Volume 4, Issue 3 (2026) 413-424

EQUATOR SCIENCE JOURNAL (ESJ)
e-ISSN: 2988-3881
Journal homepage:
https://ejournal.edukhatulistiwa.com/index.php/ESJ

VARK Learning Style Preferences and Chemistry Learning Outcomes among Grade XI Students

Yulianus Kinho[1], Anggie Siti Perdani[1]*, Nancy Susianna[2]
[1]Department of Chemistry Education, Parahyangan Catholic University, Indonesia
[2]Department of Science Education, Parahyangan Catholic University, Indonesia

Received: September 8, 2026 | Revised: October 12, 2024 | Accepted: October 29, 2026
First Available Online: October 31, 2026 | Publication Date: October 31, 2026
DOI: https://doi.org/10.61142/esj.v4i3.497

*Corresponding author: anggie.perdani@unpar.ac.id

Keywords:
Learning style preferences;
Chemistry education;
Learning outcomes;
Senior high school students;
VARK

ABSTRACT

Chemistry learning requires students to engage with abstract concepts, symbolic representations, calculations, verbal explanations, and practical activities. These characteristics may influence how students engage with and interpret chemical information through different representational forms. This study investigated students' learning style preferences based on the VARK model and examined differences in chemistry learning outcomes across VARK preference groups among Grade XI students at SMA Pasundan 2 Kota Bandung, Indonesia. A quantitative comparative ex post facto design was employed. The participants were 60 Grade XI students selected through total sampling. Data on learning style preferences were collected using a VARK questionnaire, while chemistry learning outcomes were obtained from students' semester chemistry assessment records. The data were analyzed using descriptive statistics and non-parametric inferential analysis with IBM SPSS Statistics 22. The findings indicated that 37 students (61.7%) were classified as unimodal, 13 (21.7%) as bimodal, 2 (3.3%) as trimodal, and 8 (13.3%) as quadmodal. Chemistry learning outcomes varied across the groups. Because the normality assumption was not fulfilled across the groups, the Kruskal-Wallis test was used as the main inferential analysis. The findings indicated a statistically significant difference in chemistry learning outcomes across the VARK preference groups. However, the findings do not establish that a particular learning style causes higher achievement. The findings provide empirical insight into VARK preference patterns and their relationship with chemistry achievement among senior high school students.

This is an open access article under the CC BY-SA license.

INTRODUCTION

Chemistry is a school subject that requires students to integrate different forms of knowledge and representation (Taber, 2019). Unlike subjects that may rely predominantly on verbal or factual information, chemistry involves the simultaneous interpretation of macroscopic phenomena, symbolic representations, mathematical relationships, and explanations of processes that cannot always be directly observed. Students are expected to understand chemical concepts, interpret symbols and equations, perform calculations, and, in appropriate contexts, engage in laboratory activities. The complexity of these demands makes students' ways of receiving, processing, and representing information an important consideration in chemistry education (Johnstone, 2010; Agustian et al., 2022).

The characteristics of chemistry learning have led researchers and educators to pay attention to individual differences among learners. Students may demonstrate different preferences when receiving information, such as preferring visual representations, verbal explanations, written information, or direct experiences. The VARK model categorizes these preferences into four modalities: Visual, Aural/Auditory, Read/Write, and Kinesthetic. The model has been widely used as a framework for identifying students' preferred modalities and may result in unimodal or multimodal profiles (Fleming & Mills, 1992; Fleming, 2001). In the context of the present study, a student is therefore not necessarily characterized by only one modality; the VARK framework allows students to demonstrate preferences involving two, three, or all four modalities.

The relevance of examining learning preferences in chemistry is supported by the nature of chemistry itself. Visual representations such as molecular structures, diagrams, graphs, and models can assist students in interpreting chemical phenomena (Gilbert & Treagust, 2009). Auditory preferences may be expressed through explanations, classroom discussions, and verbal interaction. Read/Write preferences are relevant to the interpretation and production of written explanations, chemical equations, and other textual information. Kinesthetic preferences may become particularly relevant when students engage in laboratory work, simulations, demonstrations, or other forms of direct experience. Thus, examining the distribution of VARK preferences can provide teachers with information about the diversity of students in a chemistry classroom.

However, the educational interpretation of learning styles requires caution. The use of learning style frameworks does not necessarily mean that instruction should be rigidly matched to an individual student's preferred modality. Reviews of the literature have found that the empirical evidence supporting the practice of matching instruction to learning styles is inconsistent (Pashler et al., 2008; Childs-Kean et al., 2020; Newton & Salvi, 2020). A review of learning-style frameworks in health science education found that most studies were descriptive and that evidence linking learning styles with learning outcomes was generally weak or inconsistent (Childs-Kean et al., 2020). Similarly, a systematic review reported widespread belief in learning styles despite limited empirical evidence supporting instructional matching (Newton & Salvi, 2020). More recently, a meta-analysis of the learning-style matching hypothesis found limited support and concluded that evidence was insufficient to justify widespread adoption of matching instruction to learning styles (Clinton-Lisell & Litzinger, 2024). Teachers' judgments of students' learning styles have also been found to differ from students' self-assessments (Papadatou-Pastou et al., 2018).

These findings suggest that learning styles should not be treated as fixed characteristics that determine students' academic performance. Rather, learning-style instruments may be considered as tools for describing students' preferences and understanding learner diversity. Recognizing these differences is essential in chemistry education because effective learning involves the integration of various forms of representation and active engagement rather than dependence on a single sensory modality.

Empirical research in chemistry education has nevertheless reported associations between learning style preferences and academic outcomes. For example, Novela et al. (2022) investigated the relationship between VARK learning styles and chemistry learning outcomes among 160 Grade XI students in Indonesia. Their findings indicated a significant relationship between learning styles and chemistry learning outcomes, with students distributed across unimodal, bimodal, trimodal, and quadmodal categories. Other recent chemistry education research has also examined learning style related variables in relation to student achievement, although the findings and research designs have

varied (Sari et al., 2025). For example, recent work examining VARK based teaching in medical biochemistry found that students predominantly demonstrated multimodal preferences, while differences in learning achievement between VARK preference groups were not statistically significant (Chinnapun & Narkkul, 2024). A separate study also examined the relationship between VARK learning styles and chemistry literacy in acid–base topics (Wulandari & Fitri, 2025).

Similar findings have also been reported in science education contexts beyond chemistry. Agni and Zainal (2023), for example, examined the relationship between students' learning styles and learning outcomes in a Limnology course using a quantitative descriptive approach. Although a statistically significant relationship was identified, the correlation was relatively weak ($r = -0.378$, $p = 0.039$). The authors suggested that learning outcomes may also be influenced by other factors, including learning resources, learning environment, learning media, interest, and motivation. These findings indicate that the relationship between learning preferences and academic achievement may vary across educational contexts and should therefore be interpreted cautiously.

The inconsistency of previous findings is important because it indicates that the relationship between learning preferences and learning outcomes cannot be generalized across educational settings. Differences in school context, curriculum, students, instruments, learning experiences, and outcome measures may contribute to different findings. A recent systematic review of differentiated instruction based on learning styles in chemistry classrooms similarly highlighted the continuing interest in learning style informed approaches while emphasizing methodological and implementation challenges (Hariyanto et al., 2025). A meta-analysis reported positive overall effects of learning-style-based instruction on academic achievement, although these findings concerned instructional interventions rather than differences between naturally occurring VARK groups (Erdem & Kaf, 2023).

The present study is situated within this research context. The source study was conducted at SMA Pasundan 2 Kota Bandung and focused on Grade XI students. The research was motivated by the need to understand students' learning characteristics in chemistry, particularly because chemistry learning involves abstract concepts, symbolic representations, calculations, and practical activities. The study used the VARK framework to identify students' learning preferences and examined their chemistry learning outcomes based on school assessment records.

The research gap lies in several areas. First, although learning styles have been studied in various educational contexts, studies specifically examining VARK preferences and chemistry learning outcomes among Indonesian senior high school students remain relatively limited. Second, previous findings concerning the association between learning styles and academic outcomes are not consistent. Some studies have reported significant relationships, whereas other research has found weak or non-significant relationships. This inconsistency indicates a need for additional evidence from different school contexts and student populations. Third, relatively few studies have simultaneously described the distribution of unimodal and multimodal VARK preferences and examined differences in chemistry learning outcomes among these groups. The source study explicitly identifies these gaps, particularly the limited research connecting VARK preferences with chemistry learning outcomes in the specific research context.

The present study therefore does not assume that one learning style is inherently superior to another. Instead, it investigates whether chemistry learning outcomes differ among students categorized according to their VARK preference profiles. This approach is important because the purpose of identifying learning preferences should be to understand learner diversity rather than to restrict students to particular instructional categories. The study consequently treats VARK as a descriptive framework for students' preferred modalities and interprets differences in achievement cautiously.

The study was conducted among 60 Grade XI students at SMA Pasundan 2 Kota Bandung. The participants represented the entire Grade XI population included in the research, and total sampling was used. Learning preferences were identified using an adapted 30-item VARK-based questionnaire comprising 16 items from VARK Questionnaire Version 9.0 and 14 supplementary items. Two university lecturers reviewed and validated the adapted instrument. The questionnaire was trialed with the same 60 Grade XI students who constituted the main study sample; thus, the trial was not based on an independent pilot sample. Chemistry learning outcomes were obtained from semester assessment records. Quantitative item-validity and reliability results have not been supplied for reporting.

Based on this background, the study aims to: (1) identify the distribution of VARK learning style preferences among Grade XI students; (2) describe students' chemistry learning outcomes; and (3) examine whether chemistry learning outcomes differ across VARK learning preference groups. The findings are expected to contribute empirical evidence to chemistry education research concerning learner diversity and the interpretation of learning preferences. In practical terms, the results may help chemistry teachers recognize that students enter the classroom with diverse preferences for engaging with information, while avoiding the assumption that a particular VARK category automatically determines academic achievement.

Importantly, the study adopts a nonexperimental perspective. Therefore, any observed differences among VARK groups should be interpreted as associations or group differences within the sample rather than evidence that a particular learning preference causes higher or lower chemistry achievement. Such a cautious interpretation is consistent with the broader literature, which continues to question strong claims concerning learning-style-based instructional matching.

In this way, the study seeks to contribute a context-specific examination of VARK learning preferences and chemistry learning outcomes among Indonesian senior high school students. Rather than promoting the use of learning styles as rigid instructional labels, the study positions VARK as one possible descriptive lens for understanding learner diversity and examines its empirical relationship with chemistry achievement in an authentic school setting.

METHOD

Research Design

This study employed a quantitative approach with a comparative ex post facto design. The design was selected because the study examined differences in chemistry learning outcomes among students who had already demonstrated different VARK learning preference profiles. The researchers did not manipulate students' learning preferences or assign students to particular learning style groups. Consequently, the study was intended to identify patterns of association and group differences rather than establish causal relationships.

The independent variable was students' learning preference based on the VARK framework, consisting of Visual (V), Aural/Auditory (A), Read/Write (R), and Kinesthetic (K) modalities. Based on the combination of dominant modalities, students were classified into four categories: unimodal, bimodal, trimodal, and quadmodal. The dependent variable was chemistry learning outcome, operationalized as students' scores on the Chemistry Final Semester Assessment (PAS) for the second semester of the 2025/2026 academic year.

Participants and Sampling

The study was conducted at SMA Pasundan 2 Kota Bandung, West Java, Indonesia, during May-June 2026. The participants consisted of all 60 Grade XI students included in the study population. The population comprised students from classes XI-2 and XI-3, with 29 and 31 students, respectively. Because the population was relatively small and all eligible students were accessible, total sampling was employed. Thus, the sample consisted of 60 students. Therefore, the findings are limited to the participating students and should not be generalized to all Indonesian senior high school students. This distinction is important when interpreting the generalizability of the findings.

Instruments and Data Sources

First, students' learning preferences were assessed using an adapted 30-item VARK-based questionnaire (VARK Learn Limited, n.d.). The instrument was developed by retaining 16 items from the VARK Questionnaire Version 9.0 and adding 14 supplementary items developed for the present study. The original VARK framework describes four learning preference modalities: Visual, Aural/Auditory, Read/Write, and Kinesthetic (Fleming & Mills, 1992; Fleming, 2001). The 14 additional items were intended to extend the questionnaire for the study context. Thus, the instrument administered here was an adaptation of VARK Version 9.0, rather than the unmodified official questionnaire. For each respondent, responses were counted across the Visual, Aural/Auditory,

Read/Write, and Kinesthetic modalities, and the resulting profiles were classified as unimodal, bimodal, trimodal, or quadmodal. The exact rules used to determine dominant modalities, including the handling of equal or closely ranked scores, require explicit documentation to make the classification reproducible.

The adapted 30-item questionnaire was reviewed by two university lecturers to assess its content relevance and suitability for the study context. However, quantitative evidence of item validity and reliability was not available for reporting. It was then trialed with the same 60 Grade XI students included in the main study, rather than with a separate pilot group. Consequently, the trial and the main analysis were based on the same participants; this procedure does not constitute independent-sample validation. The available documentation does not provide the specific expert-validation criteria or numerical results of item-validity and reliability testing, so no validity or reliability coefficients are claimed here.

Second, chemistry learning outcomes were obtained through documentation of students' Chemistry PAS scores for the second semester of the 2025/2026 academic year. The use of school assessment records provided an existing measure of students' chemistry achievement without introducing an additional achievement test specifically for this study.

VARK Response Coding and Scoring Procedure

The study employed an adapted 30-item VARK-based questionnaire comprising 16 items from VARK Questionnaire Version 9.0 and 14 supplementary items specifically developed for chemistry learning contexts. Each item presented four response options representing the Visual (V), Aural/Auditory (A), Read/Write (R), and Kinesthetic (K) learning preference modalities. Responses were coded using an item-specific VARK scoring guide. Each selected response was assigned one point to its corresponding modality, without distinguishing between correct and incorrect answers. Individual VARK scores were calculated by summing the frequency of responses assigned to each modality across the 30 items. Accordingly, the total score across the four modalities was 30 for each respondent who completed all items.

The resulting modality scores were used to identify students' learning preference profiles. Students were classified into unimodal, bimodal, trimodal, and quadmodal groups based on the number of dominant VARK modalities identified from their questionnaire scores. The operational criteria used to identify dominant modalities, including the treatment of tied or closely ranked scores, should be explicitly documented to ensure reproducibility. These classifications were used to describe students' learning preferences rather than their cognitive abilities or academic achievement.

Data Collection Procedure

Data collection was conducted after obtaining permission to conduct the study at the research site. The VARK questionnaire was administered to the participating Grade XI students. Students completed the questionnaire according to their own preferences. The completed questionnaires were then scored according to the VARK scoring procedure to determine each student's preference profile. The chemistry learning outcome data were subsequently obtained from school documentation. The two datasets VARK preference classification and Chemistry PAS scores were matched for the same participants and prepared for statistical analysis.

Data Analysis

The data were analyzed using IBM SPSS Statistics Version 22. Descriptive statistics were used to describe the distribution of VARK preference categories and the characteristics of chemistry learning outcomes. Because the VARK groups had substantially unequal sample sizes and the normality assumption was not satisfied across groups, a non-parametric approach was selected for the main inferential analysis. The Shapiro-Wilk test indicated that the unimodal group had a significance value of 0.011 and the bimodal group had a significance value of 0.001, both below 0.05. The quadmodal group had a significance value of 0.707, while the trimodal group consisted of only two students and therefore could not be adequately evaluated for normality. On this basis, the overall normality assumption was considered unmet.

The Kruskal-Wallis test was therefore used as the primary inferential procedure to examine whether chemistry learning outcomes differed across the four VARK preference groups. Statistical significance was evaluated at $\alpha = 0.05$. Levene's test was also reported as an assessment of variance homogeneity. The result was 2.396 with df1 = 3, df2 = 56, and p = 0.078, indicating that the homogeneity assumption was not rejected. An effect-size analysis was also considered in the interpretation of the findings. The Kruskal–Wallis test produced an H statistic of 8.180. An epsilon-squared effect-size estimate calculated as $(H - k + 1)/(N - k)$ yielded a value of 0.0925, where k = 4 groups and N = 60 students.

RESULTS AND DISCUSSION

Distribution of VARK Learning Preference Profiles

The first objective of this study was to identify the distribution of students' learning preference profiles based on the VARK model. The results are presented in Table 1.

Table 1. Distribution of VARK Learning Preference Profiles

VARK Preference Profile	n	Percentage (%)
Unimodal	37	61.7
Bimodal	13	21.7
Trimodal	2	3.3
Quadmodal	8	13.3
Total	60	100.0

The findings showed (see Table 1) that most students were categorized as unimodal learners, comprising 37 students (61.7%). The remaining participants demonstrated multimodal profiles, including bimodal (21.7%), quadmodal (13.3%), and trimodal (3.3%) preferences. This distribution indicates that although a single dominant modality was identified among the majority of students, a considerable proportion of learners reported preferences involving multiple modes of information processing.

The presence of both unimodal and multimodal profiles reflects the diversity of ways students engage with chemistry learning. Chemistry requires students to interpret and connect various forms of representation, including molecular models, diagrams, graphs, symbolic equations, written explanations, verbal descriptions, and laboratory experiences. Therefore, differences in VARK profiles may provide insight into students' preferred ways of accessing and organizing learning information within a subject characterized by multiple representations.

Nevertheless, VARK categories represent preference patterns rather than fixed learning abilities. The predominance of unimodal learners in this sample does not indicate that these students are limited to learning through one modality, nor does the classification imply that instruction should be restricted to their dominant preference. Instead, the findings highlight the variation that exists among learners and the importance of providing learning environments that accommodate diverse forms of engagement.

Chemistry Learning Outcomes

The second objective was to describe students' chemistry learning outcomes based on Chemistry PAS records from the second semester of the 2025/2026 academic year. The descriptive statistics of students' chemistry learning outcomes are presented in Table 2.

Table 2. Descriptive Statistics of Chemistry Learning Outcomes

Statistic	Value
N	60
Minimum	1.9
Maximum	98.0
Mean	40.07
Standard deviation	25.17

The chemistry achievement scores showed substantial variation among the 60 participants, ranging from 1.9 to 98.0, with a mean score of 40.07 and a standard deviation of 25.17. The wide distribution suggests considerable differences in students' levels of chemistry achievement within the sample.

Such variation indicates that students' achievement was likely influenced by multiple factors beyond their VARK preference profiles. Chemistry learning outcomes may be shaped by prior knowledge, motivation, interest, instructional experiences, assessment conditions, learning environment, and students' engagement with learning activities. Therefore, VARK preferences should be considered as one characteristic associated with achievement differences rather than as an isolated determinant of academic performance.

Chemistry Learning Outcomes across VARK Preference Groups

The descriptive comparison of chemistry learning outcomes across VARK preference groups is presented in Table 3.

Table 3. Mean Chemistry Learning Outcomes by VARK Preference Profile

VARK Preference Profile	n	Mean
Unimodal	37	31.34
Bimodal	13	60.86
Trimodal	2	17.60
Quadmodal	8	52.31
Total	60	40.07

The results showed differences in mean achievement among the four VARK groups. The bimodal group obtained the highest mean score (60.86), followed by the quadmodal group (52.31), unimodal group (31.34), and trimodal group (17.60). At the descriptive level, students in the bimodal and quadmodal groups demonstrated higher mean chemistry achievement scores than those in the unimodal group. However, the trimodal group showed the lowest mean score, indicating that higher achievement was not consistently observed across all multimodal categories.

However, these differences should be interpreted in relation to the uneven distribution of participants across groups. In particular, the trimodal category comprised only two students (n = 2), so its mean of 17.60 is highly sensitive to either individual score and cannot be regarded as a stable estimate of typical trimodal performance. The four groups mean are therefore descriptive summaries of this sample, not an ordered ranking of the achievement expected for each VARK profile. Unequal group sizes also make comparisons involving the smallest category especially uncertain.

The higher mean scores observed in the bimodal and quadmodal groups may reflect differences in students' learning experiences or strategies. However, these factors were not directly measured in the present study, and the observed differences should not be interpreted as evidence that multimodal preferences improve chemistry achievement. This interpretation is consistent with the nature of chemistry learning, where students are required to coordinate visual, symbolic, verbal, and practical representations. Nevertheless, the present findings describe an observed association and do not demonstrate that possessing multiple VARK preferences directly improves chemistry achievement.

Assumption Testing and Selection of the Inferential Test

Before examining differences among VARK preference groups, assumption testing was conducted to determine the appropriate statistical procedure. The Shapiro-Wilk test indicated that the unimodal group ($p = 0.011$) and bimodal group ($p = 0.001$) did not meet the normality assumption, whereas the quadmodal group showed a normal distribution ($p = 0.707$). The trimodal group was not evaluated meaningfully due to its very small sample size ($n = 2$). These results indicated that the distribution of chemistry learning outcomes varied across groups and did not fully satisfy the assumptions required for parametric analysis.

Levene's test resulted in a significance value of 0.078, indicating that the assumption of variance homogeneity was satisfied. Considering the non-normal distribution and unequal group sizes,

the Kruskal-Wallis test was selected as the most appropriate method for comparing chemistry learning outcomes across VARK preference groups.

Differences in Chemistry Learning Outcomes across VARK Groups

The Kruskal–Wallis analysis revealed a Chi-square value of 8.180 with a significance value of 0.042. Since $p < 0.05$, the null hypothesis of equal distributions across VARK preference groups was rejected. This finding indicates that differences existed in chemistry learning outcomes among students with unimodal, bimodal, trimodal, and quadmodal profiles. Although the Kruskal-Wallis test identified an overall difference among groups, it does not indicate which specific groups differed significantly. The Kruskal–Wallis test revealed a statistically significant overall difference among the four VARK groups. However, the test does not identify which specific pairs of groups differed significantly. Therefore, further pairwise comparisons using an appropriate non-parametric post hoc procedure are necessary..

Therefore, the higher descriptive mean observed in the bimodal group (60.86) should be interpreted as a pattern within this sample rather than evidence that bimodal learners consistently achieve better chemistry outcomes. The statistical findings demonstrate variation among VARK groups, while the available post hoc analysis does not support claims of superiority for any particular preference category.

Effect Size and Practical Interpretation

The magnitude of the overall group difference may be assessed using an effect-size measure appropriate for the Kruskal–Wallis test as an indicator of effect size. The reported effect-size value provides a preliminary indication of the magnitude of differences associated with VARK preference groups. However, its interpretation depends on the statistical procedure used to calculate it and should be considered alongside the study's non-experimental design and unequal group sizes.The practical meaning of this association requires careful consideration. Because the study employed an ex post facto design, students were not assigned to VARK categories and their preferences were not experimentally manipulated. Consequently, the relationship between VARK profiles and chemistry achievement may involve other influencing factors that were not examined, such as prior knowledge, motivation, instructional practices, and learning environments.

Within the broader discussion of learning styles, identifying students' preferences is different from demonstrating that instruction adapted to those preferences improves achievement. Thus, the contribution of this study lies in describing the relationship between VARK profiles and chemistry performance rather than providing evidence for VARK-based instructional matching.

Discussion of the Relationship between VARK Preferences and Chemistry Learning

The significant Kruskal-Wallis result suggests that students with different VARK preference profiles demonstrated different patterns of chemistry achievement in this sample. One possible explanation is that students' preferred ways of engaging with information may influence how they approach chemistry concepts, particularly because chemistry requires the coordination of multiple representations.

Chemistry learning involves connections between macroscopic phenomena, microscopic structures, and symbolic representations. Students frequently interact with diagrams, molecular models, equations, graphs, explanations, and experimental activities. Students reporting preferences across multiple modalities may engage with chemistry information through diverse representations. However, the present study did not directly examine students' learning strategies or instructional experiences; therefore, this explanation remains theoretical.

The descriptive findings support this possibility, as bimodal and quadmodal groups showed higher mean achievement compared with the unimodal group. However, the relationship should be viewed as an association rather than a direct effect of multimodal preferences on achievement. Students with higher academic achievement may also develop broader learning strategies over time, meaning that the direction of the relationship cannot be determined from the present research design.

In addition, interpretation should consider the unequal distribution of participants across groups. The large unimodal group ($n = 37$) and very small trimodal group ($n = 2$) influence the stability

of comparisons. Future studies involving larger and more balanced samples are needed to examine whether the observed patterns remain consistent.

Implications for Chemistry Education

The findings provide several implications for chemistry education. First, teachers may benefit from recognizing that students differ in their preferred ways of engaging with learning materials. Such awareness can support the development of learning environments that provide diverse opportunities for interaction with chemistry concepts.

Rather than designing separate instructional approaches for each VARK category, chemistry instruction may be strengthened through the integration of multiple representations. For example, teachers can combine molecular models, visual diagrams, verbal explanations, written problem-solving activities, and laboratory experiences to support conceptual understanding. A systematic review also highlights the importance of instructional approaches and educational technologies for supporting organic chemistry learning outcomes (Febliza et al., 2025).

VARK information may also function as a reflective tool that helps students recognize their learning preferences while developing flexibility in using different strategies. This approach is particularly relevant in chemistry, where successful learning requires students to move between different representations rather than rely exclusively on one mode of information.

Comparison with Previous Research

The present findings contribute to the growing body of research examining the relationship between learning preferences and academic achievement. In the current study, the Kruskal–Wallis analysis indicated an overall difference in chemistry learning outcomes across the four VARK preference profiles. This finding is consistent with previous research by Novela et al. (2022), which reported a significant relationship between VARK learning styles and chemistry learning outcomes among Grade XI students in Indonesia. However, the present findings also need to be considered alongside studies reporting weaker or non-significant relationships, indicating that the association between learning preferences and achievement may vary across educational contexts.

For example, Agni and Zainal (2023) reported a statistically significant but weak relationship between learning styles and learning outcomes in a Limnology course ($r = -0.378$, $p = 0.039$). Although their study used a correlation-based approach rather than a comparison of VARK groups, the findings similarly suggest that learning preferences alone do not provide a complete explanation of students' academic achievement. Differences in educational context, participants, assessment procedures, and other learner or instructional factors may contribute to variations in findings across studies.

The differences between the present findings and previous research may also be related to methodological characteristics. Studies have varied in their sample sizes, learning environments, instruments used to identify learning preferences, outcome measures, and statistical procedures. In the present study, VARK preferences were identified as naturally occurring learner characteristics and compared with existing chemistry assessment outcomes. Therefore, the observed differences should be interpreted as an association between preference profiles and achievement rather than as evidence of a causal effect.

An important implication of this comparison is that the findings should not be interpreted as demonstrating that one VARK profile is inherently more effective for learning chemistry. In particular, although the bimodal and quadmodal groups showed higher descriptive mean scores than the unimodal group, the omnibus Kruskal–Wallis test does not establish which specific groups differed significantly. Appropriate non-parametric post hoc comparisons are needed to examine these differences. Thus, the present study provides evidence of variation in chemistry achievement across VARK profiles within the sample, while also highlighting the need for caution when generalizing these patterns to other student populations.

Overall, the comparison with previous research reinforces the view that VARK preferences may be useful for describing learner diversity, but they should not be treated as a single or definitive predictor of chemistry learning outcomes. Further research using larger and more balanced samples, multiple measures of learning, and longitudinal or experimental designs would be valuable for

examining how learning preferences interact with instructional practices and other factors associated with chemistry achievement.

Study Limitations

Several limitations should be considered when interpreting these findings. First, the study involved only 60 students from a single senior high school. Therefore, the findings represent the characteristics of this sample and cannot be generalized directly to all Indonesian senior high school students. Second, the distribution of VARK categories was highly unequal (unimodal n = 37; bimodal n = 13; trimodal n = 2; quadmodal n = 8). With only two trimodal students, the estimated trimodal mean is unstable and unusually sensitive to individual observations; the group also offers insufficient information for meaningful distributional assessment. Consequently, the significant omnibus Kruskal–Wallis result should not be interpreted as evidence that trimodal students generally perform worse, or that any VARK category is superior. This imbalance limits the precision and external validity of the group comparisons.

Third, although the Kruskal-Wallis test was selected due to non-normal data distribution, the combination of unequal group sizes and distributional differences requires cautious interpretation. The adapted questionnaire has measurement limitations. Its 14 supplementary items were reviewed as part of expert validation by two university lecturers, and the full 30-item questionnaire was trialed with the same 60 students included in the main study. Because no independent pilot sample was used, instrument trial and substantive analysis relied on the same participants. Moreover, without reported quantitative item-validity or reliability statistics, the psychometric properties of this adapted instrument cannot be independently assessed. Future studies should conduct and document independent pilot testing and suitable psychometric evaluation.

Finally, the study examined the relationship between VARK preferences and chemistry achievement without including other variables that may influence learning outcomes, such as prior knowledge, motivation, interest, instructional strategies, and learning environment. The cross-sectional ex post facto design also limits causal interpretation. Future research should involve larger samples, multiple schools, balanced VARK categories, and longitudinal or experimental approaches to further examine how learner characteristics interact with chemistry learning processes.

CONCLUSION AND SUGGESTION

The findings indicate that Grade XI students demonstrated diverse VARK learning preferences, dominated by unimodal (61.7%), followed by bimodal (21.7%), quadmodal (13.3%), and trimodal (3.3%). Bimodal students obtained the highest mean chemistry score (60.86), followed by quadmodal (52.31), unimodal (31.34), and trimodal (17.60). The Kruskal–Wallis test revealed a statistically significant overall difference in chemistry learning outcomes across VARK categories, $\chi^2(3) = 8.180$, $p = .042$. However, pairwise post hoc comparisons are needed to identify specific group differences, and the small trimodal group (n = 2) limits the generalizability of the findings. These results indicate an association rather than a causal relationship, as other factors may influence chemistry achievement.

Chemistry teachers are encouraged to provide multimodal learning experiences rather than restricting instruction to students' preferred VARK categories. Future research should involve larger, more balanced samples from multiple schools and consider potential confounding variables, including prior knowledge, motivation, and learning experiences. Longitudinal, experimental, or quasi-experimental studies are recommended to examine the interaction between learning preferences and instructional approaches, with appropriate pairwise post hoc analyses when statistically justified.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, Y.K. and A.S.P.; methodology, Y.K. and A.S.P.; investigation, Y.K.; data curation, Y.K.; formal analysis, Y.K. and A.S.P.; interpretation of results, Y.K., A.S.P., and N.S.; writing original draft preparation, Y.K. and A.S.P.; writing review and editing, A.S.P. and N.S.; supervision, A.S.P. and N.S.; and project administration, A.S.P. All authors have read and approved the final version of the manuscript.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to SMA Pasundan 2 Kota Bandung for providing access and support during the data collection process. The authors also thank the Grade XI students who participated in the study and contributed their learning preference and academic achievement data. The authors acknowledge Universitas Katolik Parahyangan for providing the academic environment that supported the completion of this research.

DECLARATION OF GENERATIVE AI SOURCES

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language improvement, manuscript organization, and drafting support. All generated content was carefully reviewed, revised, and verified by the authors. The authors take full responsibility for the accuracy, interpretation, originality, and final content of the manuscript.

REFERENCES

Agni, R., & Zainal, S. (2023). Exploring the relationship between visual learning styles and learning outcomes in limnology course: A quantitative descriptive study. *Equator Science Journal, 1*(1), 31–38. https://doi.org/10.61142/esj.v1i1.5

Agustian, H. Y., Finne, L. T., Jørgensen, J. T., Pedersen, M. I., Gammelgaard, B., Christiansen, F. V., & Nielsen, J. A. (2022). Learning outcomes of university chemistry teaching in laboratories: A systematic review of empirical literature. *Review of Education, 10*(2), Article e3360. https://doi.org/10.1002/rev3.3360

Childs-Kean, L. M., Edwards, M., & Smith, M. D. (2020). Use of learning style frameworks in health science education. *American Journal of Pharmaceutical Education, 84*(7), Article ajpe7885. https://doi.org/10.5688/ajpe7885

Chinnapun, M., & Narkkul, P. (2024). Enhancing learning in medical biochemistry by teaching based on VARK learning style for medical students. *Advances in Medical Education and Practice, 15*, 1021–1030. https://doi.org/10.2147/AMEP.S472532

Clinton-Lisell, V., & Litzinger, C. (2024). Is it really a neuromyth? A meta-analysis of the learning styles matching hypothesis. *Frontiers in Psychology, 15*, Article 1428732. https://doi.org/10.3389/fpsyg.2024.1428732

Erdem, E., & Kaf, Ö. (2023). Effect of learning styles on academic achievement: A meta-analysis. *TAY Journal, 7*(1), 26–43. https://doi.org/10.29329/tayjournal.2023.537.02

Febliza, A., Kadarohman, A., Aisyah, S., Abdullah, N., & Susilawati. (2025). Improving students' achievement in organic chemistry: A systematic review of experimental studies. *Journal of Turkish Science Education, 22*(2), 393–418. https://doi.org/10.36681/tused.2025.020

Fleming, N. D. (2001). *Teaching and learning styles: VARK strategies*. VARK Learn Limited.

Fleming, N. D., & Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To Improve the Academy, 11*(1), 137–155. https://doi.org/10.1002/j.2334-4822.1992.tb00213.x

Gilbert, J. K., & Treagust, D. F. (Eds.). (2009). *Multiple representations in chemical education*. Springer. https://doi.org/10.1007/978-1-4020-8872-8

Hariyanto, S. A., Sulistyaningsih, & Suprihatiningrum, J. (2025). Differentiated instruction based on learning styles in chemistry classrooms: A systematic review of models, outcomes, and implementation challenges. *Hydrogen: Jurnal Kependidikan Kimia, 13*(3), 611–617. https://doi.org/10.33394/hjkk.v13i3.15933

Johnstone, A. H. (2010). You can't get there from here. *Journal of Chemical Education, 87*(1), 22–29. https://doi.org/10.1021/ed800026d

Newton, P. M., & Salvi, A. (2020). How common is belief in the learning styles neuromyth, and does it matter? A pragmatic systematic review. *Frontiers in Education, 5*, Article 602451. https://doi.org/10.3389/feduc.2020.602451

Novela, D., Irwandi, D., & Fairusi, D. (2022). Hubungan gaya belajar terhadap hasil belajar kimia. *Jurnal Riset Pendidikan Kimia, 12*(1), 24–30. https://doi.org/10.21009/JRPK.121.04

Papadatou-Pastou, M., Gritzali, M., & Barrable, A. (2018). The learning styles educational neuromyth: Lack of agreement between teachers' judgments, self-assessment, and students' performance. *Frontiers in Education, 3*, Article 105. https://doi.org/10.3389/feduc.2018.00105

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105–119. https://doi.org/10.1111/j.1539-6053.2009.01038.x

Sari, R. I., Rasmiwetti, & Wulandari, P. A. (2025). Pengaruh gaya belajar terhadap hasil belajar kimia kelas XI SMA Negeri 2 Tambang. *Journal of Research and Education Chemistry, 7*(1), 185–201. https://doi.org/10.25299/jrec.2025.vol7(1).21875

Taber, K. S. (2019). *The nature of the chemical concept: Re-examining the foundations of chemical education*. Royal Society of Chemistry.

VARK Learn Limited. (n.d.). *The VARK questionnaire*. https://vark-learn.com/the-vark-questionnaire/

Wulandari, N. I., & Fitri, B. Y. (2025). Hubungan antara gaya belajar dengan kemampuan literasi kimia peserta didik pada materi asam basa fase F SMA/MA. *SECONDARY: Jurnal Inovasi Pendidikan Menengah, 5*(3), 358–366. https://doi.org/10.51878/secondary.v5i3.6507