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Examining the Representation of Laboratory Skills in High School Chemistry Textbooks: A Content Analysis of Acid–Base Titration Materials

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Abstract: Laboratory skills are essential for developing students' scientific practices and experimental competencies in chemistry learning. Since textbooks serve as major instructional resources, differences in the representation of laboratory skills may influence students' opportunities to acquire these competencies. Therefore, this study aimed to compare the representation of laboratory skills in acid–base titration materials across four senior high school chemistry textbooks representing the KTSP, 2013, Merdeka, and Cambridge IGCSE curricula. A directed qualitative content analysis approach was employed. The research subjects consisted of acid–base titration sections from four textbooks, and the instrument used was a coding framework comprising five categories of laboratory skills: planning skills, manipulative skills, safety and laboratory ethics skills, observation and recording skills, and analysis and interpretation skills. Data were collected through document analysis and coded independently by two raters. Coding consistency was established through inter-rater reliability and Cohen's kappa coefficient, followed by consensus coding. Data were analyzed using frequency distributions and qualitative comparisons. The findings revealed differences in the emphasis placed on laboratory skills across textbooks. Analytical and interpretative skills were more prominently represented, whereas safety and laboratory ethics received less attention. These findings highlight the need for a more balanced representation of laboratory competencies in chemistry textbooks.

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INTRODUCTION

Chemistry is a branch of science that emphasizes not only conceptual understanding but also the development of scientific processes through laboratory activities. Laboratory instruction plays a crucial role in helping students construct conceptual understanding, develop higher-order thinking skills, and gain authentic experiences in scientific inquiry. Well-designed laboratory learning environments can promote higher-order thinking skills (Stephenson & Sadler-McKnight, 2016). Chemistry laboratories should serve as environments where students learn how to do chemistry rather than merely verify previously learned concepts (Seery, 2020). Furthermore, Alberto et al. (2024) reported that innovative instructional strategies increasingly focus on developing students' cognitive, scientific, collaborative, and research skills to prepare them for authentic scientific practice.

Laboratory skills constitute an essential component of chemistry learning and are regarded as indispensable competencies for students. These skills encompass the proper use of laboratory apparatus and chemicals, implementation of experimental procedures, measurement techniques, data recording, interpretation of results, and adherence to safety practices. According to Seery (2020), laboratory experiences should enable students to engage in authentic chemical practices rather than function solely as confirmatory exercises. Moreover, recent developments in chemistry education indicate a shift from verification-based laboratory activities toward inquiry-oriented approaches that foster scientific practices and transferable skills (Agustian, 2025).

In Indonesian secondary schools, chemistry laboratory activities are generally supported by multiple instructional resources, including chemistry textbooks, laboratory manuals or practical modules, student worksheets (Lembar Kerja Peserta Didik, LKPD), and teacher-developed instructional materials.

Laboratory manuals and worksheets primarily provide procedural guidance during experiments, whereas textbooks function as the principal curriculum-aligned learning resource by introducing scientific concepts, explaining experimental principles, and preparing students for practical work.

In the teaching and learning process, textbooks remain one of the primary instructional resources used by both teachers and students. Beyond serving as sources of conceptual knowledge, textbooks also support laboratory instruction by presenting experimental contexts, introducing laboratory equipment and procedures, and facilitating the integration of theoretical concepts with practical activities. Consequently, the quality of laboratory representations within textbooks significantly influences students' opportunities to develop laboratory skills. Chen et al. (2024) reported that representations of scientific methods in chemistry laboratory activities have evolved in response to changes in curricula and science education paradigms. These findings highlight the importance of examining laboratory-related content in textbooks to ensure that learning resources adequately support the development of students' scientific competencies.

In chemistry education, textbooks play an essential role in supporting laboratory instruction by integrating theoretical concepts with practical activities. Although laboratory manuals and student worksheets provide procedural guidance during experiments, textbooks serve as the primary curriculum-aligned instructional resource that introduces experimental concepts, explains laboratory techniques, and prepares students for practical work. Consequently, the extent to which laboratory skills are represented in textbooks may influence students' opportunities to develop laboratory competencies and scientific practices.

One chemistry topic characterized by a strong experimental nature is acid–base titration. This topic involves a variety of laboratory skills, including the use of burettes and volumetric pipettes, accurate volume measurements, observation of indicator color changes, data recording, and interpretation of titration results to determine solution concentrations. Therefore, acid–base titration offers considerable opportunities to foster students' laboratory skills. The design of effective laboratory activities has also become an important concern in contemporary chemistry education research due to their contribution to the development of scientific and pedagogical competencies (Hidayah et al., 2023). Although numerous studies have investigated laboratory learning and the development of practical skills, most previous research has focused on instructional design, laboratory models, and student learning outcomes (Seery, 2020). Studies specifically examining the extent to which laboratory skills are represented in senior high school chemistry textbooks, particularly in the acid–base titration topic for Grade 11 students, remain limited. Because textbooks are often the primary learning resource used by teachers and students, understanding how laboratory skills are represented within textbook content is essential to determine whether these materials adequately support the development of students' laboratory competencies. This limitation indicates a research gap that warrants further investigation.

Despite the growing emphasis on laboratory skills in chemistry education, limited research has examined how these skills are represented in senior high school chemistry textbooks, particularly in acid–base titration materials. Since textbooks remain an important instructional resource for supporting laboratory learning, understanding the extent to which they represent laboratory skills is essential. Accordingly, this study addresses the following research question: How are laboratory skills represented in Grade 11 chemistry textbooks on the topic of acid–base titration? To answer this question, the present study analyzes the representation of laboratory skills embedded in Grade 11 chemistry textbooks through qualitative content analysis using an established laboratory skills framework. Specifically, the study identifies and analyzes the representation of laboratory skills within acid–base titration materials. The findings are expected to provide valuable insights for teachers, textbook authors, and curriculum developers in improving the quality of instructional resources that support laboratory-based chemistry learning and promote students' scientific literacy.

METHOD

Research Design

This study employed a directed qualitative content analysis approach to compare the representation of laboratory skills in four chemistry textbooks covering acid–base titration topics. This approach has been widely used in textbook evaluation studies because it enables researchers to examine the presence, emphasis, and distribution of educational components within instructional materials

(Marfuatun et al., 2024). Descriptive research investigates circumstances, conditions, and other factors, with the results presented in the form of a research report (Arikunto & Suharsimi, 2013). The textbooks analyzed consisted of (1) a KTSP-based textbook, (2) a Curriculum 2013 textbook, (3) a Merdeka Curriculum textbook, and (4) Longman Chemistry for IGCSE. The comparison aimed to identify similarities and differences in the extent to which laboratory skills were represented across the textbooks.

Coding Framework

The coding framework was developed based on laboratory skill dimensions identified in previous studies on laboratory learning and scientific practices (Abrahams & Millar, 2008). To improve the transparency and consistency of the content analysis, the framework in Table 1 consisted of five laboratory skill dimensions, each accompanied by specific indicators and operational definitions used during the coding process. The dimensions included Preparation Skills, Manipulative Skills, Laboratory Safety and Ethics, Observation and Recording Skills, and Data Analysis and Interpretation Skills. Each indicator was operationally defined in a coding manual to ensure consistent identification and categorization of laboratory skills across all textbook units.

Table 1. Coding framework for laboratory skills

Laboratory Skill Dimension	Indicators	Operational Definition
Preparation Skills	Formulating hypotheses; identifying variables; selecting apparatus and materials; planning procedures	Text explicitly requires students to prepare or design an experiment before implementation.
Manipulative Skills	Using burette; pipette; measuring solutions; preparing standard solutions	Text describes or instructs the correct operation of laboratory equipment or techniques.
Laboratory Safety and Ethics	Safety symbols; PPE; waste disposal; accident prevention	Text includes laboratory safety instructions or ethical laboratory practices.
Observation and Recording Skills	Recording observations; measuring; tabulating data	Text requires students to observe, measure, or record experimental results.
Data Analysis and Interpretation Skills	Calculations; graphing; drawing conclusions; explaining results	Text requires students to analyze data or interpret experimental findings.

Coding Procedure

Two coders with backgrounds in chemistry education independently coded all thematic units identified in the four textbooks. Prior to the coding process, both coders reviewed the coding manual and discussed sample units to establish a common understanding of the operational definitions. Each indicator was scored dichotomously. After independent coding, discrepancies between coders were discussed until consensus was achieved. The final coding results were used for subsequent analysis. According to O'Connor & Joffe (2020), the involvement of multiple coders enhances the transparency and trustworthiness of qualitative content analysis by reducing subjective bias.

Inter-Rater Reliability

To ensure the consistency and reliability of the coding results, inter-rater reliability was assessed using percentage agreement and Cohen's kappa coefficient. Percentage agreement was used to determine the proportion of coding decisions on which both coders agreed. However, because percentage agreement does not account for chance agreement, Cohen's kappa coefficient was additionally calculated as a more robust measure of reliability. A kappa value within the substantial or almost perfect category indicates a high level of consistency between coders and demonstrates the reliability of the coding scheme. The interpretation of the kappa coefficient followed the criteria proposed by Landis & Koch, (1977)
Below 0.00 poor agreement, 0.00–0.20 slight agreement,
0.21–0.40 fair agreement,
0.41–0.60 moderate agreement,
0.61–0.80 substantial agreement, 0.81–1.00 almost perfect agreement.

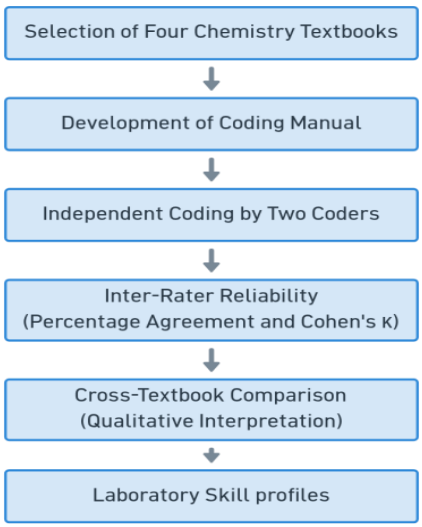


Figure 1. Research Procedure Chart

Qualitative Interpretation

A qualitative interpretation was conducted to examine how laboratory skills were represented within the textbooks. Representative excerpts, illustrations, tables, and activities were used as evidence to support interpretations. Cross-textbook comparisons were then performed to identify common patterns and distinctive characteristics. Particular attention was given to differences associated with curriculum orientation and educational context.

RESULT AND DISCUSSION

Content analysis was conducted on the acid–base titration section of a Grade 11 chemistry textbook using thematic units comprising textual explanations, laboratory procedures, illustrations, tables, and questions that reflected laboratory skills. A total of 20 thematic units representing laboratory skills were identified and subsequently subjected to analysis. The distribution of laboratory skill representations identified in the acid–base titration materials is presented in Table 2.

Table 2. Laboratory Skill Indicator Analysis

Categories	Subcategories
Planning Skills	Formulating hypotheses
	Identifying variables
	Selecting apparatus and materials
	Designing experimental procedures
Manipulative Skills	Using laboratory apparatus
	Handling chemicals
	Performing experimental procedures
	Conducting repeated measurements
Safety and Laboratory Ethics Skills	Following laboratory regulations
	Using personal protective equipment
	Safe handling of chemicals and apparatus
	Waste management
Observation and Recording Skills	Making observations
	Accurate measurements
	Recording experimental data
	Presenting data
Analysis and Interpretation Skills	Processing data
	Interpreting results
	Drawing conclusions
	Relating findings to scientific concepts

Inter-rater reliability was assessed using percentage agreement and Cohen's kappa coefficient for each textbook. As presented in Table 3, the percentage agreement between the two raters ranged from 90% to 95%, indicating a high level of coding consistency. The obtained kappa coefficients ranged from 0.800 to 0.875. According to the criteria proposed by Landis & Koch (1977), three textbooks demonstrated almost perfect agreement, whereas one textbook exhibited substantial agreement.

Table 3. Agreement Value and Cohen's Kappa Coefficient

No	Book	% Deal	Kappa	Categories
1	A	95	0.828	almost perfect agreement
2	B	95	0.875	almost perfect agreement
3	C	90	0.800	substantial agreement
4	D	95	0.875	almost perfect agreement
Average		93.75	0.845	almost perfect agreement

Specifically, Books A, B, and D achieved percentage agreement values of 95%, with kappa coefficients of 0.828, 0.875, and 0.875, respectively, indicating almost perfect agreement between the two raters. In contrast, Book C showed a slightly lower percentage agreement of 90% and a kappa coefficient of 0.800, corresponding to substantial agreement. Overall, these findings, with an average of 93.75% agreement and a kappa coefficient of 0.845, suggest that the coding procedure was highly reliable and that the resulting data were suitable for subsequent content analysis and cross-textbook comparison.

Table 4. Recapitulation of the Appearance Percentage of Laboratory Skill Indicator in Each Book

No	Laboratory Skills	Percentage of Indicator Distribution in Books (%)			
		A	B	C	D
1	Planning Skills (PS)	15	15	15	10
2	Manipulative Skills (MS)	20	20	5	20
3	Safety and Laboratory Ethics Skills (SLES)	10	5	0	5
4	Observation and Recording Skills (ORS)	20	15	20	20
5	Analysis and Interpretation Skills (AIS)	20	20	20	20
	Amount	85	75	60	75

Table 4 shows that the four chemistry textbooks differ in the representation of laboratory skill categories in acid–base titration materials. Although the overall distributions vary among textbooks, Analysis and Interpretation Skills (AIS) were consistently the most-represented category, accounting for 20% of the indicators across almost all textbooks. This finding suggests that the textbooks place considerable emphasis on enabling students to analyze experimental results, interpret data, and relate empirical observations to chemical concepts. Such an emphasis is appropriate because acid–base titration requires students to process quantitative data, perform calculations, and draw evidence-based conclusions.

Abrahams and Millar (2008) argued that laboratory activities become educationally meaningful when students are encouraged not only to follow experimental procedures but also to interpret observations and connect them with scientific concepts. Likewise, Chen and Eilks (2019) found that practical activities presented in secondary chemistry textbooks tend to emphasize conceptual understanding and interpretation of experimental evidence more than inquiry-oriented laboratory practices. Therefore, the strong representation of Analysis and Interpretation Skills observed in this study reflects the important role of textbooks in supporting students' conceptual reasoning during laboratory learning.

In contrast, Safety and Laboratory Ethics Skills (SLES) showed the lowest representation across the analyzed textbooks and were not explicitly represented in Book C. This finding indicates that laboratory safety receives considerably less attention than other laboratory skill categories. According to Rahayu and Muqtada (2023), laboratory competence encompasses not only conceptual understanding and technical skills but also knowledge of laboratory safety, proper chemical handling, and responsible laboratory practices. Similarly, Shana and Abulibdeh (2020) emphasized that effective practical work requires students to develop procedural, technical, and safety competencies simultaneously. Consequently, the limited representation of safety-related indicators may reduce opportunities for students to develop safe

laboratory habits before participating in experimental activities.

Figure 2 shows differences in the representation of laboratory skills among the four textbooks, which also indicate variations in instructional emphasis. Books A and D provide a more balanced representation of laboratory skills than Book C, suggesting differences in textbook design and pedagogical priorities. Chen and Eilks (2019) similarly reported that the representation of practical work varies substantially across chemistry textbooks due to differences in curriculum orientation, textbook structure, and educational objectives. These findings suggest that textbook evaluation should consider not only conceptual coverage but also the extent to which laboratory skills are explicitly represented to support meaningful laboratory learning.

The findings indicate that the analyzed textbooks provide varying opportunities for students to develop laboratory competencies, reflecting different instructional emphases across curriculum contexts. This observation is consistent with Cooper and Stowe (2018), who emphasized that effective chemistry education should be informed by evidence-based instructional approaches that integrate conceptual understanding with scientific practices.



Figure 2. Chart of Indicator Distribution in Books

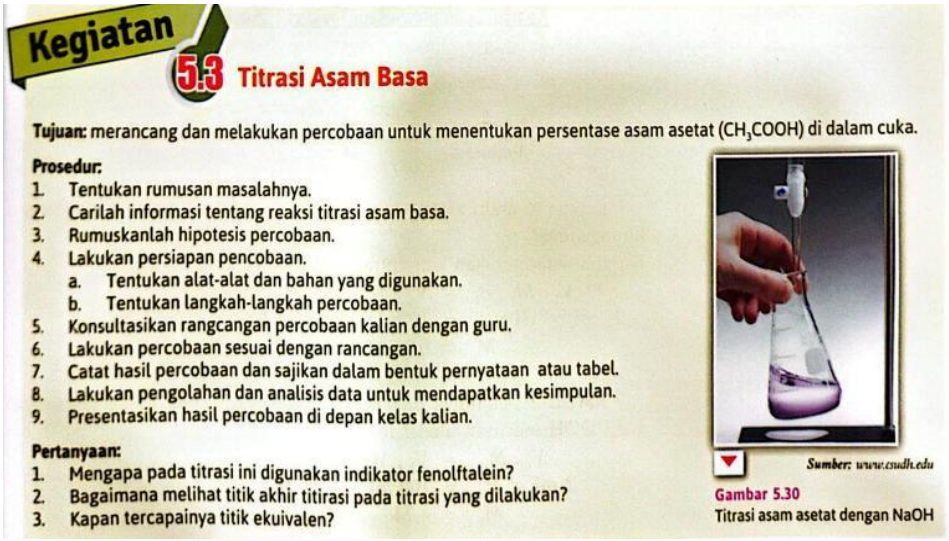
Planning Skills

According to Seery (2020), chemistry laboratory activities should provide students with opportunities to learn how to perform chemistry rather than merely verify theoretical concepts, highlighting the importance of operational competencies in laboratory learning. Similarly, Agustian (2025) argued that contemporary laboratory education has shifted from verification-oriented practical work toward inquiry-based activities that foster authentic scientific practices and higher-order laboratory skills. Planning Skills were most explicitly represented in Book B, particularly in the inquiry-based practical activity presented in Activity 5.3 (Figure 3). Students were required to formulate research questions, develop hypotheses, identify variables, select appropriate apparatus and materials, and design experimental procedures before conducting the experiment. In addition, students were instructed to analyze the collected data and communicate their findings through classroom presentations. These activities demonstrate that the textbook emphasizes planning as an integral component of scientific inquiry rather than treating experimentation as a procedural task.

This finding is consistent with the perspectives of Seery (2020) and Agustian (2025), who emphasized that effective laboratory learning should engage students in planning and decision-making processes that mirror authentic scientific investigations. By encouraging students to formulate research questions and design experimental procedures independently, Book B provides opportunities to develop inquiry skills that extend beyond following prescribed laboratory instructions. Such experiences may enhance students' scientific reasoning, problem-solving abilities, and understanding of experimental design.

Furthermore, the practical activities are accompanied by explicit laboratory regulations and safety precautions before experimentation begins. Abrahams and Millar (2008) argued that meaningful practical work should integrate procedural knowledge with conceptual understanding to enable students to connect laboratory experiences with scientific ideas. Therefore, the inclusion of planning activities alongside laboratory safety guidance suggests that Book B supports not only students' procedural preparedness but

also their awareness of responsible laboratory practice. This balanced representation is important because effective laboratory learning requires students to plan, conduct, and reflect upon scientific investigations within a safe and structured learning environment.



Kegiatan 5.3 Titrasi Asam Basa

Tujuan: merancang dan melakukan percobaan untuk menentukan persentase asam asetat (CH_3COOH) di dalam cuka.

Prosedur:
1. Tentukan rumusan masalahnya.
2. Carilah informasi tentang reaksi titrasi asam basa.
3. Rumuskanlah hipotesis percobaan.
4. Lakukan persiapan pencobaan.
   a. Tentukan alat-alat dan bahan yang digunakan.
   b. Tentukan langkah-langkah percobaan.
5. Konsultasikan rangcangan percobaan kalian dengan guru.
6. Lakukan percobaan sesuai dengan rancangan.
7. Catat hasil percobaan dan sajikan dalam bentuk pernyataan atau tabel.
8. Lakukan pengolahan dan analisis data untuk mendapatkan kesimpulan.
9. Presentasikan hasil percobaan di depan kelas kalian.

Pertanyaan:
1. Mengapa pada titrasi ini digunakan indikator fenolftalein?
2. Bagaimana melihat titik akhir titirasi pada titrasi yang dilakukan?
3. Kapan tercapainya titik ekuivalen?

Sumber: www.csudh.edu

Gambar 5.30
Titrasi asam asetat dengan NaOH

Figure 3. Planning Skills in Book B

Manipulative Skills

Manipulative Skills were prominently represented in Books A, B, and D, each contributing 20% of the total indicators. In contrast, Book C demonstrated considerably lower representation, accounting for only 5%. This finding suggests that Book C places less emphasis on practical competencies, such as handling laboratory apparatus, manipulating chemicals, and performing experimental procedures. Since acid–base titration requires students to master precise laboratory techniques, limited representation of these skills may reduce opportunities for students to develop procedural competence before conducting experiments.

The representation of Manipulative Skills in Book B is evident from the illustration accompanying the acid–base titration procedure (Figure 4). The figure demonstrates the proper technique for holding the Erlenmeyer flask while operating the burette during titration. This visual representation provides guidance on the correct handling of laboratory equipment and illustrates the physical skills required to perform titration accurately. Accordingly, the figure can be categorized as an indicator of laboratory apparatus handling, which constitutes an essential component of manipulative skills.



Sumber: Dokumen penerbit

Gambar 5.24
Cara memegang erlemeyer dan buret saat titrasi

Figure 4. Manipulative Skills in Book B

This finding is consistent with the perspective of Seery (2020), who argued that chemistry laboratories should enable students to learn how to perform chemistry through authentic practical experiences rather than merely verify theoretical concepts. Similarly, Agustian (2025) emphasized that contemporary laboratory education increasingly focuses on developing authentic laboratory competencies, including operational and technical skills required for scientific investigations. Therefore, explicit representations of laboratory techniques, such as the correct manipulation of burettes and

volumetric glassware, play an important role in helping students acquire procedural competence before entering the laboratory.

Furthermore, Abrahams and Millar (2008) argued that meaningful practical work requires students not only to manipulate laboratory equipment correctly but also to understand the scientific purpose underlying each experimental action. Therefore, the inclusion of visual representations demonstrating proper laboratory techniques contributes to students' procedural understanding while supporting the integration of conceptual and practical knowledge. Nevertheless, because manipulative skill indicators were represented only in a limited number of activities, additional illustrations and procedural guidance could further strengthen students' laboratory readiness and confidence when conducting acid–base titration experiments.

Observation and Recording Skills

Observation and Recording Skills were well represented across the four textbooks, ranging from 15% to 20% of the identified indicators. The relatively high proportion of this category indicates that the textbooks consistently provide opportunities for students to observe experimental phenomena and systematically record the resulting data. Evidence of this skill category in Book B was identified through a data table documenting the volume of NaOH used in three titration trials, followed by the calculation of the average volume (Figure 5). Such activities encourage students to organize quantitative observations systematically and provide an essential foundation for subsequent data analysis.

The representation of Observation and Recording Skills reflects the central role of accurate observation in chemistry laboratory learning. According to Abrahams and Millar (2008), effective laboratory activities should enable students to establish meaningful connections between practical observations and the scientific concepts they represent. Likewise, Seery (2020) emphasized that careful observation and systematic data recording are fundamental scientific practices, as reliable experimental evidence underpins scientific reasoning and interpretation. Consequently, providing structured opportunities to record measurements and observations can enhance students' ability to produce accurate experimental data while strengthening their understanding of scientific inquiry.



c. **Hasil Pengamatan**

Contoh:

Titrasi ke-	Jumlah mL NaOH
1	24
2	25
3	26
Rata-rata hasil	25

Figure 5. Observation and Recording Skills in Book B

The use of structured data tables in Book B also supports students in recognizing patterns and identifying potential experimental errors before concluding. Agustian (2025) highlighted that contemporary laboratory education increasingly values authentic scientific practices in which students actively collect, evaluate, and communicate experimental evidence rather than merely complete predetermined procedures. Accordingly, the inclusion of observation and recording activities in the analyzed textbooks supports the development of students' scientific process skills and prepares them for more advanced laboratory investigations.

Overall, the relatively consistent representation of Observation and Recording Skills across the textbooks suggests that textbook authors recognize the importance of accurate data collection in laboratory learning. However, these activities could be further strengthened by incorporating opportunities for students to reflect on data quality, identify possible sources of error, and justify their observations using scientific reasoning, thereby fostering more comprehensive laboratory competence.

Safety and Laboratory Ethics Skills

Safety and Laboratory Ethics Skills exhibited the lowest level of representation among all laboratory skill categories. This category accounted for only 10% in Book A, 5% in Books B and D, and was entirely absent in Book C. These findings indicate that laboratory safety receives considerably less emphasis than other laboratory competencies, despite its fundamental role in ensuring safe and

responsible scientific practice. The limited representation suggests that topics such as laboratory regulations, the use of personal protective equipment (PPE), safe chemical handling, and waste disposal are not comprehensively addressed in the analyzed textbooks.

Evidence of Safety and Laboratory Ethics Skills in Book A was identified through both visual and textual features accompanying the acid–base titration experiment (Figure 6). An illustration depicts the use of protective gloves while handling laboratory apparatus, emphasizing the importance of PPE in minimizing potential hazards during experimental activities. In addition, a cautionary note reminds students to consult their teacher before conducting the experiment, thereby reinforcing awareness of laboratory regulations and responsible laboratory conduct. Similarly, Book B includes a warning statement alongside the experimental procedures (Figure 7), encouraging students to follow laboratory rules during experimentation. Although these features promote safety awareness, they are limited to brief reminders and lack detailed explanations of chemical hazards, emergency procedures, or waste management practices.

This finding is consistent with the view of Hofstein and Mamlok-Naaman (2007), who argued that effective laboratory experiences should develop not only conceptual understanding but also responsible laboratory behavior and scientific work habits. More recently, Seery (2020) emphasized that learning chemistry in the laboratory requires students to acquire authentic laboratory competencies, including safe and appropriate laboratory practices. Likewise, Agustian (2025) highlighted that contemporary laboratory education increasingly recognizes safety awareness as an integral component of scientific competence rather than merely a procedural requirement. Therefore, the relatively limited representation of safety-related indicators observed in this study suggests that students may receive insufficient support in developing safe laboratory behaviors through textbook-based learning alone.

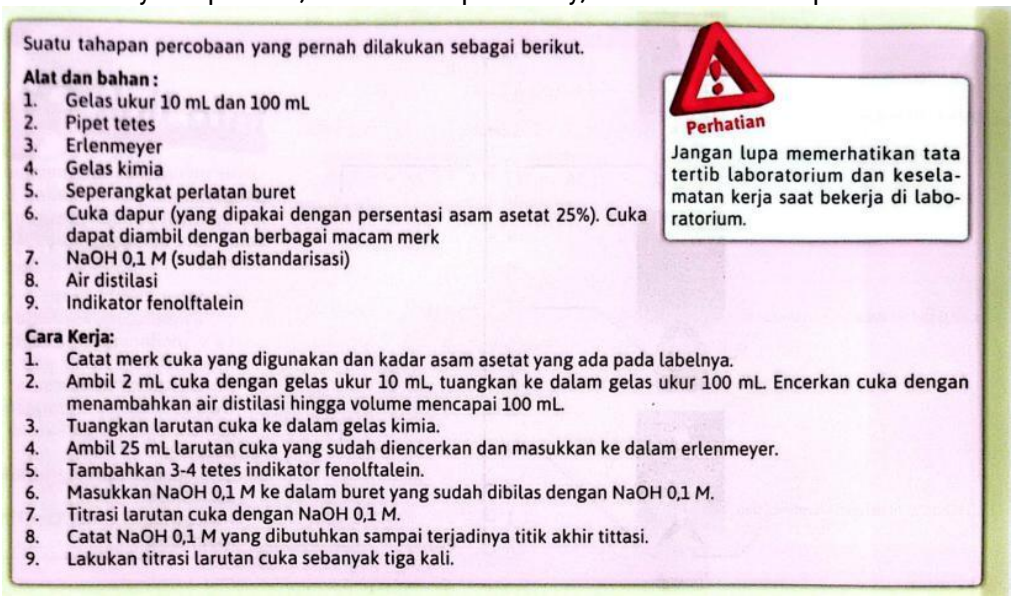


Figure 6. Safety and Laboratory Ethics Skills in Book A

Although the analyzed textbooks provide opportunities for students to perform laboratory activities, the relatively limited representation of Safety and Laboratory Ethics Skills suggests that laboratory competence is not yet represented comprehensively. According to Bretz (2019), effective laboratory courses should intentionally develop multiple dimensions of student learning rather than assuming that laboratory participation alone leads to meaningful educational outcomes. Consequently, laboratory safety should be explicitly integrated into textbook content alongside technical and analytical skills.

Another notable limitation is the absence of explicit guidance on reading the liquid level in a burette according to the lower meniscus. Accurate meniscus reading is essential because it directly influences the determination of titrant volume and the reliability of experimental results. Although the textbooks provide illustrations demonstrating the proper handling of laboratory apparatus, detailed explanations of accurate measurement techniques are largely absent. According to Abrahams and Millar (2008), meaningful laboratory learning requires students to understand not only what procedures to perform but also why specific techniques are necessary to obtain valid and reliable experimental data. Consequently, integrating more comprehensive safety guidance together with accurate measurement techniques would better support students in developing both procedural competence and responsible laboratory practice. Overall, the findings indicate that laboratory safety is represented more implicitly than explicitly in the analyzed textbooks. Future textbook development should incorporate more comprehensive safety instructions, including chemical hazard communication, appropriate use of PPE, waste disposal procedures, emergency responses, and accurate laboratory measurement techniques. Such improvements

would better align textbook content with the objectives of contemporary chemistry education, which emphasize laboratory competence, scientific responsibility, and safe scientific practice.



Suatu tahapan percobaan yang pernah dilakukan sebagai berikut.

Alat dan bahan :

1. Gelas ukur 10 mL dan 100 mL
2. Pipet tetes
3. Erlenmeyer
4. Gelas kimia
5. Seperangkat perlatan buret
6. Cuka dapur (yang dipakai dengan persentasi asam asetat 25%). Cuka dapat diambil dengan berbagai macam merk
7. NaOH 0,1 M (sudah distandarisasi)
8. Air distilasi
9. Indikator fenolftalein

Perhatian

Jangan lupa memerhatikan tata tertib laboratorium dan keselamatan kerja saat bekerja di laboratorium.

Cara Kerja:

1. Catat merk cuka yang digunakan dan kadar asam asetat yang ada pada labelnya.
2. Ambil 2 mL cuka dengan gelas ukur 10 mL, tuangkan ke dalam gelas ukur 100 mL. Encerkan cuka dengan menambahkan air distilasi hingga volume mencapai 100 mL.
3. Tuangkan larutan cuka ke dalam gelas kimia.
4. Ambil 25 mL larutan cuka yang sudah diencerkan dan masukkan ke dalam erlenmeyer.
5. Tambahkan 3-4 tetes indikator fenolftalein.
6. Masukkan NaOH 0,1 M ke dalam buret yang sudah dibilas dengan NaOH 0,1 M.
7. Titrasi larutan cuka dengan NaOH 0,1 M.
8. Catat NaOH 0,1 M yang dibutuhkan sampai terjadinya titik akhir tittasi.
9. Lakukan titrasi larutan cuka sebanyak tiga kali.

Figure 7. Safety and Laboratory Ethics Skills in Book B

Analysis and Interpretation Skills

Analysis and Interpretation Skills showed the highest proportion among the identified laboratory skill categories across the four textbooks. This finding indicates that the textbooks place considerable emphasis on activities requiring students to process experimental data, interpret observations, and draw scientific conclusions. In the acid–base titration materials, students are frequently required to analyze pH changes during titration, interpret titration curves, determine equivalence points, and explain the relationship between experimental observations and acid–base theories. These activities demonstrate that the textbooks prioritize evidence-based reasoning as an essential component of laboratory learning. This finding is consistent with the perspective of Stephenson and Sadler-McKnight (2016), who argued that appropriately designed laboratory instruction promotes students' critical thinking, scientific reasoning, and evidence-based decision-making. Likewise, Seery (2020) emphasized that the primary purpose of chemistry laboratories is not merely to perform experimental procedures but to develop students' ability to think and reason like chemists through the interpretation of experimental evidence. Therefore, the strong representation of Analysis and Interpretation Skills observed in this study reflects the important role of textbook activities in supporting students' conceptual understanding and scientific reasoning.

Furthermore, Agustian (2025) noted that recent laboratory education research has shifted from verification-oriented practical work toward authentic scientific practices that engage students in interpreting evidence, evaluating data quality, and constructing scientific explanations. The emphasis on interpreting titration curves and explaining acid–base phenomena observed in the analyzed textbooks is consistent with this contemporary perspective. However, although analytical skills were strongly represented, opportunities for students to evaluate experimental limitations, identify sources of error, and justify the reliability of experimental results remained relatively limited. Providing such opportunities would further strengthen students' higher-order reasoning and inquiry competencies.

Overall, the findings demonstrate that all five categories of laboratory skills are represented in the acid–base titration materials, although their distribution is uneven. Analysis and Interpretation Skills received the greatest emphasis, whereas Safety and Laboratory Ethics Skills were represented least frequently. This imbalance suggests that the analyzed textbooks prioritize conceptual understanding and data interpretation over the development of safe laboratory practices and procedural competencies. According to Abrahams and Millar (2008), effective laboratory learning should integrate practical manipulation, observation, analysis, and conceptual understanding rather than emphasizing one component in isolation. Consequently, a more balanced representation of laboratory skill dimensions would better support the development of comprehensive laboratory competence.

Distinct characteristics were observed among the four textbooks regarding their representation

of laboratory skills. Book A primarily emphasized analysis and interpretation through explanations of titration concepts but provided relatively limited procedural guidance and safety-related content. Book B presented the most balanced distribution by integrating planning, manipulative, observation and recording, safety, and analytical skills within inquiry-oriented laboratory activities. Book C strongly emphasized data analysis and collaborative learning but lacked explicit representations of safety and laboratory ethics. In contrast, Book D provided the most comprehensive representation of manipulative skills by explaining techniques such as correct meniscus reading, repeated titrations, and the importance of experimental accuracy. These differences indicate that each textbook reflects a distinct pedagogical orientation, ranging from concept-centered learning to inquiry-based and procedural laboratory instruction. Similar variations in the representation of practical work across chemistry textbooks have also been reported by Chen and Eilks (2019), who found that textbook design and curriculum orientation substantially influence the types of laboratory competencies emphasized. Therefore, evaluating the representation of laboratory skills provides valuable insights into how textbooks support the development of students' practical competence and scientific literacy.

The observed differences in laboratory skill representation have important instructional implications. Textbooks that emphasize analytical and interpretative skills, such as Books A and C, may effectively support students' conceptual understanding and scientific reasoning. However, if these analytical activities are not accompanied by sufficient opportunities to develop manipulative and safety-related skills, students may acquire theoretical knowledge without developing the practical competencies required for effective laboratory work. Conversely, textbooks that provide balanced representations of planning, manipulative, observation, safety, and analytical skills, such as Book B, are more likely to support comprehensive laboratory competence by integrating scientific reasoning with hands-on laboratory practice.

These differences may also influence teachers' instructional decisions and students' laboratory experiences. Since textbooks often serve as the primary instructional resource in secondary chemistry education, teachers may naturally emphasize the laboratory skills most prominently represented in the selected textbook. Consequently, textbooks that underrepresent laboratory safety or planning skills may inadvertently reduce opportunities for students to develop responsible laboratory behavior, experimental design abilities, and safe working practices. Seery (2020) emphasized that chemistry laboratories should cultivate authentic scientific practices rather than focusing solely on procedural execution. Similarly, Agustian (2025) argued that contemporary laboratory education should provide balanced opportunities for students to develop technical, cognitive, and scientific reasoning competencies.

From a curriculum perspective, the findings suggest that textbook authors should strive for a more balanced representation of laboratory skills. While a strong emphasis on data analysis and interpretation supports students' scientific reasoning, equal attention should be given to planning, manipulative techniques, observation, and laboratory safety. Abrahams and Millar (2008) argued that meaningful laboratory learning emerges when students are able to integrate practical manipulation with conceptual understanding and reflective interpretation. Therefore, a balanced representation of laboratory skills would better support the development of scientifically literate students who are capable of conducting laboratory investigations safely, accurately, and critically.

This study has several limitations that should be acknowledged. First, the analysis was limited to four Grade 11 chemistry textbooks representing different curriculum frameworks and focused exclusively on acid–base titration materials. Therefore, the findings cannot be generalized to other chemistry topics or all textbooks used in secondary education. Second, the study employed qualitative content analysis to examine the representation of laboratory skills within textbook content without investigating how these representations are implemented in classroom or laboratory settings. Consequently, the findings describe the potential opportunities for laboratory skill development provided by the textbooks rather than students' actual laboratory competencies or learning outcomes. Finally, the coding framework focused on five laboratory skill dimensions; other aspects of laboratory learning, such as inquiry levels, assessment strategies, and digital laboratory resources, were beyond the scope of this study.

Future research should expand the analysis to additional chemistry topics and a broader range of textbooks representing different curricula and educational contexts. Furthermore, textbook content analysis could be complemented with classroom observations, teacher interviews, or student performance assessments to investigate how the representation of laboratory skills influences teaching practices and students' laboratory competence. Future studies may also refine and validate the laboratory skill coding

framework by incorporating additional dimensions of laboratory learning, such as inquiry processes, digital laboratory activities, and scientific argumentation.

CONCLUSION

This study addressed the research question concerning how laboratory skills are represented in Grade 11 chemistry textbooks on acid–base titration materials. The findings demonstrate that all five laboratory skill dimensions—Planning Skills, Manipulative Skills, Safety and Laboratory Ethics Skills, Observation and Recording Skills, and Analysis and Interpretation Skills—are represented across the analyzed textbooks. However, the representation is uneven, with greater emphasis placed on manipulative, observational, and analytical skills than on laboratory safety and ethics. These findings indicate that while the textbooks provide opportunities for students to develop several important laboratory competencies, they differ in the extent to which they support comprehensive laboratory learning.

The study contributes to chemistry education by providing a systematic analysis of laboratory skill representation using a qualitative content analysis framework. The findings highlight that differences in textbook design and curriculum orientation influence the balance of laboratory skills presented to students. A more balanced representation of planning, manipulative, observational, analytical, and safety-related competencies would better support inquiry-based laboratory learning, scientific literacy, and the development of authentic laboratory competence.

Despite these contributions, this study was limited to four Grade 11 chemistry textbooks and focused exclusively on acid–base titration materials. Consequently, the findings should be interpreted as representing the laboratory learning opportunities embedded within textbook content rather than actual classroom implementation or students' laboratory competence.

Future research should extend this analysis to other chemistry topics, additional textbooks representing different curricula, and different educational contexts. Furthermore, integrating textbook content analysis with classroom observations, teacher interviews, and student performance assessments would provide deeper insights into how textbook representations influence laboratory instruction and the development of students' laboratory competencies.

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AI USE STATEMENT

OpenAI's ChatGPT was utilized to support language refinement, specifically in correcting grammatical errors and improving sentence structure. It was not used to generate manuscript content, perform data analysis, interpret research findings, or draw conclusions. The authors independently carried out all research activities and are fully accountable for the accuracy and integrity of the manuscript.

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