


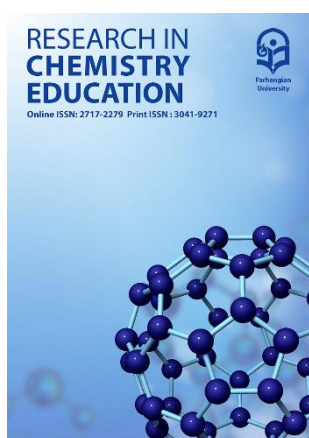


Measuring the compliance of the 11th grade chemistry textbook with Kolb's experiential learning model

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Abstract:

Background and Objective: This study aimed to analyze the content of the 11th-grade chemistry textbook based on Kolb's experiential learning theory. According to Kolb's theory, effective learning occurs when individuals can balance concrete experiences with abstract conceptualization, as well as reflective observation with active experimentation. **Methods:** The research was conducted using a quantitative approach with deductive content analysis. The study population included all educational content of the 11th-grade chemistry textbook (academic year 2023-2024) across three chapters, examined through a census method. The research tool was a researcher-made checklist based on Kolb's four learning indicators, with content validity confirmed by a CVI of 0.95 and reliability by Scott's agreement coefficient between the four coders, 0.91, and based on the Miles-Huberman index, 0.90 for all themes. To analyze the content of the 11th grade chemistry textbook, the entire content of the book was examined with the "topic" analysis unit, and the data were analyzed using MAXQDA 2020 software and statistical methods including frequency counting, percentage, and Shannon entropy. **Findings:** The results revealed that abstract conceptualization had the highest representation (49.46%) in the textbook content, along with the highest information load (0.476) and importance coefficient (1.623). The indicators of concrete experience (26.98%) and reflective observation (22.79%) ranked next. In contrast, active experimentation had the lowest frequency (0.87%), information load (0.293), and importance coefficient (1.000). **Conclusion:** The findings suggest that while the 11th-grade chemistry textbook succeeds in delivering theoretical concepts, it requires revisions to balance theoretical and practical learning. Future editions should enhance laboratory and applied components to achieve more comprehensive experiential learning.

Keywords: Kolb's experiential learning theory, Textbook content analysis, 11th grade chemistry, Learning indicators, Curriculum planning.

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Introduction

Learning, as a dynamic and interactive process, has always been a focus of educational theorists. Within this context, David Kolb's Experiential Learning Model (1984) has emerged as one of the key frameworks in the psychology of learning, shaped by the intellectual traditions of John Dewey (1938) and Kurt Lewin (1951). This model is based on the principle that effective learning occurs not merely through the one-way transmission of knowledge, but through a cycle of experience, reflection, conceptualization, and experimentation (Kolb, 2015).

According to Kolb's theory, learning is effective when individuals can balance concrete experiences and abstract conceptualizations, as well as reflective observation and active experimentation. This theory posits learning as a problem-solving process that occurs within a four-stage cycle. The process unfolds as follows: First, the learner engages in a new concrete experience. Second, the learner actively observes and reflects on that experience from multiple perspectives. Third, through reflection, the learner forms concepts, rules, and general theories about the experience. Finally, the learner uses these new concepts to make decisions and test them in novel situations (Kolb & Kolb, 2017). These four stages form a continuous learning cycle, in which learners internalize new knowledge through interaction with their environment, reflection, and cognitive reconstruction. By emphasizing the balance between concrete experience (such as conducting an experiment) and abstract conceptualization (such as understanding theories), this theory can help bridge the gap between different levels of thinking.

Given the widespread influence of this model across various learning domains (Kayes, 2002; Miettinen, 2000), research has also explored its applications in digital environments, blended learning, and professional development (Healey & Jenkins, 2007). Thus, it can be argued that Kolb's experiential learning model is not only a robust theoretical framework but also a powerful practical tool for enhancing the quality of education and training at various levels.

In education, chemistry has consistently faced challenges due to its conceptual, experimental, and abstract nature (Johnston, 2010; Yaghoubi, 2025; Shirinzadeh, 2024). Among the most significant of these challenges are:

- **The Gap Between Levels of Thinking:** This gap prevents students from effectively connecting the macroscopic world (observations), the microscopic world (particles and molecules), and the symbolic world (formulas and equations). Such disconnection often results in fragmented understanding and rote learning (Talanker, 2011).
- **Abstract and Counterintuitive Concepts:** Concepts such as atomic structure, chemical bonding, and the mole are inherently abstract due to their non-observable nature, requiring learners to possess strong spatial visualization and abstract thinking abilities (Wu & Shah, 2004).
- **Conceptual Density and Complexity:** The high volume of interrelated concepts in chemistry can lead to cognitive overload, making the learning process difficult for students (Johnson, 1997).

Multiple studies have shown that this model can facilitate chemistry learning through hands-on experience (Bahrami Madaah et al., 2023; Iyamuremye et al., 2023), self-reflection (Pentuch, 2025; Alavi & Sifae, 2023), theoretical modeling, and practical application (Briggs, 2007). As an effective framework, it demonstrates significant utility in improving the comprehension of chemical concepts, developing laboratory skills, and strengthening analytical thinking.

On the other hand, textbooks, as the primary medium of knowledge transmission, play a decisive role in facilitating or hindering this cycle. However, the structure of many traditional textbooks, due to their one-sided emphasis on abstract concepts, fails to achieve a balance among the four stages of learning. For example, in chemistry education, concepts such as

stoichiometry or thermodynamics may be taught without adequate connection to practical experiments, leading to superficial learning and an inability to transfer knowledge to new situations.

In contrast, textbooks designed based on Kolb's model incorporate activities such as group projects, analysis of laboratory data, and real-world problem solving; thereby fostering analytical and applied thinking skills. Although numerous studies have explored the application of Kolb's theory in education, content analysis of textbooks based on this theoretical framework particularly in Iran has not yet received attention. A review of research conducted on the content analysis of chemistry textbooks for the second level of secondary education (Sohrabi et al., 2019; Golestaneh & Nazarizadeh, 2025; Yousefi Niasari & Ouli, 2023; Dadashzadeh & Haghighat, 2024) indicates that various aspects of these textbooks have been examined, but their alignment with Kolb's experiential learning model has not yet been studied.

Therefore, in this research, using the content analysis method, the alignment of educational textbooks (focusing on Chemistry 2 for the 11th grade of the second cycle of secondary education) with Kolb's experiential learning model has been evaluated. The main objectives of this research include determining the extent to which the textbook addresses each of the four stages of the learning cycle, identifying the strengths and weaknesses of the textbook content from the perspective of Kolb's theory, and providing practical strategies for improving the quality of educational content. This evaluation can provide a scientific basis for offering practical suggestions to textbook authors, teachers, and educational policymakers, and can serve as a step toward qualitative transformation in chemistry education and the promotion of deep and sustainable learning among students.

Research Background

A systematic review of previous research indicates that Kolb's experiential learning theory has been investigated and applied in three main areas within chemistry education: enhancing laboratory skills and conceptual understanding, developing innovative laboratory teaching models, and its application in science education and educational content analysis.

Numerous studies have examined the impact of Kolb's learning cycle on enhancing practical skills and understanding of chemical concepts. For example, Downey's (1999) research demonstrated that applying this model in chemistry laboratories leads to improved experimental design abilities, reduced computational errors, and a stronger connection between theory and practice. Similarly, Hanson and Wolfskill's (2000) study on complex chemical concepts such as thermodynamics found that systematically implementing Kolb's four stages results in deeper understanding and reduced learning anxiety among students.

In line with the transformation of laboratory education, Abdulwahed and Nagy (2009) integrated hands on and virtual laboratories to develop a model based on Kolb's theory, which led to a significant improvement in the learning outcomes of chemical engineering students. This approach was further refined by Moze (2020) within an educational framework incorporating multimedia exercises, substantially enhancing students' conceptual understanding and motivation.

Ajayi and colleagues (2019), in a comparative study, demonstrated that the Kolb model significantly enhances the quality of science teaching compared to traditional methods. On the other hand, content analyses, such as the study by Chiappetta and Fillman (2007), indicate that science textbooks primarily focus on conveying abstract concepts and often neglect other stages of the learning cycle.

Therefore, a review of the research indicates that Kolb's model can be applied across various areas of chemistry—from teaching fundamental concepts to advanced research—and that experiential learning is not merely a theory but a powerful practical strategy in chemistry education. Thus, while the effectiveness of Kolb's theory in chemistry education has been

confirmed in previous studies, the research background reveals that no study has analyzed the content of Iranian chemistry textbooks based on the four stages of Kolb's experiential learning cycle (concrete experience, reflective observation, abstract conceptualization, and active experimentation). For the first time, this research analyzes the eleventh-grade chemistry textbook, assessing the extent to which balance is maintained between theoretical and practical elements in the educational content, and offers practical recommendations for revising textbook development based on the principles of experiential learning.

Accordingly, the key objectives of content analysis based on the Kolb model are to determine the level of attention paid by the 11th grade chemistry textbook to each of the four stages of experiential learning, identify weaknesses (such as lack of reflective or practical activities), and provide suggestions for its correction and rewriting. This analysis can help transform educational systems and take a step towards sustainable and effective learning.

The central research questions in this study include the following:

1. To what extent does the 11th-grade chemistry textbook provide opportunities for concrete experience, reflective observation, abstract conceptualization, and active experimentation?
2. What is the information load (E_j) and the importance coefficient (W_j) in the 11th-grade chemistry textbook, based on the indicators of Kolb's experiential learning theory?

Methodology

The present study is quantitative and was conducted using deductive content analysis. In deductive content analysis, a theoretical framework or a set of predefined concepts is used to analyze the text. In this study, the concepts of Kolb's experiential learning theory are considered as the analytical framework (Tabrizi, 2014).

The statistical population of this research consisted of all educational content in the 11th-grade chemistry textbook for the academic year 2023-2024. Given the nature of the subject and the limited population, sampling was conducted as a census (entire population). The 11th-grade chemistry textbook comprises 127 pages of educational content across three chapters: "Let's Appreciate the Gifts of the Earth," "In Search of Healthy Food," and "Clothing, an Endless Need."

To conduct the content analysis, a researcher-made checklist based on the indicators of Kolb's experiential learning approach was used. This checklist was developed based on the concepts of Kolb's experiential learning theory and includes three items for each of the four indicators: "Concrete Experience," "Reflective Observation," "Abstract Conceptualization," and "Active Experimentation," totaling 12 items (Appendix 1). Scoring for each item was performed as yes/no for every analyzed unit examined and recorded.

To assess the content validity of this checklist, the Content Validity Index (CVI) was utilized based on the input of 10 educational experts, and it was confirmed (Table 1). Its reliability was also calculated using Scott's coefficient of agreement among four coders, yielding a value of 0.91. Furthermore, the agreement coefficient among the four coders, based on the Miles-Huberman index, was 0.90 for all themes (0.88 for the Concrete Experience indicator, 0.89 for Reflective Observation, 0.91 for Abstract Conceptualization, and 1.00 for Active Experimentation).

Table 1– Content Validity Index (CVI)

Indicators	Items	CVI	Accept-Reject
Concrete Experience	1	1	Accept
	2	0.90	Accept
	3	0.90	Accept
Reflective Observation	4	1	Accept
	5	1	Accept
	6	0.90	Accept
Abstract Conceptualization	7	1	Accept
	8	0.90	Accept
	9	1	Accept
Active Experimentation	10	1	Accept
	11	0.90	Accept
	12	0.90	Accept
Total		0.95	Accept

To analyze the content of the 11th-grade chemistry textbook and collect data, the indicators were first determined, and a checklist was subsequently developed. Categorization and indicator determination were carried out using the deductive method, meaning the categories were defined prior to conducting the analysis (Nourian, 2008), and content analysis was performed based on a deductive approach.

In this study, all educational content of the textbook including text, images, activities, and questions was reviewed by four coders familiar with Kolb's experiential learning approach and the content of the 11th-grade chemistry book. The coders were trained by a researcher knowledgeable in Kolb's experiential approach and its application in education, through six 90-minute sessions.

The unit of analysis and recording was the theme, defined as a specific message intended by the content creator. The counting method was based on frequency determination. In this process, the analysts examined the content and compared it with the items corresponding to the four experiential learning indicators. If the content matched the items of any of the four indicators, it was coded as an instance of that indicator. The level of agreement among coders was assessed using Scott's coefficient and the Miles-Huberman index. For recording and managing the content analysis data, the software MAXQDA 2020 was used. The analysis included frequency counting, percentage calculation, and Shannon entropy analysis.

Results

After preparing the indicators of Kolb's experiential learning theory, the frequencies of the indicators along with concrete examples from the 11th-grade chemistry textbook were compiled. Then, the total frequencies obtained for each indicator were summarized in Table 2. Finally, the data in this table were normalized (P_{ij}) using the Shannon entropy method. Subsequently, based on the second step of this method, the information load of the data was calculated. At the end, following the third step,

the coefficient of importance of the information was also determined. This process helped clarify which component, overall, received the highest level of attention and importance.

Therefore, to answer the first research question "To what extent does the 11th-grade chemistry textbook provide opportunities for concrete experience, reflective observation, abstract conceptualization, and active experimentation?" a frequency and percentage table of Kolb's experiential learning theory indicators in the 11th-grade chemistry textbook was prepared (Table 2).

Table 2 – Frequency and Percentage of Kolb's Experiential Learning Theory Indicators in the 11th-Grade Chemistry Textbook

Indicators	Concrete Experience		Reflective Observation		Abstract Conceptualization		Active Experimentation	
	frequency	percentage	frequency	percentage	frequency	percentage	frequency	percentage
	Chapter 1	46	32.12%	57	28.64%	94	47.24%	2
Chapter 2	68	27.42%	64	25.81%	113	45.46%	3	1.21%
Chapter 3	60	30.30%	26	13.13%	112	56.57%	0	00.00%
total	174	26.98%	147	22.79%	319	49.46%	5	0.87%

Table 2 presents the analysis of Kolb's experiential learning theory indicators concrete experience, reflective observation, abstract conceptualization, and active experimentation in the 11th-grade chemistry textbook. The results show that across all three chapters, the indicator "abstract conceptualization" has the highest frequency, with a total of 319 instances (49.46%), highlighting the textbook's strong emphasis on theoretical and abstract concepts. This is followed by "concrete experience" with 174 instances (26.98%) and "reflective observation" with 147 instances (22.79%), indicating a moderate focus on sensory activities and mental reflection. In contrast, "active experimentation" appears only 5 times (0.87%), reflecting the textbook's notable weakness in promoting learning through action and hands-on experience. In summary, the 11th-grade chemistry textbook predominantly concentrates on the theoretical and abstract dimensions of learning, while dedicating far less attention to laboratory-based and applied activities.

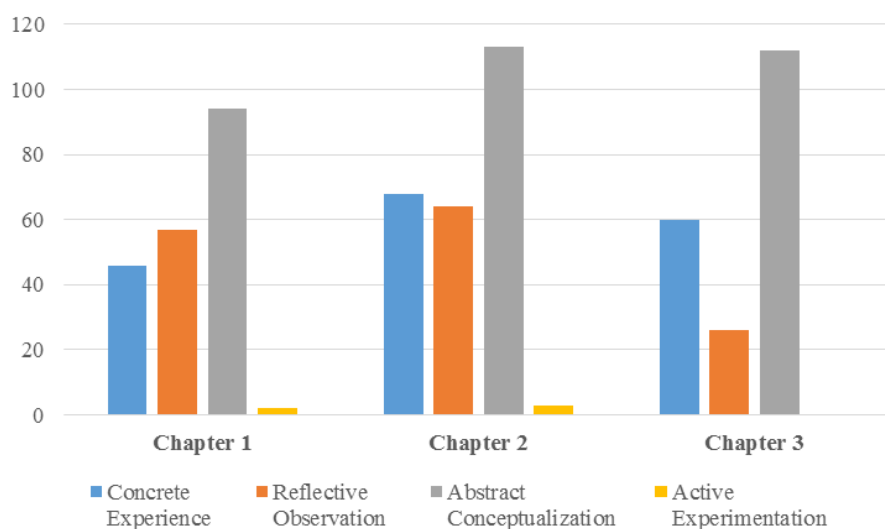


Figure 1- Frequency of Kolb's experiential learning theory indicators in the 11th grade chemistry textbook according to the three chapters of the book

Figure 1 shows the frequency of Kolb's experiential learning theory indicators in the 11th-grade chemistry textbook across its three chapters. As can be observed in Chapter 1, titled "Let's Appreciate the Gifts of the Earth," the highest frequencies correspond, in order, to the indicators of abstract conceptualization, reflective observation, concrete experience, and active experimentation. In Chapter 2, titled "In Search of Healthy Food," the highest frequencies correspond, in order, to abstract conceptualization, concrete experience, reflective observation, and active experimentation. In Chapter 3, titled "Clothing, an Endless Need," the highest frequencies also correspond, in order, to abstract conceptualization, concrete experience, reflective observation, and active experimentation. Thus, it can be concluded that the distribution of indicator frequencies is not uniform across the three chapters of the textbook.

To examine the statistically significant differences in the frequencies of the indicators abstract conceptualization, concrete experience, and reflective observation across the chapters, the Kruskal–Wallis test was used. Meanwhile, for assessing significant differences in the frequency of the active experimentation indicator, the Mann–Whitney U test was applied due to the absence of the active experimentation indicator in Chapter 3.

Table 3- Statistical tests comparing the frequency of learning indicators across chapters

Test	Variable	Chi-square	df	p-value
Kruskal–Wallis	Abstract Conceptualization	0.01	2	0.999
	Concrete Experience	66.49	2	0.001
	Reflective Observation	42.06	2	0.001
Mann–Whitney U	Active Experimentation	0.01	2	0.999

Table 3 presents the results of the Kruskal–Wallis and Mann–Whitney U tests used to examine the statistical significance of differences in the frequencies of the indicators abstract conceptualization, concrete experience, and reflective observation across the chapters. As shown, the differences in the frequencies of concrete experience and reflective observation across the chapters are statistically significant at the 0.05 level ($p < 0.05$). In contrast, the differences in the frequencies of abstract conceptualization and active experimentation are not statistically significant at this level ($p > 0.05$).

To answer the second research question that "What are the information load (E_j) and importance coefficient (W_j) based on the indicators of Kolb's experiential learning theory in the 11th-grade chemistry textbook?" the information load and importance coefficient of the indicators of Kolb's experiential learning theory in this textbook were calculated as presented in Table 4.

Table 4- Information load and importance coefficient of learning indicators in the 11th-grade chemistry book

Indicator	Concrete Experience	Reflective Observation	Abstract Conceptualization	Active Experimentation
Information Load (E_j)	0.476	0.450	0.472	0.293
Importance Coefficient (W_j)	1.609	1.535	1.623	1.000

Table 4 presents the information load (E_j) and importance coefficient (W_j) of Kolb's experiential learning theory indicators in the 11th-grade chemistry textbook. Accordingly, abstract conceptualization with an information load of 0.476 and an importance coefficient of 1.623 has the greatest impact on the textbook's content, which aligns with the results from Table 2 and reflects the book's primary emphasis on theoretical and abstract learning. This is followed by concrete experience ($E_j = 0.472$, $W_j = 1.609$) and reflective observation ($E_j = 0.450$, $W_j = 1.535$), indicating the textbook's moderate attention to the experiential and reflective dimensions of learning. In contrast, active experimentation with the lowest information load (0.293) and importance coefficient (1.000) once again confirms the weakness of the content in fostering practical and experiential learning. These findings suggest that while the 11th-grade chemistry textbook performs well in conveying theoretical concepts, it requires substantial revision to enhance laboratory and applied skills.

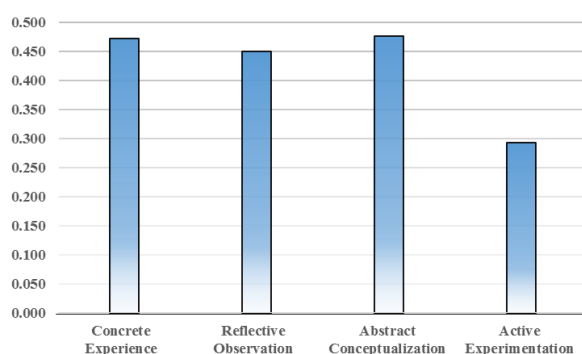


Figure 2 – Information load of Kolb's experiential learning theory indicators in the 11th-grade chemistry

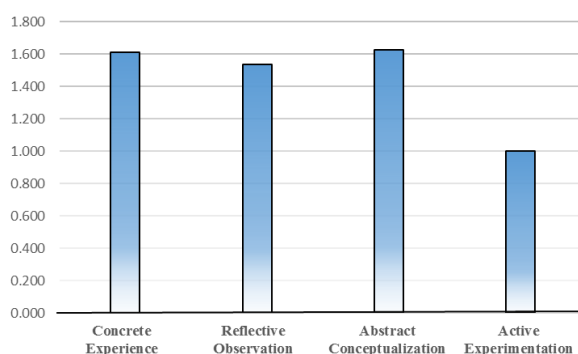


Figure 3 – Importance coefficient of Kolb's experiential learning theory indicators in the 11th-grade chemistry textbook

Figures 2 and 3 illustrate the information load and importance coefficient of Kolb's experiential learning theory indicators in the 11th-grade chemistry textbook. As shown and in accordance with Table 4, the highest information load and importance coefficient correspond to the abstract conceptualization indicator, while the lowest correspond to the active experimentation indicator. Thus, it can be concluded that the importance coefficients of Kolb's experiential learning theory indicators in the 11th-grade chemistry textbook are not equal.

Discussion and Conclusion

The present study aimed to analyze the content of the 11th grade chemistry textbook based on Kolb's experiential learning theory. The findings showed that the distribution of the components of this theory in the textbook under study was not balanced, and the most emphasis was on the abstract conceptualization index (49.46%) and the least attention was paid to the active

experimentation index (0.87%). Also, Shannon entropy analysis confirmed that the importance coefficients of the components were not the same, and the priorities were, in order, abstract conceptualization, concrete experience, reflective observation, and active experimentation.

Various researchers have examined the application of Kolb's experiential learning model in designing and implementing teaching methods (Moučinič et al., 2020), teacher training (McWhorter, 2024), the quality of science teaching (Ajayi et al., 2019), learning complex chemistry concepts (Hanson & Wolfskill, 2000), enhancing secondary chemistry education through experiential learning (Yao, 2023), improving laboratory skills in chemistry (Domingue, 1999), and other areas of education.

However, consistent with the findings of Hanson and Wolfskill (2000), Moučinič et al. (2020), and Yao (2023), the results of this study indicate that the 11th-grade chemistry textbook, despite providing relatively adequate coverage of theoretical and observational concepts, performs poorly in terms of active and experience-based learning. The active experimentation stage requires students to test the theories or models they have developed. This is where learning is put to the test where students apply what they have theorized in new situations and examine the results of their ideas in practice, which is crucial for deepening understanding and reinforcing learning.

In explaining the findings, it can be said that Kolb (2015) begins his model by defining two critical dimensions on which the learning process depends: access to information and transformation of information. Access to information can occur through concrete experience or abstract conceptualization, while the transformation of experience requires two modes of information processing: reflective observation and active experimentation.

Kolb's experiential learning model serves as a framework for resolving the tension between how information is gathered and how it is used. It emphasizes learning through experience and evaluating learners based on their prior experiences. This model highlights the importance of learners' involvement in all learning processes and explores how experience contributes to learning (Zhai et al., 2017). In other words, Kolb views the learning process as a context in which individuals move between concrete experience, abstract conceptualization, reflective observation, and active experimentation. Thus, the effectiveness of learning depends on the ability to balance these four learning stages, which Kolb describes as dialectically linked activities that promote meaningful learning.

In the experiential learning process, two aspects are particularly noteworthy: the use of "here and now" concrete experiences to test ideas, and the use of feedback to modify practices and theories. Kolb argues that the learning cycle can begin at any of the four stages and should be understood as a continuous, spiraling development. Furthermore, for learning to be complete, all four stages must occur. This approach to learning requires granting greater autonomy and responsibility to learners, as well as their direct involvement in the learning process within the learning environment. It also encourages learners to become adaptable, incorporate all possible learning methods within the complete learning cycle, and develop effective skills and metacognitive abilities (Kolb & Kolb, 2017).

Therefore, it appears that the limited attention given to the active experimentation indicator in the 11th-grade chemistry textbook may be attributed to the classical approach used in textbook authorship, which emphasizes the transmission of fundamental concepts, laws, and computational methods rather than designing experiments and employing an experience-based cycle. On the other hand, another factor may be the challenge of fully implementing Kolb's experiential learning model in a textbook, along with the need for laboratory space to conduct various types of practical activities.

In summary, the results of this study underscore the importance of developing educational content that addresses all stages of the Kolb cycle and promotes comprehensive learning. Specifically, since active experimentation plays a pivotal role in deepening the understanding of chemical concepts and enhancing students' scientific skills, it is recommended that in future

revisions, the authors of this textbook strive to achieve a balance among the four components of experiential learning by incorporating laboratory activities, hands-on projects, and interactive assignments into the content. Simultaneously, practical guidelines for implementing these activities should be provided in the 11th-grade chemistry teacher's guide.

Such approaches effectively develop students' abilities to apply knowledge in practical contexts. Additionally, it is recommended that teachers, inspired by this model, employ active teaching methods, conceptual modeling, and design small in-class experiments. By designing and implementing these practical exercises, teachers can help students master concepts accurately, internalize knowledge, and achieve deep and lasting learning outcomes. Furthermore, it is suggested that the experiential learning model be implemented by teachers through innovative platforms, as it offers a dynamic and effective approach to chemistry education. Virtual platforms can simulate experiential scenarios, allowing students to perform operations and observations in a simulated environment. This approach fosters a deeper understanding of concepts by immersing students in practical, real-world scenarios. For future research, conducting similar studies in other science subjects and designing integrated educational models based on Kolb's theory and modern technologies is recommended.

This study, like other research, had certain limitations. For instance, the content analysis was conducted solely on the 11th-grade chemistry textbook, which may limit its generalizability to chemistry textbooks of other grade levels. Additionally, using content analysis based on Kolb's model required interpretation and judgment by the researchers; therefore, the results may be influenced by their perspectives and expertise, potentially leading to bias or differences in interpretation.

Conflict of Interest

The authors have declared no conflicts of interest.

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Appendix 1- Content Analysis Checklist Based on Kolb's Experiential Learning Approach

Indicator	Item	Analytical Categories
Concrete Experience	1	Laboratory/Practical Activities
	2	Using Tangible Examples from Real Life
	3	Images/Videos Depicting Real Experiences
Reflective Observation	4	Reflection-Oriented Questions (Why? How?)
	5	Reflective Writing Assignments (e.g., Lab Reports)
	6	Opportunities for Group Discussion of Experiences
Abstract Conceptualization	7	Presenting Scientific Formulas/Diagrams/Models
	8	Hypothesis-Formulation Exercises
	9	Comparing Scientific Theories
Active Experimentation	10	Real-World Application Projects
	11	Creative Problem-Solving Tasks
	12	Student-Designed Experiments