to the advancement of functional thinking in contrast to the practical orientation of the Accommodator style.

Table 5. Games-Howell’s Post-Hoc test

Learning Style (I)	Learning Style (J)	Mean Difference (I-J)	Std. Error	Sig	Requisites for significance Difference	Conclusion
Divergent	Convergent	8.554	1.635	0.000	0.000 < 0.05	Significant Difference
	Assimilator	3.108	1.160	0.049	0.049 < 0.05	Significant Difference
	Accommodator	8.866	2.057	0.000	0.000 < 0.05	Significant Difference
Convergent	Divergent	-8.554	1.635	0.000	0.000 < 0.05	Significant Difference
	Assimilator	-5.446	1.775	0.017	0.017 < 0.05	Significant Difference
	Accommodator	0.313	2.457	0.999	0.999 > 0.05	No Significant Difference
Assimilator	Divergent	-3.108	1.160	0.049	0.049 < 0.05	Significant Difference
	Convergent	5.466	1.775	0.017	0.017 < 0.05	Significant Difference
	Accommodator	5.759	2.171	0.050	0.050 < 0.05	Significant Difference
Accommodator	Divergent	-8.866	2.057	0.000	0.000 < 0.05	Significant Difference
	Convergent	-0.313	2.457	0.999	0.999 > 0.05	No Significant Difference
	Assimilator	-5.759	2.171	0.050	0.050 ≤ 0.05	Significant Difference

Overall, the analysis findings demonstrate that students' learning styles significantly influence their functional thinking abilities. Among the diverse learning styles, the Divergent style stands out as the most effective in promoting functional thinking development, exhibiting notable distinctions when compared to alternative learning styles. The Assimilator style occupies the second position in this hierarchy, while the Convergent and Accommodator styles encounter more substantial impediments in the advancement of functional thinking. These findings have substantial implications for pedagogical strategies, suggesting that methodologies that emphasize reflection and analysis may be more advantageous in enhancing students' functional thinking capabilities.

Discussion

Kolb's learning style plays a pivotal role in mathematical learning. This is evidenced by the 25% contribution of Kolb's learning styles to mathematical learning outcomes (Sujadi et al., 2019). Notably, the Kolb learning style accounts for a 57% contribution to algebra achievement (Ganesen et al., 2020). These research findings were grounded on the analysis of functional thinking as a component of algebra, employing Kolb's student learning styles as a framework.

The findings of this study revealed that students with a divergent learning style constituted the learning style with the highest percentage of participants, comprising 29.93%. Conversely, students with an assimilator learning style were the learning style with the lowest percentage of participants, accounting for 17.52%. This finding differs from previous studies that suggested convergence as the most preferred learning style among first- and secondary school students (Ganesen et al., 2020). Furthermore, it contradicts a study conducted by Fatkhiyyah et al. (2019), which indicated that the accommodator learning style is the most preferred learning style among Indonesian students. These discrepancies may stem from various factors, including cultural influences, teaching methodologies, or even the nature of the curriculum. For instance, students in specific environments may develop divergent skills due to teaching approaches that emphasize critical thinking and reflection.

Concurrently, a preference for convergence or accommodation may manifest where problem-solving or practical experimentation is prioritized. Recognizing these variations underscores the paramount importance of tailoring educational approaches to cater to the diverse learning requirements of students. Further exploration of these disparities can offer profound insights into the influence of contextual factors and environmental elements on learning preferences.

The study elucidates significant variations in students' functional thinking and problem-solving abilities contingent upon their divergent, convergent, assimilator, and accommodator learning styles. These findings corroborate previous research conducted by Fatkhiyyah et al. (2019), Ganesen et al. (2020), Hamdani (2021), and Damavandi et al. (2011), underscoring the congruence between Kolb's learning styles and diverse learning accomplishments.

For instance, Ganesen et al. (2020) observed a positive correlation between students' learning styles and their algebra problem-solving abilities, indicating that these styles influence students' approaches to mathematical challenges. Similarly, Juniawan et al. (2024) demonstrated that problem-solving variations originate from each student's preferred learning method, reinforcing the notion that tendencies such as experimentation or conceptual analysis shape outcomes.

Furthermore, Fatkhiyyah et al. (2019) identified significant disparities in mathematical communication skills among the four learning styles, demonstrating how each style's distinctive characteristics influence students' capacity to express and discuss mathematical concepts. For instance, students with a divergent learning style who excel in observation and reflection may adopt a problem-solving approach distinct from those with a convergent style, which emphasizes practical solutions and logical analysis. These findings emphasize the significance of comprehending learning styles in fostering problem-solving strategies and enhancing communication abilities within the educational context.

This finding contradicts the research of Ocampo et al. (2023), which demonstrated no substantial correlation between learning style and academic achievement in mathematics. However, it is crucial to recognize that the absence of a significant relationship does not imply the complete absence of any relationship (Ocampo et al., 2023). Rather, it suggests the potential existence of a relationship between learning styles and other aspects of academic achievement, such as functional thinking.

Figure 7 illustrates that students with divergent learning styles exhibit the highest average functional thinking score, followed by assimilator learning styles. This finding aligns with a study conducted by Dermawan et al. (2021), which demonstrated that students with divergent learning styles possess the highest average in mathematics problem-solving abilities. Furthermore, they have demonstrated proficiency in solving problems up to the point of verification (Muttaqin et al., 2019). Dwiyanto and Kurniasih (2024) further highlighted the strengths of students with divergent learning styles in communication and mathematization, which are crucial components of mathematics literacy. Additionally, a study conducted by Miswanto (2024) revealed that despite possessing incoherent computational thinking skills, students with divergent learning styles possess the ability to think computationally to solve mathematical problems systematically and comprehensively. This finding corroborates a study conducted by Purwasih et al. (2024), which demonstrated that students with divergent learning are capable of generalizing patterns in three distinct stages: representation, mathematical object, and interpretation.

The findings of this study do not align with another study that found that students with divergent learning styles experience the greatest difficulty in specializing, conjecturing, and generalizing (Maulina et al., 2021). Conversely, another study by Hajaró et al. (2021) demonstrated that students with assimilator learning styles possess a high level of mathematical representation. Furthermore, students with an assimilator learning style are capable of describing the problem situation and utilizing mathematical solutions that are applicable to the analysis of other forms (Rohmanawati et al., 2021).

Several factors may account for the discrepancies in research findings. Firstly, variations in the characteristics of study participants, such as differences in educational backgrounds, learning environments, or levels of prior knowledge, can significantly impact the outcomes. Secondly, methodological differences, including the instruments and procedures used to measure learning styles and mathematical skills, may contribute to inconsistent conclusions. Thirdly, cultural and contextual factors, such as variations in teaching methods, curricula, or educational systems, likely influence students' learning experiences and performance. Finally, differences in research focus—such as the emphasis on specific mathematical skills like conjecturing or representation—may result in divergent interpretations of the effects of learning styles on mathematical abilities.

Conclusion

This study elucidates the correlation between Kolb's learning styles and students' functional thinking. Specifically, students exhibiting a divergent learning style exhibited superior functional thinking capabilities compared to those who adopted convergent, assimilator, or accommodator learning styles. Furthermore, the divergent learning style predominated among the study participants. These findings underscore substantial distinctions between the divergent and assimilator learning styles, underscoring the paramount importance of adaptable teaching methodologies to augment students' functional thinking. Consequently, this study provides practical implications for mathematics educators in devising more personalized and responsive teaching strategies tailored to students' learning preferences, particularly with the aim of enhancing their algebraic proficiency.

Although this study makes a significant contribution, several limitations must be acknowledged. Firstly, the study's sample was drawn from a specific population group, potentially limiting the generalizability of the findings to broader populations. Secondly, the research exclusively examined the relationship between Kolb's learning styles and functional thinking, disregarding other factors such as motivation, learning environments, or individual cognitive abilities. Thirdly, the assessment of learning styles and functional thinking was conducted within a specific context that may not fully encapsulate variations in everyday learning scenarios.

How to effectively address learning designs that accommodate students' individual learning styles remains ongoing debate amongst the experts. For future research, several recommendations can be proposed. Firstly, expanding the sample to include students from diverse geographical, social, and cultural backgrounds could enhance the external validity of the findings. Secondly, studies exploring the interaction between learning styles and other factors, such as teaching strategies, student motivation, and family support, may provide a more comprehensive understanding of the influence of learning styles on functional thinking. Thirdly, employing longitudinal approaches is suggested to understand the dynamics of students' functional thinking over time and across various learning contexts. Furthermore, research could also focus on developing innovative instructional tools specifically designed to accommodate students' learning styles, thereby contributing to more effective mathematics education.

Acknowledgment

The authors would like to thank the Editor and the anonymous reviewers for their valuable comments and suggestions that greatly contribute to improving the quality of the manuscript. The authors are also thankful to the Rector of Universitas Islam Negeri Mataram for financial support (Grant No. 4542 Year 2022).

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