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A Comparative Study of Vocational High School Students' Conceptual Understanding of Trigonometric Ratios Based on VARK Learning Styles

Lela Faizuna^{1*}; Eka Sulistyawati²; Dewi Hamidah³

^{1,2,3} Tadris Matematika, Universitas Islam Negeri Syekh Wasil Kediri, East

Java, Indonesia

Correspondence e-mail: lelaifaizuna@gmail.com

Abstract:

Students' conceptual understanding in mathematics is essential for connecting mathematical concepts and applying them to solve problems. However, students may demonstrate different characteristics in learning and processing information based on their learning preferences. Examining the relationship between learning styles and conceptual understanding is important to determine whether differences in students' learning preferences are reflected in their mathematical understanding. Such evidence is needed to guide teachers in making informed instructional decisions rather than relying on assumptions about learning style categories. Examining this relationship in trigonometric learning is particularly relevant because the abstract nature of trigonometric ratios requires students to connect representation, procedures, and mathematical meanings. This study aimed to describe the conceptual understanding of vocational high school students on trigonometric ratios based on VARK learning styles and to determine whether there were significant differences in conceptual understanding among VARK learning style groups. This study employed a quantitative comparative approach. A saturated sampling technique was used, yielding a sample of 103 eleventh-grade students from a vocational high school in Kediri Regency. Data were collected using a conceptual understanding test and a VARK learning style questionnaire. The data were analyzed using descriptive statistics based on conceptual understanding indicators and the Kruskal-Wallis test to examine differences among learning style groups. The results showed variations in the mean conceptual understanding scores among VARK groups. The *Read/write*-Kinesthetic group obtained the highest mean score of 53.75, while the Visual-Auditory-Kinesthetic group obtained the lowest mean score of 40.50. Analysis by indicator also revealed variations in students' performance across learning style groups. However, the Kruskal-Wallis test showed no significant difference in students' conceptual understanding based on VARK learning styles ($p = 0.781 > 0.05$). These findings indicate that variations in VARK learning styles were not accompanied by statistically significant differences in conceptual understanding of trigonometric ratios. The findings may encourage teachers to avoid relying solely on learning style categories when designing mathematics instruction.

Keywords: Conceptual Understanding; Trigonometric Ratios; VARK Learning Styles; Comparative Study

Introduction

Conceptual understanding is one of the essential competencies in mathematics learning. It is not limited to remembering formulas; it also encompasses students' ability to comprehend, restate, interpret, connect, and apply concepts in various situations (Sanjaya 2011; Hutagalung 2017). Conceptual understanding provides the foundation for studying mathematical concepts in greater depth, because students who understand concepts can connect their existing knowledge to the situations they encounter (Lestari et al., 2025). Therefore, it is important to examine students' conceptual understanding, particularly in mathematical topics whose concepts are closely interrelated.

One topic that demands conceptual understanding is trigonometric ratios. This topic concerns the relationship between angles and sides in right triangles and involves the concepts of sine, cosine, and tangent (Susanto et al., 2023). Mastering trigonometric ratios is not achieved by memorizing formulas alone; it requires understanding the meaning of each ratio between sides and angles. In addition, trigonometric ratios underpin the learning of subsequent mathematical topics, such as limits, three-dimensional geometry, calculus, and integrals (Kepa, 2019). However, the study by Silvia et al. (2024) showed that some students still do not meet all the indicators of conceptual understanding of trigonometric ratios. Suendarti & Liberna (2021) also showed that students' attainment of conceptual understanding of this topic is uneven. This condition indicates that students' conceptual understanding of trigonometric ratios needs further investigation.

Students' conceptual understanding can be influenced by various internal and external factors. Internal factors include prior knowledge, motivation, *self-efficacy*, learning style, and personal characteristics, whereas external factors include learning strategies, instructional models, the learning environment, and family support (Nurhangesti & Seruni, 2024). Among these factors, learning style relates to the way students receive, process, and understand information (DePorter & Hernacki, 2013). Accordingly, differences in learning style may be related to differences in students' conceptual understanding in mathematics learning.

One model that can be used to identify learning style tendencies was developed by Neil D. Fleming. According to Fleming, learning styles can be grouped into four types: visual (V), auditory (A), *read/write* (R), and kinesthetic (K), abbreviated as VARK (Prithishkumar & Michael, 2014). These four styles differ in how they receive and process information. Visual students tend to benefit from pictures or diagrams, auditory students from explanations and discussion, *read/write* students from reading and writing activities, and kinesthetic students from practical activities or direct experience (Locke et al., 2024; Yotta, 2023). These differing characteristics suggest that students with different learning style tendencies may also exhibit different characteristics of conceptual understanding.

Previous studies support a link between learning style and conceptual understanding. Putri & Yuhana (2022) studied vocational high school students with visual, auditory, and kinesthetic learning styles and found a relationship between learning style and conceptual understanding of systems of two-variable linear equations (SPLDV). Meanwhile, Edo et al. (2022) studied elementary school students with visual, auditory, and kinesthetic learning styles and showed that students' conceptual understanding can be examined according to different learning style characteristics. On the topic of trigonometric ratios, Kepa (2019) studied senior high school students with visual, auditory, and kinesthetic learning styles and found differences in the characteristics of conceptual understanding by learning style. These findings indicate

that learning style is a relevant aspect to examine in order to understand the characteristics of students' conceptual understanding of trigonometric ratios.

Nevertheless, these studies do not fully address the research problem of the present study. The existing study at the vocational high school level, by Putri & Yuhana (2022), addressed SPLDV; therefore, research on vocational high school students' conceptual understanding of trigonometric ratios according to learning style remains limited. Accordingly, this study examines vocational high school students' conceptual understanding of trigonometric ratios by considering all four VARK learning style categories, namely visual, auditory, *read/write*, and kinesthetic. In addition, this study not only describes students' conceptual understanding by learning style but also analyzes whether there are differences in conceptual understanding among VARK learning style groups. Thus, this study is important for providing an overview of vocational high school students' conceptual understanding of trigonometric ratios and for broadening research on the characteristics of conceptual understanding at the vocational high school level.

Based on the foregoing, this study aims to (1) describe students' conceptual understanding of trigonometric ratios according to VARK learning styles and (2) analyze whether there are differences in students' conceptual understanding of trigonometric ratios in terms of VARK learning styles. The results of this study are expected to enrich research on vocational high school students' conceptual understanding by VARK learning style and to serve as a reference for similar studies on different topics or educational levels. Practically, the results can help students recognize their learning style tendencies so that they can choose appropriate learning strategies. In addition, this study can serve as a consideration for teachers and schools in designing instruction that suits students' learning style characteristics.

Methods

This study used a quantitative approach with a causal-comparative design, aiming to compare students' conceptual understanding of trigonometric ratios according to VARK learning styles without administering any treatment to the research subjects. The study was conducted with Grade 11 students at a vocational high school in Kediri Regency. The population comprised 103 students, consisting of 36 students in Grade 11 Culinary 1, 33 in Culinary 2, and 34 in Culinary 3. Saturated sampling was used, so the entire population served as the research sample.

The research data consisted of learning style data and students' conceptual understanding data. Data were collected using a questionnaire and a test. The questionnaire was used to identify students' learning styles using the VARK Questionnaire Version 8.01, which consists of 16 items. This instrument was developed by Fleming (2001) on the basis of four learning modalities, namely visual, auditory, *read/write*, and kinesthetic. Based on these modalities, Fleming classified learning styles as unimodal or multimodal. In a unimodal learning style, a person has only one dominant learning modality, namely one of visual, auditory, *read/write*, or kinesthetic. In a multimodal learning style, by contrast, a person has more than one dominant learning modality. In this study, the dominant learning style was determined by the highest score in each category.

Next, students' conceptual understanding was measured using an essay test on trigonometric ratios. The test was developed on the basis of five indicators of conceptual understanding: restating a concept, classifying objects according to the properties or conditions of a concept, giving examples and non-examples, presenting a concept in various forms of representation, and applying and relating concepts in various situations.

After the test instrument had been developed, its content validity was estimated through *expert judgment* by two expert validators.

The data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to describe students' conceptual understanding by VARK learning style through means, standard deviations, frequencies, and percentages. Conceptual understanding scores were categorized into three levels (high, moderate, and low) using the interval width formula as follows.

$$\text{Interval Width} = \frac{(\text{ideal maximum score} - \text{ideal minimum score})}{\text{Number of classes}}$$

This formula was applied to the total score and to each indicator score, with an ideal minimum score of 0 and three classes. The ideal maximum scores for indicators 1 to 5 are 6, 24, 20, 6, and 14, respectively, so the ideal maximum total score is 70. The category ranges for the total score are presented in Table 1, and the category ranges for each indicator are presented in Table 2.

Table 1. Categorization Intervals for the Total Conceptual Understanding Score

Interval	Category
$0.00 \leq x < 23.33$	Low
$23.33 \leq x < 46.67$	Moderate
$46.67 \leq x < 70.00$	High

Table 2. Categorization Intervals for Each Indicator of Conceptual Understanding

Indicator	Category		
	Low	Moderate	High
Indicator 1	$0.00 \leq x < 2.00$	$2.00 \leq x < 4.00$	$4.00 \leq x < 6.00$
Indicator 2	$0.00 \leq x < 8.00$	$8.00 \leq x < 16.00$	$16.00 \leq x < 24.00$
Indicator 3	$0.00 \leq x < 6.67$	$6.67 \leq x < 13.34$	$13.34 \leq x < 20.00$
Indicator 4	$0.00 \leq x < 2.00$	$2.00 \leq x < 4.00$	$4.00 \leq x < 6.00$
Indicator 5	$0.00 \leq x < 4.67$	$4.67 \leq x < 9.34$	$9.34 \leq x < 14.00$

Inferential analysis began with a normality test using the *Shapiro-Wilk* test. If the data met the assumptions of normality and homogeneity, differences in conceptual understanding among learning style groups were analyzed using *One-Way ANOVA*. If the parametric assumptions were not met, the *Kruskal-Wallis* test was used as a nonparametric analysis. Data analysis was performed using SPSS.

Results and Discussion

Findings

This study involved 103 students whose learning styles were identified through the VARK instrument. The grouping results showed that students' learning styles consisted of unimodal and multimodal styles. Unimodal learning styles included visual, auditory, *read/write*, and kinesthetic, whereas multimodal learning styles included auditory-kinesthetic, *read/write*-kinesthetic, and visual-auditory-kinesthetic. The kinesthetic group was the largest, with 69 students (67%), whereas the visual-auditory-kinesthetic group was the smallest, with 2 students (1.9%). Table 3 below presents the distribution of students' learning styles.

Table 3. Students' Learning Styles

No.	Learning Style	Number of Students
1.	Visual	7
2.	Auditory	8
3.	Read/Write	8
4.	Kinesthetic	69
5.	Auditory, Kinesthetic	5
6.	Read/Write, Kinesthetic	4
7.	Visual, Auditory, Kinesthetic	2
8.	Total	103

The conceptual understanding test on trigonometric ratios showed that, among the 103 students, the lowest score was 28 and the highest was 64. The overall mean was 49.74 with a standard deviation of 8.297. Based on the categorization, 73 students (70.9%) were in the high category and 30 students (29.1%) were in the moderate category. No students were in the low category.

Table 4. Descriptive Statistics of Conceptual Understanding Scores by Learning Style

Conceptual Understanding Score				
Learning Style	Mean	N	Std. Deviation	
Visual	51.29	7	3.861	
Auditory	48.25	8	8.031	
<i>Read/write</i>	47.63	8	7.726	
Kinesthetic	50.09	69	8.677	
<i>Read/write</i> , Kinesthetic	53.75	4	5.315	
Auditory, Kinesthetic	49.00	5	7.583	
Visual, Auditory, Kinesthetic	40.50	2	17.678	
Total	49.74	103	8.297	

Table 4 shows variation in the mean conceptual understanding scores among the learning style groups. The *read/write*-kinesthetic group obtained the highest mean, 53.75, whereas the visual-auditory-kinesthetic group obtained the lowest mean, 40.50. Judging by the standard deviation of each group, the conceptual understanding scores of students with a visual learning style had the narrowest spread compared with the other learning style groups, whereas the kinesthetic group had the widest spread. This means that the conceptual understanding scores of students in the visual group were very close to one another relative to the group mean. In contrast, the conceptual understanding scores of students in the kinesthetic group were highly varied relative to the group mean.

Conceptual understanding scores were then analyzed according to five indicators: (1) restating a concept, (2) classifying objects according to the properties or conditions of a concept, (3) giving examples and non-examples, (4) presenting a concept in various forms of representation, and (5) applying and relating concepts in various situations. Table 5 below presents the descriptive statistics for the indicator of restating a concept.

Table 5. Descriptive Statistics for Indicator 1

Indicator1							
Learning_Style	Mean	Variance	N	Minimum	Maximum	Range	Std. Deviation
Auditory	3.75	6.214	8	1	6	5	2.493
Auditory, Kinesthetic	5.00	2.000	5	3	6	3	1.414
Kinesthetic	4.90	2.740	69	1	6	5	1.655
Read/Write	3.75	4.500	8	1	6	5	2.121
Read/Write, Kinesthetic	5.25	2.250	4	3	6	3	1.500
Visual	4.71	5.571	7	0	6	6	2.360
Visual, Auditory, Kinesthetic	5.50	.500	2	5	6	1	.707
Total	4.74	3.235	103	0	6	6	1.798

For the indicator of restating a concept (Table 5), most learning style groups were in the high category. The visual-auditory-kinesthetic group obtained the highest mean, 5.50, whereas the auditory and *read/write* groups obtained the lowest mean, 3.75, and were in the moderate category. In terms of standard deviation, the visual-auditory-kinesthetic group had the smallest spread of scores, 0.707, whereas the auditory group had the largest, 2.493. This indicates that the scores of students in the visual-auditory-kinesthetic group were relatively close together, whereas those of students in the auditory group were more varied. Overall, the mean score for indicator 1 was 4.74 with a standard deviation of 1.798. This result indicates variation in conceptual understanding scores on indicator 1 among students, both within the same learning style group and between learning style groups.

Next, Table 6 below presents the descriptive statistics for the indicator of classifying objects according to the properties or conditions of a concept.

Table 6. Descriptive Statistics for Indicator 2

Indicator2							
Learning_Style	Mean	Variance	N	Minimum	Maximum	Range	Std. Deviation
Auditory	20.38	20.839	8	11	24	13	4.565
Auditory, Kinesthetic	21.00	18.000	5	15	24	9	4.243
Kinesthetic	20.87	16.615	69	6	24	18	4.076
Read/Write	20.50	10.857	8	17	24	7	3.295
Read/Write, Kinesthetic	22.00	1.333	4	21	23	2	1.155
Visual	21.14	7.810	7	17	24	7	2.795
Visual, Auditory, Kinesthetic	17.00	72.000	2	11	23	12	8.485
Total	20.80	15.536	103	6	24	18	3.942

For the indicator of classifying objects according to the properties or conditions of a concept, all learning style groups were in the high category. The highest mean was obtained by the *read/write*-kinesthetic group, at 22.00, whereas the lowest mean was obtained by the visual-auditory-kinesthetic group, at 17.00. Thus, all groups were relatively able to identify and classify objects based on the characteristics of the concept of trigonometric ratios. In terms of standard deviation, the *read/write*-kinesthetic group had the smallest spread of scores, 1.155, whereas the visual-auditory-kinesthetic group had the largest, 8.485. This indicates that the scores of students in the *read/write*-kinesthetic group were relatively close to their group mean, whereas those of students in the visual-auditory-kinesthetic group were more varied. Overall, the mean score for indicator 2 was 20.80 with a standard deviation of 3.942. This result indicates that

students' scores on the indicator of classifying objects according to the properties or conditions of a concept varied across learning style groups, although the means of all groups were within a relatively high score range.

Next, Table 7 below presents the descriptive statistics for the indicator of giving examples and non-examples of a concept.

Table 7. Descriptive Statistics for Indicator 3

Indicator3							
Learning_Style	Mean	Variance	N	Minimum	Maximum	Range	Std. Deviation
Auditory	14.13	19.268	8	6	20	14	4.390
Auditory, Kinesthetic	12.60	36.800	5	3	19	16	6.066
Kinesthetic	14.57	24.338	69	1	20	19	4.933
Read/Write	14.38	6.839	8	8	16	8	2.615
Read/Write, Kinesthetic	17.00	4.667	4	15	20	5	2.160
Visual	13.57	13.952	7	7	17	10	3.735
Visual, Auditory, Kinesthetic	8.00	72.000	2	2	14	12	8.485
Total	14.32	22.416	103	1	20	19	4.735

For the indicator of giving examples and non-examples of a concept, the *read/write*-kinesthetic group obtained the highest mean, 17.00, whereas the visual-auditory-kinesthetic group obtained the lowest mean, 8.00. In terms of standard deviation, the *read/write*-kinesthetic group had the smallest spread of scores, 2.160, whereas the visual-auditory-kinesthetic group had the largest, 8.485. This indicates that the scores of students in the *read/write*-kinesthetic group were relatively close to their group mean, whereas those of students in the visual-auditory-kinesthetic group were more varied. Overall, the mean score for indicator 3 was 14.32 with a standard deviation of 4.735. Based on the categories of conceptual understanding used in this study, the auditory-kinesthetic and visual-auditory-kinesthetic groups were in the moderate category, whereas the other groups were in the high category. These results indicate that students' ability to give examples and non-examples of a concept varied, in terms of both mean scores and the spread of scores in each learning style group.

Next, Table 8 below presents the descriptive statistics for the indicator of presenting a concept in various forms of representation.

Table 8. Descriptive Statistics for Indicator 4

Indicator4							
Learning_Style	Mean	Variance	N	Minimum	Maximum	Range	Std. Deviation
Auditory	3.50	8.571	8	0	6	6	2.928
Auditory, Kinesthetic	4.00	6.500	5	0	6	6	2.550
Kinesthetic	2.64	5.087	69	0	6	6	2.256
Read/Write	2.25	3.929	8	0	5	5	1.982
Read/Write, Kinesthetic	4.00	4.667	4	1	6	5	2.160
Visual	2.71	5.571	7	0	6	6	2.360
Visual, Auditory, Kinesthetic	.00	.000	2	0	0	0	.000
Total	2.75	5.328	103	0	6	6	2.308

For the indicator of presenting a concept in various forms of representation, most learning style groups were in the moderate category. The auditory-kinesthetic and *read/write*-kinesthetic groups obtained the highest means, each at 4.00, whereas the

visual–auditory–kinesthetic group obtained a mean of 0 and was in the low category. These results indicate that the ability to represent a concept in another form still needs attention. In terms of standard deviation, the *read/write* group had the narrowest spread of scores, 1.982, whereas the auditory group had the widest, 2.928. This indicates that the scores of students with a *read/write* learning style tended to be more homogeneous than those of the other learning style groups, whereas the scores of students with an auditory learning style were more varied around the mean.

Next, Table 9 below presents the descriptive statistics for the indicator of applying and relating concepts in various situations.

Table 9. Descriptive Statistics for Indicator 5

Indicator5							
Learning_Style	Mean	Variance	N	Minimum	Maximum	Range	Std. Deviation
Auditory	6.50	12.286	8	0	10	10	3.505
Auditory, Kinesthetic	6.40	8.800	5	2	10	8	2.966
Kinesthetic	7.12	9.222	69	0	12	12	3.037
Read/Write	6.75	12.786	8	0	10	10	3.576
Read/Write, Kinesthetic	5.50	3.667	4	4	8	4	1.915
Visual	9.14	3.810	7	6	12	6	1.952
Visual, Auditory, Kinesthetic	10.00	.000	2	10	10	0	.000
Total	7.14	9.158	103	0	12	12	3.026

For the indicator of applying and relating concepts in various situations, most learning style groups were also in the moderate category. The visual–auditory–kinesthetic group obtained the highest mean, 10.00, whereas the *read/write*–kinesthetic group obtained the lowest mean, 5.50. In terms of standard deviation, the visual–auditory–kinesthetic group had the narrowest spread of scores, 0.000, followed by the visual group, 1.952. In contrast, the *read/write* group had the widest spread of scores, 3.576. This indicates that the scores of students with a visual–auditory–kinesthetic learning style were uniform, whereas the scores of students with a *read/write* learning style were more varied around the mean. This indicator concerns students' ability to use the concepts of sine, cosine, and tangent to solve problems in various situations.

Analysis

The results show that variation in mean conceptual understanding does not directly indicate significant differences in ability among learning style groups. The *read/write*–kinesthetic group obtained the highest total mean, but that group consisted of only four students. Conversely, the visual–auditory–kinesthetic group consisted of only two students, so its mean should be interpreted with caution. Therefore, interpretation based on means needs to be complemented by inferential analysis.

The normality test results showed that the visual, auditory, *read/write*, kinesthetic, auditory–kinesthetic, and *read/write*–kinesthetic groups had *Shapiro–Wilk* significance values above 0.05. However, the visual–auditory–kinesthetic group could not be tested for normality because it consisted of only two students. This condition means that the normality assumption could not be confirmed for all groups. In addition, several groups had relatively small numbers of members, so the analysis proceeded with the Kruskal–Wallis test.

Table 10. Kruskal–Wallis Test Results

Test Statistics ^{a,b}	
	Total_score
Kruskal-Wallis H	3.221
df	6
Asymp. Sig.	.781
a. Kruskal Wallis Test	
b. Grouping Variable: GB	

Source: Research data

The Kruskal–Wallis test yielded an H statistic of 3.221 with 6 degrees of freedom and a significance value of 0.781. This significance value is greater than 0.05. Thus, based on the data of this study, no significant difference was found in students' conceptual understanding of trigonometric ratios among VARK learning style groups. This finding indicates that differences in means in the descriptive statistics are not sufficient to claim an inferential difference in ability among groups. Although the *read/write*–kinesthetic group had the highest mean and the visual–auditory–kinesthetic group had the lowest mean, these variations have not been shown to be statistically significant. In other words, students with visual, auditory, *read/write*, kinesthetic, or combined learning styles had relatively similar levels of conceptual understanding in the context of this study.

These results show that conceptual understanding in mathematics is related not only to students' preferences for receiving information. On the topic of trigonometric ratios, students must understand concepts, connect several pieces of information, represent situations in mathematical form, and apply concepts to solve problems. Therefore, other factors such as prior knowledge, learning motivation, and instructional strategies may also play a role in the development of conceptual understanding. The findings of this study are consistent with the study by Wijayanti et al. (2025), which also found no significant difference in conceptual understanding of mathematics by learning style.

Viewed by indicator, the results show different patterns. The abilities to restate concepts, classify objects, and give examples and non-examples tended to be in the high category in most groups. In contrast, the abilities to present concepts in various forms of representation and to apply concepts in different situations tended to be in the moderate category. This shows that students were relatively better able to understand and express basic concepts than to use those concepts in more complex representations or contexts.

The findings on the representation indicator also show the importance of the ability to convert mathematical information into another form. On the topic of trigonometric ratios, students may understand a problem verbally but still have difficulty converting that information into an illustration of a triangle or an appropriate mathematical model. Representation ability is needed so that students can meaningfully connect information, symbols, images, and mathematical concepts.

For the indicator of applying and relating concepts, most groups were in the moderate category. This shows that students were able to use the concept of trigonometric ratios, but their application in new situations was not yet fully optimal. This ability requires not only mastery of formulas but also the ability to recognize relevant information, select the appropriate concept, and connect the concept to the situation at hand. This is consistent with the view of NCTM (2000) on the importance of connecting mathematical ideas and applying them in various situations.

Overall, the results show that VARK learning styles give an overview of the variation in students' learning preferences, but in this study they did not show a significant difference in conceptual understanding of trigonometric ratios. This finding implies that instruction need not be directed at only one particular learning style. Providing diverse learning activities, such as explanations, discussions, visual representations, written exercises, and practical activities, can give students opportunities to use various ways of understanding concepts. In this way, conceptual understanding can be developed without confining students to a single learning style category.

Conclusion

Based on the results of the study, it can be concluded that students' conceptual understanding of trigonometric ratios, by VARK learning style, was generally in the high category. Although there were differences in mean conceptual understanding among the learning style groups, the Kruskal–Wallis test yielded a significance value of 0.781 (> 0.05). Thus, there was no significant difference in students' conceptual understanding by VARK learning style.

Viewed by indicator of conceptual understanding, students' abilities to restate concepts, classify objects, and give examples and non-examples tended to be in the high category. Meanwhile, the abilities to represent concepts in various forms and to apply and connect concepts in particular situations still showed more varied results. This finding indicates that variation in VARK learning styles does not significantly differentiate the level of students' conceptual understanding of trigonometric ratios.

These results indicate that mathematics learning, particularly on trigonometric ratios, needs to give students opportunities to understand concepts through various activities. Varied instructional approaches can be used to accommodate students' learning characteristics without limiting instruction to a single learning style category. This study has limitations in the uneven distribution of learning style groups. Most students belonged to the kinesthetic group, whereas some multimodal learning style groups consisted of only a few students. This condition means that comparisons among groups need to be interpreted with caution. In addition, this study involved only Grade 11 students at one school and was limited to the topic of trigonometric ratios, so its results cannot yet be broadly generalized.

Future research is recommended to examine more deeply students' ability to present concepts in various forms of representation and to apply and relate the concept of trigonometric ratios in various situations. In addition, future studies could explore factors other than VARK learning styles that may be related to students' conceptual understanding.

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