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PROBLEM-BASED LEARNING IN VITAMIN CHEMISTRY TO IMPROVE STUDENTS' NUTRITION INFORMATION INTERPRETATION SKILLS

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ABSTRACT

Abstract: Nutrition information interpretation skills are an essential component of nutrition literacy that should be developed among prospective chemistry teachers. This study aimed to analyze the implementation of Problem-Based Learning in vitamin chemistry to improve nutrition information interpretation skills among 18 chemistry education students. This study employed a pre-experimental one-group pretest-posttest design implemented over two class meetings, each lasting 100 minutes. Student activity observations and worksheet performance were used as descriptive supporting data. The paired-samples *t*-test revealed a statistically significant difference between the pretest and posttest scores ($t(17) = -13.304$, $p < .001$, Cohen's $d = 3.14$), with the mean score increasing from 37.04 to 87.04 (N-Gain = 0.60, moderate category). Students' learning activities and worksheet performance achieved average scores of 90.28% and 92.70%, respectively, both categorized as very good, with the greatest improvement observed in the applying skills and interactive skills dimensions. These findings suggest that Problem-Based Learning has the potential to support the development of students' nutrition information interpretation skills through contextual chemistry learning connected with authentic food-related problems, implying that similar contextual approaches may be considered for strengthening nutrition literacy within chemistry teacher education programs.

Abstrak: Keterampilan interpretasi informasi gizi merupakan bagian penting dari literasi nutrisi yang perlu dikembangkan pada mahasiswa calon guru kimia. Penelitian ini bertujuan untuk menganalisis penerapan *Problem-Based Learning* pada materi vitamin dalam meningkatkan keterampilan interpretasi informasi gizi pada 18 mahasiswa pendidikan kimia. Penelitian ini menggunakan desain praeksperimen dengan rancangan *one-group pretest-posttest yang dilaksanakan dalam dua kali pertemuan,*

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masing-masing berdurasi 100 menit. Observasi aktivitas mahasiswa dan penilaian lembar kerja digunakan sebagai data deskriptif pendukung. Hasil uji *paired-samples t-test* menunjukkan perbedaan yang signifikan secara statistik antara skor *pretest* dan *posttest* ($t(17) = -13{,}304$, $p < 0{,}001$, Cohen's $d = 3{,}14$), dengan rata-rata skor meningkat dari 37,04 menjadi 87,04 (N-Gain = 0,60, kategori sedang). Aktivitas mahasiswa dan kinerja penyelesaian lembar kerja masing-masing memperoleh rata-rata 90,28% dan 92,70% dengan kategori sangat baik, dengan peningkatan tertinggi pada dimensi *applying skills* dan *interactive skills*. Temuan ini menunjukkan bahwa *Problem-Based Learning* berpotensi mendukung pengembangan keterampilan interpretasi informasi gizi melalui pembelajaran kimia kontekstual yang dikaitkan dengan permasalahan pangan autentik, yang mengindikasikan bahwa pendekatan kontekstual serupa dapat dipertimbangkan untuk memperkuat literasi nutrisi dalam program pendidikan calon guru kimia.

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INTRODUCTION

The increasing availability of fortified food products has made nutrition information on food labels an essential source for making informed dietary choices. However, the benefits of nutrition labeling depend not only on the availability of nutrition information but also on individuals' ability to understand, interpret, and apply that information appropriately. These competencies are recognized as important components of nutrition literacy, which encompasses the ability to obtain, understand, apply, communicate, and critically evaluate nutrition information in various contexts (Krause et al., 2016; Silk et al., 2008; Zhang et al., 2022). Consequently, developing nutrition information interpretation skills has become increasingly important for preparing individuals to make informed dietary decisions and promote healthier eating behaviors.

Nutrition information displayed on fortified food products generally includes nutrient composition and the percentage of the Recommended Dietary Allowance, providing consumers with information regarding nutritional adequacy and safe consumption. However, interpreting such information requires an understanding of the scientific characteristics of nutrients. In vitamin chemistry, chemical structure, polarity, and solubility

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influence absorption, storage, physiological function, and the potential risk of toxicity when vitamins are consumed excessively (Gropper, 2021; Institute of Medicine, 2000). Therefore, learning vitamin chemistry should not only focus on conceptual understanding but also enable students to relate chemical concepts to nutrition information encountered in everyday food products.

Despite the widespread availability of nutrition labels, the public's ability to interpret nutrition information remains limited. Studies conducted in Indonesia have reported that consumers pay limited attention to nutrition information and often experience difficulties interpreting nutrition labels appropriately (Aprianti et al., 2023; Mauludyani et al., 2021). Similar findings have been reported internationally, indicating that nutrition-label use is strongly associated with educational attainment, literacy level, and socioeconomic characteristics, resulting in inconsistent utilization of nutrition information for dietary decision-making (Campos et al., 2011; Yang et al., 2024). These findings indicate that improving access to nutrition information alone is insufficient without simultaneously developing individuals' nutrition information interpretation skills.

This issue is particularly relevant in chemistry education because prospective chemistry teachers are expected to master chemical concepts and facilitate meaningful connections between scientific knowledge and real-life contexts. Nevertheless, nutrition-related contexts remain insufficiently integrated into chemistry education. Previous studies have suggested that nutrition competencies among pre-service teachers should be strengthened through contextual learning experiences to better support future nutrition-literacy education (Bermejo et al., 2024; Fadila et al., 2025; Snelling et al., 2023). These findings highlight the need for instructional approaches that integrate chemistry concepts with authentic food-related contexts.

Problem-Based Learning has been widely recognized as an instructional model that facilitates knowledge construction through authentic problem-solving, collaborative learning, and student-centered inquiry (Arends, 2012; Raman et al., 2024; Yew & Goh, 2016). Previous studies have demonstrated that Problem-Based Learning enhances conceptual understanding, higher-order thinking, and problem-solving abilities in chemistry education (Dolmans et al., 2016; Raman et al., 2024). From a theoretical perspective, the characteristics of Problem-Based Learning are closely aligned with the multidimensional nature of nutrition information interpretation skills. Problem orientation encourages students

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to identify nutrition-related issues, investigation facilitates obtaining and understanding scientific information, collaborative discussion supports interactive communication, and reflection and evaluation promote the application and critical evaluation of nutrition information when making dietary decisions.

The nutrition information interpretation skills examined in this study were adapted from the multidimensional nutrition literacy framework proposed by Zhang et al. (2022), comprising six dimensions: knowledge, understanding, obtaining skills, applying skills, interactive skills, and critical skills. This framework conceptualizes nutrition literacy as extending beyond factual knowledge to include the ability to locate, interpret, communicate, apply, and critically evaluate nutrition-related information. Although the framework has been applied in nutrition literacy research among the general population, its application in chemistry education, particularly in learning vitamin chemistry, remains largely unexplored.

Previous studies have generally investigated Problem-Based Learning in chemistry education, nutrition literacy, and nutrition-label interpretation as separate research topics. However, limited research has integrated vitamin chemistry with authentic food-label analysis through Problem-Based Learning while simultaneously examining nutrition information interpretation skills using the six-dimensional framework proposed by Zhang et al. (2022). Accordingly, empirical evidence explaining how contextual chemistry learning supports the development of these six dimensions among prospective chemistry teachers is limited. To address this gap, the present study integrates vitamin chemistry concepts with authentic nutrition-label analysis through Problem-Based Learning while examining students' nutrition information interpretation skills across the six dimensions proposed by Zhang et al. (2022). Rather than focusing solely on learning achievement or problem-solving abilities, this study specifically investigated how contextual chemistry learning is associated with the development of nutrition information interpretation skills, thereby providing empirical evidence to support the integration of chemistry education and nutrition literacy.

Therefore, this study aimed to analyze the implementation of Problem-Based Learning in vitamin chemistry and examine its association with the development of nutrition information interpretation skills among chemistry education students across six dimensions: knowledge, understanding, obtaining skills, applying skills, interactive skills, and critical skills.

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METHOD

This study employed a quantitative pre-experimental design using a one-group pretest-posttest design, which is appropriate for examining changes before and after an educational intervention in a single group without a comparison group (Campbell, 1963). Measurements were conducted before and after the implementation of Problem-Based Learning (PBL). To complement the quantitative findings, student activity observations and student worksheet performance were analyzed descriptively to provide additional evidence regarding the implementation of the learning process. The overall research procedure is illustrated in Figure 1.

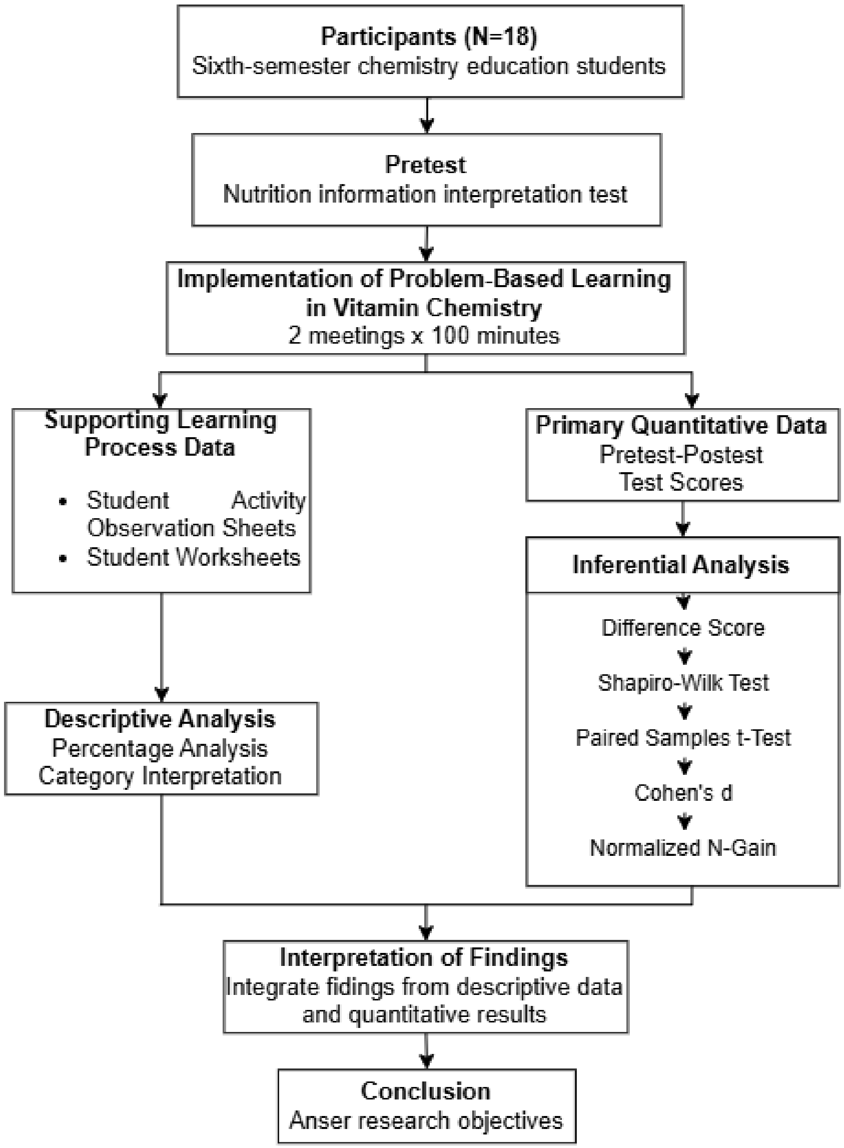

Figure 1. The Overall Reseach Procedure

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The participants consisted of 18 sixth-semester chemistry education students, aged approximately 20 years, enrolled in the *Kimia Aditif dan Adiktif* (Food Additives and Addictive Substances Chemistry) course, specifically within the *Nutrifikasi* (food fortification) topic area, in which vitamin fortification was one of the learning topics. Participants were selected using purposive sampling, as they had completed prerequisite chemistry courses that enabled them to analyze the vitamin structure, physicochemical properties, and consumption safety in fortified food products. Because *Kimia Aditif dan Adiktif* is an elective course with fixed and limited enrollment, all 18 enrolled students constituted the entire eligible population for this topic during the study period; consequently, the sample size was determined by the total population rather than by a separate sampling calculation. As the course consisted of a single intact class, all enrolled students were included as research participants.

The intervention was conducted over two meetings, each lasting 100 min (2 credit hours). Before the intervention began, students received an explanation of the learning procedures, classroom activities, and assessment criteria. Participation formed part of regular classroom learning; therefore, no formal ethical approval or written informed consent was obtained, as the study was conducted as routine educational practice rather than as a clinical or medical intervention. Nevertheless, students were informed of the purpose of the study before data collection, and their participation had no influence on their course grades.

The researcher facilitated Problem based Learning. As the researcher also served as the course instructor during the intervention, the possibility of instructor-related bias cannot be completely excluded and is acknowledged as a limitation of this study.

Students worked collaboratively in four discussion groups, each consisting of four to five randomly assigned students, allowing students with different levels of prior chemistry knowledge to collaborate and engage in peer learning throughout the problem-solving process. Student learning activities were observed by four observers, each of whom monitored one discussion group using the same rubric. Prior to data collection, all observers were briefed on regarding the observation indicators and scoring procedures to ensure consistency during classroom observations. Because each observer evaluated a different discussion group, inter-rater reliability could not be calculated, which is acknowledged as a limitation of observational data.

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For the dimension-level analysis presented in the Results section, participants were further classified into low-, moderate-, and high-achievement groups using the 27% grouping method based on cumulative grade point average (GPA). The upper 27% (n = 5) were categorized as the high-achievement group, the lower 27% (n = 5) as the low-achievement group, and the remaining students (n = 8) as the moderate-achievement group. The corresponding GPA ranges were 3.50–3.76, 2.96–3.23, and 3.28–3.49, respectively.

The research instruments consisted of student activity observation sheets, problem-based student worksheets, and pretest-posttest essay tests. Student activities were evaluated using observation sheets containing indicators aligned with the five Problem-Based Learning phases. Student worksheets documented students' problem-solving processes throughout each learning phase. The pretest and posttest each consisted of six essay questions, with one question representing each dimension of nutrition information interpretation skills—knowledge, understanding, obtaining skills, applying skills, interactive skills, and critical skills—adapted from the framework proposed by Zhang et al. (2022). The same indicators were assessed in both tests, although different fortified food products were used as contextual stimuli to minimize recall bias.

Responses to the pretest and posttest were assessed using an analytic scoring rubric ranging from 0 to 3, while student worksheets were evaluated using the same 0–3 rubric according to predetermined performance criteria. The scoring rubric was defined as follows: a score of 0 was assigned to no response or an irrelevant answer; a score of 1 for a response that mentioned a relevant concept but was scientifically inaccurate; a score of 2 for an accurate response with an incomplete explanation; and a score of 3 for an accurate and complete response supported by scientific reasoning.

Instrument validity was established through expert judgment by two chemistry education lecturers, who evaluated the instruments in terms of content relevance, construction, and language clarity. The instruments were revised according to the validators' recommendations before implementation. The student worksheets obtained a content validity score of 92%, whereas the pretest-posttest instrument obtained 94%, indicating that both instruments were considered highly feasible for classroom implementation. The use of expert judgment as evidence of content validity is widely recommended during the development of educational instrument development. Validator agreement was further evaluated using the Content

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Validity Index (CVI). Both the Scale-CVI based on universal agreement (S-CVI/UA) and the average Scale-CVI (S-CVI/Ave) were 1.00, indicating perfect agreement between the two validators across all evaluated items (Polit et al., 2007; Polit & Beck, 2006).

Internal consistency reliability (e.g., Cronbach's alpha) was not calculated, as each essay item was intentionally designed to measure a different dimension of nutrition information interpretation skills rather than multiple indicators of a single latent construct. Consequently, internal consistency estimates do not appropriately represent the measurement characteristics of the instrument. Prior to the main study, the pretest and posttest instruments were piloted with 10 students who had previously completed the Kimia Aditif dan Adiktif course, to evaluate item clarity and completion time before administration to the actual research participants.

Table 1. Research Instruments

Instrument	Data Analysis Technique
Student Activity Observation Sheets	Descriptive analysis and percentage interpretation
Problem-Based Student Worksheets	Descriptive analysis and percentage interpretation
Pretest and Posttest Questions	Shapiro–Wilk normality test, paired-samples t-test, Cohen's *d*, and normalized N-Gain analysis

Learning activities followed the five phases of Problem-Based Learning proposed by Arends. (2012): orienting students to the problem, organizing students for learning, guiding investigation, developing and presenting results, and analyzing and evaluating the problem-solving process. Learning problems were contextualized using fortified food products, requiring students to analyze vitamin composition, chemical structure, polarity, solubility, nutrition information labels, and safe intake levels based on the Tolerable Upper Intake Level (UL) before formulating evidence-based consumption recommendations.

Student activity observations and worksheet scores were converted into percentages and interpreted descriptively to characterize the implementation of the learning process. The percentage scores were classified as very good (81–100%), good (71–80%), fair (61–70%), poor (51–60%), and very poor (≤50%).

Quantitative data were analyzed by first examining the normality of the difference scores (posttest–pretest) using the Shapiro–Wilk test, which is recommended for small-sample sizes. Because the difference scores were

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normally distributed ($W = 0.955$, $p = .517$), changes in students' performance were analyzed using a paired-samples t-test with a significance level of 0.05. Statistical findings were reported together with Cohen's d as the effect size and normalized N-Gain according to Hake. (1999)to evaluate the magnitude of improvement, calculated using the formula $g = (S_{post} - S_{pre}) / (S_{max} - S_{pre}) \times 100\%$, where Spost and Spre represent the posttest and pretest scores, respectively, and Smax represents the maximum possible score. N-gain values were categorized as high ($g \geq 0.70$), moderate ($0.30 \leq g < 0.70$), and low ($g < 0.30$).

RESULT AND DISCUSSION

Student Activities During the Implementation of Problem-Based Learning

Student activities were observed throughout the implementation of Problem-Based Learning (PBL) using an observation sheet consisting of indicators aligned with the five phases of the PBL model. The results showed that students actively participated in every phase of the learning process, with all activity scores falling within the very good category. The average percentage of student activities during each learning phase is shown in Table 2.

Table 2. Student Activities During Each Phase of Problem-Based Learning

Learning Phase	Average (%)	Category
Orienting Students to the Problem	91.67	Very Good
Organizing Students for Learning	88.89	Very Good
Guiding Investigation	87.96	Very Good
Developing and Presenting the Results	91.67	Very Good
Analyzing and Evaluating the Problem-Solving Process	91.20	Very Good
Overall	90.28	Very Good

Overall, the results indicate that students actively participated throughout the implementation of Problem-Based Learning, with all learning phases achieving very good levels of participation. Students were consistently involved in identifying problems, conducting investigations, discussing evidence, and communicating their findings, reflecting the learner-centered nature of PBL in which knowledge is constructed through collaborative inquiry (Arends, 2012; Dolmans et al., 2016; Yew & Goh, 2016).

The highest activity scores were obtained during the orienting students to the problem and developing and presenting the results phases (91.67%).

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During the orientation phase, students analyzed nutrition labels from fortified food products, identified differences in vitamin composition, and formulated initial questions based on real-world nutritional problems. Presenting contextual problems at the beginning of learning appeared to encourage students' engagement during subsequent learning activities and encourage active participation throughout the subsequent learning process, consistent with the principle of PBL that authentic problems serve as meaningful learning triggers (Hmelo-Silver, 2004; Raman et al., 2024; Savery, 2015).

Similarly, high participation during the presentation phase reflected students' active involvement in synthesizing investigation results, preparing scientific posters, presenting evidence-based recommendations, and responding to questions from their peers. These activities require students to communicate scientific arguments and justify their reasoning, providing opportunities for knowledge construction through collaborative discussion (Dolmans et al., 2016; Loyens et al., 2015).

Although the guiding investigation phase obtained the lowest percentage (87.96%), it remained within the very good category. This phase required students to integrate multiple chemistry concepts—including vitamin structure, polarity, solubility, Recommended Dietary Allowance (RDA), and Tolerable Upper Intake Level (UL)—before evaluating fortified food products. Therefore, the slightly lower score may reflect the greater cognitive demands associated with scientific investigation rather than reduced engagement, as investigative activities in PBL generally require students to construct explanations independently from available evidence (Dolmans et al., 2016; Raman et al., 2024).

High participation was also observed during the organizing students for learning and analyzing and evaluating the problem-solving process phases. Students organized learning tasks, distributed responsibilities within their groups, reflected on their reasoning, and evaluated the validity of their proposed solutions. These activities illustrate the collaborative and reflective characteristics of PBL that support students in monitoring both their problem-solving processes and the quality of their decisions (Arends, 2012; Loyens et al., 2015).

Overall, the observation findings indicate that PBL successfully facilitated active participation throughout the learning process. Although classroom observations do not directly measure learning outcomes, they provide supporting evidence that students were meaningfully engaged in

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learning activities designed to develop nutrition information interpretation skills.

Student Performance on Problem-Based Student Worksheet

Student worksheets were assessed to evaluate students' performance throughout the problem-solving process during the implementation of Problem-Based Learning (PBL). The assessment covered all five learning phases: problem orientation, learning organization, investigation, presentation of results, and evaluation of problem-solving. The average worksheet scores for each phase are presented in Table 3.

Table 3. Student Worksheet Performance in Each Phase of Problem-Based Learning

Learning Phase	Average (%)	Category
Orienting Students to the Problem	94.8	Very Good
Organizing Students for Learning	95.9	Very Good
Guiding Investigation	88.6	Very Good
Developing and Presenting the Results	87.8	Very Good
Analyzing and Evaluating the Problem-Solving Process	96.4	Very Good
Overall	92.7	Very Good

Overall, student worksheet performance reached 92.7%, indicating that students successfully completed the problem-solving activities throughout the intervention. Students were able to identify nutrition-related problems, analyze vitamin chemistry concepts, interpret nutrition label information, and formulate evidence-based recommendations, suggesting that the intended sequence of PBL activities was implemented effectively.

The highest worksheet score was obtained during the analysis and evaluation of the problem-solving process phase (96.4%). At this stage, students critically reviewed the evidence collected during the investigation and justified their recommendations regarding vitamin consumption using scientific arguments. For example, students explained how differences in vitamin polarity influence storage in the human body and used this information to evaluate whether consuming multiple fortified products could potentially exceed the Tolerable Upper Intake Level (UL). Such reflective evaluation is an essential component of PBL because it encourages students to examine the validity of their reasoning while

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strengthening conceptual understanding (Arends, 2012; Dolmans et al., 2016; Yew & Goh, 2016).

The developing and presenting the results phase obtained the lowest worksheet score (87.8%), although it remained in the very good category. During this phase, students synthesized investigation results, prepared scientific posters, communicated evidence-based arguments, and responded to questions from other groups. These tasks require not only conceptual understanding but also scientific communication skills, which generally demand greater cognitive and collaborative effort than written analysis. Similar findings have been reported in previous studies showing that presenting and defending scientific arguments represents one of the more challenging stages of inquiry- and problem-based learning (Dolmans et al., 2016; Raman et al., 2024).

Overall, the worksheet findings complement the classroom observation results by demonstrating that students not only participated actively throughout the learning process but also successfully completed problem-solving tasks aligned with the intended learning objectives. Together, these descriptive findings provide supporting evidence that students meaningfully engaged with the contextual learning activities prior to the quantitative evaluation of nutrition information interpretation skills.

Improvement of Nutrition Information Interpretation Skills

To determine changes in students' nutrition information interpretation skills following the implementation of Problem-Based Learning (PBL), quantitative analyses were conducted using descriptive statistics, assumption testing, paired-samples t-test, and normalized N-Gain analysis. Table 4 presents the descriptive statistics of students' pretest and posttest scores.

Table 4. Descriptive Statistics of Pretest and Posttest Scores

	N	Min	Max	Mean	Std. Deviation
Pretest	18	11.11	66.67	37.04	11.90
Posttest	18	72.22	100.00	87.04	8.31

The descriptive results indicate a substantial increase in students performance following the intervention. The mean score increased from 37.04 to 87.04, while the smaller standard deviation observed in the posttest suggests that students' performance became more homogeneous after participating in the learning activities.

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Before hypothesis testing, the assumption of normality was examined using the Shapiro–Wilk test on the difference scores (posttest–pretest). The results are shown in Table 5.

Table 5. Tests of Normality (Shapiro-Wilk)

	Statistic	df	Sig.
Difference (Posttest-Pretest)	0.955	18	0.517

Because the significance value exceeded 0.05 (p = .517), the difference scores were normally distributed. Therefore, the assumption required to conduct a paired-samples *t*-test was satisfied. The result of the paired-samples *t*-test are presented in Table 6.

Table 6. Paired Samples Test

	Mean Diff	Std. Dev	Std. Error Mean	95% CI	t	df	Sig. (2-tailed)	Cohen's d
Pretest-Posttest	-50.00	15.94	3.76	42.07 to 57.93	-13.304	17	<0.001	3.14

The paired-samples t-test revealed a statistically significant difference between students' pretest and posttest scores ($t(17) = -13.304$, $p < .001$, 95% CI [42.07, 57.93]). The effect size (Cohen's d = 3.14) indicates a very large practical effect (Cohen, 1988), suggesting that participation in the PBL intervention was associated with substantial improvement in nutrition information interpretation skills.

However, these findings should be interpreted cautiously. Because this study employed a one-group pretest-posttest design without a comparison group, the observed improvement cannot be attributed exclusively to Problem-Based Learning. Testing effects, collaborative learning experiences, maturation, and instructor influence have also have contributed to the observed gains. Therefore, the results indicate an association between participation in the intervention and improved student performance rather than definitive evidence of instructional effectiveness.

To evaluate the magnitude of improvement, normalized N-Gain analysis was subsequently performed. The overall results are listed in Table 7.

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Table 7. Normalized N-Gain

N	Mean N-Gain	Category
18	0.60	Medium

The overall normalized N-Gain was 0.60, indicating a moderate level of improvement according to Hake (1999). This value represents the average of individual students' N-Gain scores rather than an N-Gain calculated directly from the overall pretest and posttest means.

To obtain a more detailed understanding of students' learning progress, normalized N-Gain values were further analyzed across the six dimensions of nutrition information interpretation skills proposed by Zhang et al. (2022). The results are shown in Table 8.

Table 8. Mean N-Gain Scores by Dimension and Achievement Group

Dimension	Class			N-Gain	Category
	Low	Moderate	High		
Knowledge	1.00	0.50	0.20	0.56	Moderate
Understanding	0.60	0.75	0.60	0.65	Moderate
Obtaining Skills	0.20	0.12	-0.20	0.04	Low
Applying Skills	0.93	0.95	1.00	0.96	High
Interactive Skills	0.73	0.87	0.60	0.73	High
Critical Skills	0.70	0.62	0.70	0.67	Moderate
Mean				0.60	Moderate

Achievement groups were classified using the 27% method based on cumulative grade point average (GPA), consisting of five, eight, and five students in the hight-, moderate-, and low-achievement groups, respectively.

Dimension-level analysis indicated that learning gains varied across the six dimensions of nutrition information interpretation skills. The highest improvements were observed in applying skills (N-Gain = 0.96) and interactive skills (N-Gain = 0.73), whereas obtaining skills showed only minimal improvement (N-Gain = 0.04). Knowledge, understanding, and critical skills demonstrated moderate gains.

Overall, these findings suggest that participation in the PBL activities was more strongly associated with improvements in students' ability to apply chemistry concepts and communicate evidence-based interpretations than with improvements in basic information retrieval skills. This pattern is consistent with the characteristics of Problem-Based Learning, which emphasizes the application of knowledge, collaborative inquiry, and

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scientific communication in authentic learning contexts (Arends, 2012; Dolmans et al., 2016; Yew & Goh, 2016).

Because this study employed a one-group pretest-posttest design without a comparison group, the observed improvements should be interpreted with cautioun. Testing effects, collaborative learning experiences, and natural learning progression have also have contributed to the reported learning gains. The following sections discuss each dimension individually in relation to previous literature.

The knowledge dimension achieved a normalized N-Gain of 0.56, indicating moderate improvement. Students with lower initial achievement demonstrated greater gains than those with higher initial achievement, likely because they had greater opportunities to develop foundational knowledge of vitamin chemistry. During PBL activities, students identified vitamin types, recognized chemical names on fortified food labels, and related these compounds to their physiological functions, supporting the conceptual foundation required for subsequent investigation (Arends, 2012). This finding is consistent with previous studies that reported that nutrition knowledge is associated with prior educational experience and familiarity with nutrition information (Aprianti et al., 2023; Yang et al., 2024; Zhang et al., 2022).

The understanding dimension demonstrated a moderate improvement with an N-Gain of 0.65, indicating that students became more capable of interpreting nutrition information after participating in the PBL activities. Rather than memorizing nutritional facts, students explained relationships between vitamin properties, physiological functions, and nutrition-label information while discussing authentic consumption scenarios. During the investigation phase, they compared fortified food products, interpreted nutrition labels, and justified their conclusions with scientific evidence.

This qualitative improvement is illustrated by comparing of one student's pretest and posttest responses to structurally equivalent items, as presented in Table 9. The shift from a misconception regarding the meaning of percentage RDA values to an accurate, quantitatively reasoned interpretation illustrates the conceptual development that occurred following the implementation of Problem-Based Learning.

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Table 9. Sample Pretest–Posttest Response Comparison (Understanding Dimension)

	Pretest	Posttest
Item	"Vitamin B2: 20% RDA per serving" — explain what this value means	"Vitamin B6: 38% RDA per serving" — explain what this value means
Student Response	"The maximum consumption limit according to the RDA"	"One serving fulfills 38% of the person's total daily Vitamin B6 requirement... 62% of the daily requirement is still needed, which should be obtained from other food sources"
Interpretation	Misconception: percentage RDA interpreted as an upper safety threshold	Accurate, quantitatively reasoned interpretation of percentage RDA as proportional daily contribution

These findings are consistent with the principles of Problem-Based Learning, in which conceptual understanding develops through collaborative investigation and knowledge construction rather than direct transmission of information (Dolmans et al., 2016; Yew & Goh, 2016).Similar findings have been reported by Zhang et al. (2022), who emphasized that understanding nutrition information extends beyond factual knowledge to interpreting its meaning in real-life contexts. Accordingly, the observed improvement suggests that students developed a deeper conceptual understanding of vitamin chemistry while strengthening their ability to meaningfully interpret nutrition information.

The obtaining skills dimension showed the lowest improvement among the six dimensions, with an N-Gain of 0.04. Although this result may appear to indicate limited improvement, it is more plausibly explained by a ceiling effect. Students had already demonstrated relatively strong abilities to locate nutrition information, such as vitamin content, Recommended Dietary Allowance (RDA) percentages, serving sizes, and other label information before the intervention. Consequently, the high initial performance limited the amount of measurable improvement that could be achieved. This is further supported by the actual pretest and posttest means for this dimension, which were 90.74 and 96.30, respectively, confirming that students had already achieved a high level of performance in obtaining nutrition information prior to the intervention.

This interpretation is consistent with Zhang et al. (2022), who described obtaining information as a foundational component of nutrition

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literacy that generally develops before higher-order interpretive and evaluative skills. Similarly, Yang et al. (2024) reported that frequent exposure to food labels primarily improves individuals' ability to retrieve nutrition information rather than interpret or critically evaluate it. Therefore, the low N-Gain in this dimension should not be interpreted as evidence that PBL was ineffective; instead, it suggests that the intervention primarily supported students' progression from information retrieval toward higher-order interpretation and application.

The applying skills dimension demonstrated the highest improvement, with an N-Gain of 0.96, indicating that students substantially improved their ability to apply chemistry concepts when interpreting nutrition information in authentic food contexts. During the PBL activities, students analyzed relationships among vitamin structure, polarity, solubility, physiological function, Recommended Dietary Allowance (RDA) values, and Tolerable Upper Intake Levels (UL) before formulating evidence-based consumption recommendations. These tasks require students to integrate multiple chemistry concepts rather than simply recalling factual information.

This finding is consistent with the characteristics of Problem-Based Learning, which emphasizes applying scientific knowledge to solve authentic problems through collaborative investigation (Arends, 2012; Yew & Goh, 2016). By repeatedly transferring theoretical chemistry concepts to real-world nutrition-label interpretation, students strengthened their ability to apply conceptual knowledge in practical decision-making.

Nevertheless, the exceptionally high N-Gain should be interpreted cautiously. Students' very low pretest performance in this dimension suggests a possible floor effect, meaning that the large improvement may partly reflect substantial room for learning before instruction rather than the instructional model alone. Consequently, future studies employing comparison groups are needed to determine the extent to which these gains can be specifically attributed to Problem-Based Learning.

The interactive skills dimension achieved a high N-Gain of 0.73, indicating that students strengthened their ability to communicate, exchange ideas, and construct evidence-based arguments while collaboratively solving nutrition-related problems. Throughout the intervention, students worked in small discussion groups, prepared scientific posters, presented their investigation results, and responded to questions from their peers. These activities required students to not only

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understand nutrition information but also to explain and defend their interpretations through scientific discussions.

This finding is consistent with the collaborative nature of Problem-Based Learning, in which social interaction serves as an important mechanism for knowledge construction (Dolmans et al., 2016; Yew & Goh, 2016). Similar improvements in scientific communication have been reported in chemistry education studies that have implemented PBL (Raman et al., 2024). The high N-Gain observed in this dimension suggests that collaborative learning activities provided students with meaningful opportunities to communicate and refine evidence-based interpretations of nutrition information.

The critical skills dimension achieved a moderate N-Gain of 0.67, indicating that students improved their ability to evaluate nutrition information and formulate evidence-based consumption decisions. During the PBL activities, students compared fortified food products, evaluated vitamin intake relative to the Recommended Dietary Allowance (RDA) and Tolerable Upper Intake Level (UL), and justified their recommendations using scientific evidence. These tasks require higher-order reasoning beyond factual recall.

This moderate improvement is consistent with previous studies suggesting that critical thinking develops progressively through repeated opportunities for analysis and reflection rather than within a short instructional period (Raman et al., 2024). Similarly, Zhang et al. (2022) argued that advanced nutritional literacy requires not only conceptual understanding but also the ability to critically evaluate information before making informed health decisions. Therefore, although students demonstrated meaningful progress, the relatively short duration of the intervention may have limited further development of critical evaluation skills.

Overall, the dimension-level findings indicate that participation in the PBL intervention was associated with greater improvements in concept application and scientific communication than in foundational knowledge acquisition or critical evaluation. This pattern is consistent with the collaborative and inquiry-oriented characteristics of PBL while also reflecting differences in students' initial competencies and the relatively short duration of the intervention.

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CONCLUSION

The findings of this study indicate that the implementation of Problem-Based Learning (PBL) in vitamin chemistry was associated with improvements in students' nutrition information interpretation skills within the context of chemistry learning. The greatest improvements were observed in the applying skills and interactive skills dimensions, suggesting that learning activities involving authentic food-related problems provide opportunities for students to apply chemistry concepts and communicate scientific information in meaningful contexts. Together with the descriptive findings from student activities and worksheet performance, these results suggest that contextual problem solving can support the development of nutrition information interpretation skills among prospective chemistry teachers.

This study has several limitations. This study employed a one-group pretest-posttest design without a comparison group and involved a relatively small sample from a single institution. Therefore, the observed improvements cannot be attributed solely to the PBL intervention, and alternative explanations such as testing effects, maturation, or instructor influence cannot be excluded. Consequently, the findings should be interpreted as evidence of the potential of PBL rather than definitive evidence of its effectiveness. Future research should employ controlled experimental designs with larger and more diverse samples, longer intervention periods, and additional chemistry topics to provide stronger evidence regarding the contribution of contextual Problem-Based Learning to the development of nutrition information interpretation skills.

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