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Aligning Chemistry Learning with Medical Laboratory Technology Vocational Competencies: A Needs and Curriculum Accommodation Analysis

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Abstract
The chemistry content provided in the Merdeka Curriculum is expected to support students' vocational competencies. However, its suitability for the learning needs of the Medical Laboratory Technology (Teknologi Laboratorium Medik/TLM) vocational program has not been systematically evaluated. This study aimed to evaluate the extent to which the chemistry contents required for the TLM program are accommodated in the learning objectives and teaching materials of the Proyek IPAS and Basic Medical Laboratory Technology (DDTLM) subjects. This study employed an evaluative research design with a qualitative approach. Data were collected through document analysis of the learning objectives and teaching materials of the Proyek IPAS, DDTLM, and Laboratory Support Services subjects, as well as semi-structured interviews with teachers. The data were analyzed using Qualitative Content Analysis (QCA) to identify the chemistry contents required for TLM vocational competencies and to evaluate their accommodation in the analyzed curriculum documents. The findings indicate that the identified chemistry contents are only partially accommodated in the Proyek IPAS and DDTLM subjects. Proyek IPAS primarily provides fundamental chemistry contents as general scientific knowledge, whereas DDTLM introduces several concepts through laboratory activities. Nevertheless, several chemistry contents relevant to laboratory procedures and clinical examinations were found to be insufficiently accommodated or presented without authentic TLM contexts. Based on these findings, a synthesis of the identified chemistry contents and their relevant TLM contexts was developed to summarize the chemistry knowledge required within the scope of the analyzed curriculum. The study concludes that the analyzed curriculum documents only partially accommodate the chemistry contents required to support learning in the TLM context. The findings provide a reference for future efforts to contextualize chemistry learning and support the development of chemistry teaching materials for the Medical Laboratory Technology program.

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INTRODUCTION

Vocational High Schools (Sekolah Menengah Kejuruan, SMK) are educational institutions designed to develop occupation-specific competencies, with the primary goal of equipping students with the knowledge and skills required to meet the demands of the workforce and industry (Ministry of Education, Culture, Research, and Technology) (Kemendikbud, 2020). These diverse occupational competencies form the basis for the national vocational education framework, which classifies vocational education into ten fields of expertise. Each field consists of several study programs, resulting in a total of 50 vocational programs and 128 areas of specializa-

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tion (Kemendikbud, 2024).

One of the vocational programs offered in SMK is Medical Laboratory Technology (*Teknologi Laboratorium Medik*, TLM) (BSKAP, 2025). The TLM program prepares students to support the profession of Medical Laboratory Technologists healthcare professionals who are competent in analyzing human body fluids and tissues to generate diagnostic information regarding individual and public health conditions (Kemnaker, 2018).

According to the Learning Outcomes (*Capaian Pembelajaran*, CP) of the Merdeka Curriculum, these competencies are developed through the Laboratory Support Services subject in Grades 11 and 12. This course requires students to understand specimen handling procedures, including the operating principles of laboratory instruments and the scientific concepts underlying laboratory testing. Achieving these competencies requires a solid foundation in the basic sciences, particularly chemistry (Scanlan, 2013). Chemistry is essential because biological specimens analyzed in medical laboratories originate from the human body, where physiological and pathological processes occur through molecular-level mechanisms (Litwack, 2017). Furthermore, various disciplines within medical laboratory science, including clinical chemistry, hematology, histopathology, and microbiology, rely extensively on chemical substances and reactions during laboratory testing. Reagents and other chemical substances are used throughout the analytical process, from reagent preparation and instrument calibration to sample analysis for diagnostic and therapeutic purposes (Baliga et al., 2025; Ping, 2023).

As a foundational subject in vocational education, chemistry plays a critical role in supporting vocational learning by providing the scientific knowledge necessary for developing occupational competencies (Wiyarsi et al., 2015). In line with this perspective, Metasari et al. (2023) identified the need to align chemistry instruction with the competency requirements of the TLM program. Their study proposed a set of chemistry learning competencies covering concept essential for TLM education, including chemical properties, personal protective equipment (PPE), chemical waste management, fundamental chemical laws and calculations, laboratory reagents, chemical principles of point-of-care testing (POCT), blood electrolytes, hydrocarbons, acid-base chemistry, buffer solutions, colloids, osmosis, organic macromolecules, and disinfectants in the context of medical laboratory examinations. These competencies served as the basis for aligning the chemistry curriculum with the Medical Laboratory Technology program under the 2013 Curriculum, when Chemistry was still taught as a separate subject.

Under the Merdeka Curriculum, however, Chemistry is no longer offered as an independent subject. According to the Learning Outcomes for Phase E, chemistry-related content is distributed across the Integrated Science Project (Proyek IPAS) and Fundamentals of Medical Laboratory Technology (*Dasar-Dasar Teknologi Laboratorium Medik*, DDTLM) courses (Kemendikdasmen, 2025). The Merdeka Curriculum also provides schools with the flexibility to develop Learning Objectives that reflect students' characteristics and the needs of specific vocational programs (Rizky et al., 2025). A preliminary document analysis conducted at the participating school revealed that the Learning Objectives for the Integrated Science Project were developed based on instructional materials emphasizing everyday-life contexts.

This condition highlights the need to examine the chemistry content and contexts required to support the competency demands of the Medical Laboratory Technology (TLM) vocational program. Furthermore, it is necessary to investigate the extent to which these chemistry content and contexts are accommodated in the Learning Objectives and teaching materials of the Proyek IPAS and Basic Medical Laboratory Technology (DDTLM) subjects in Phase E. The findings of this study are expected to provide a basis for identifying the chemistry content and contexts relevant to the competency requirements of the TLM program and to inform future efforts to contextualize chemistry learning within the Merdeka Curriculum.

METHOD

This study employed an evaluative research design with a qualitative approach. An evaluative research design is used to assess the extent to which a program, policy, or document aligns with specific criteria or identified needs (Maxwell, 2013). In this study, the evaluative design was applied to examine the extent to the required

chemistry content and contexts were accommodated in the Learning Objectives and teaching materials of the Proyek IPAS and DDTLM subjects.

The study began by identifying the chemistry content and context required for the Medical Laboratory Technology (TLM) vocational program using data obtained from semi-structured interviews with vocational teachers and document analysis of the learning objectives and teaching materials of the Laboratory Support Services subjects. The interview data and document analysis were integrated to identify and compile the chemistry content and context required to support the vocational competencies of the program.

The identified chemistry content and context were subsequently used as the evaluation criteria to examine the extent to which these content and context were accommodated in the learning objectives and teaching materials of the Proyek IPAS and Basic Medical Laboratory Technology (DDTLM) subjects. Additional interviews with the Proyek IPAS and DDTLM teachers were conducted to support the interpretation of the document analysis and the evaluation of the accommodation of the identified chemistry contents and their relevant contexts. Finally, the results of the accommodation analysis were synthesized to summarize the identified chemistry contents, their relevant TLM contexts, and their accommodation within the analyzed curriculum documents.

The research was conducted at SMK Kesehatan Rajawali, with two participants. The selected participants were considered relevant to the research objectives because they were directly involved in implementing the Merdeka Curriculum in both the Proyek IPAS subject and the TLM vocational subjects. One teacher was responsible for teaching Proyek IPAS and the Clinical Chemistry and Immunoserology concentration areas within the Laboratory Support Services subject, another teacher was responsible for teaching DDTLM, Hematology and Microbiology areas within the Laboratory Support Services subject.

Data were collected through document analysis and semi-structured interviews. The analyzed documents included the Learning Objectives (TP) and the teaching materials of the Proyek IPAS and Laboratory Support Services subject. These documents were selected because they represent the intended curriculum and the instructional content implemented in the Medical Laboratory Technology VHS. Semi-structured interviews were conducted using an interview guide designed according to the objectives of the study. Each interview lasted approximately 30–45 minutes and was audio-recorded with the participants' consent before being transcribed verbatim for analysis. The interview questions were tailored to each participant's teaching responsibilities. The interview questions were tailored to the participants' multiple teaching responsibilities. Their roles as teachers of the Laboratory Support Services concentration subjects provided information for identifying the chemistry content and context required to support TLM vocational competencies. Meanwhile, their roles as teachers of Proyek IPAS and Basic Medical Laboratory Technology (DDTLM) were used to support the interpretation of the document analysis and to evaluate the extent to which the identified chemistry content and context were accommodated in these subjects.

The data were analyzed using Qualitative Content Analysis (QCA) with an inductive category formation approach proposed by Mayring (2000, 2021; 2023). This approach was employed to identify the chemistry content and context required to support TLM vocational competencies from the learning objectives, teaching materials, and interview data. The identified chemistry content and context were subsequently used as the evaluation criteria to examine the extent to which they were accommodated in the learning objectives and teaching materials of the Proyek IPAS and Basic Medical Laboratory Technology (DDTLM) subjects. The analysis consisted of five stages: (1) determining the unit of analysis, (2) coding the data, (3) identifying the chemistry content and context, (4) evaluating the accommodation of the identified chemistry content and context, and (5) interpreting the findings.

The trustworthiness of this study was established based on the criteria proposed by Lincoln and Guba (1985), namely credibility, dependability, confirmability, and transferability. To ensure the trustworthiness of the findings, methodological and source triangulation were employed to enhance credibility, an audit trail was maintained to establish dependability,

systematic documentation of the analytical process was used to support confirmability, and thick description was provided to facilitate transferability.

Credibility was established through methodological and source triangulation. Methodological triangulation was conducted by comparing the results of document analysis with interview data, while source triangulation involved comparing information obtained from the learning objectives, teaching materials, and interviews with the participating teachers. Dependability was ensured by maintaining an audit trail that systematically documented the research process, including data collection, data analysis, and decision-making throughout the study. **Confirmability was ensured by systematically documenting the coding process, the identification of chemistry** content and context**, the accommodation analysis, and the synthesis of the findings so that the results could be traced back to the original data sources.** Transferability was enhanced through thick description by providing detailed information about the research context, participants, data sources, data collection procedures, and data analysis process.

RESULTS AND DISCUSSION

Required Chemistry Content and Contexts for the TLM VHS

The required chemistry content was identified through qualitative content analysis of the learning objectives of the Laboratory Support Services (Clinical Chemistry, Imunoserology, Hematology and Microbiology) subjects and semi-structured interviews with Laboratory Support Services teachers. As the learning objectives generally describe competencies at a broad level, the corresponding teaching materials were examined to identify the specific TLM content represented by each learning objective. The identified TLM content was subsequently examined using relevant TLM teaching materials and scientific literature to identify the underlying chemistry contexts associated with the vocational activities. The chemistry contexts were then interpreted using standard chemistry references to determine the chemistry content required to explain the underlying chemical principles. An example of the identification process is presented in Table 1.

Table 1. Example of Chemistry Contexts Identification

Unit of Analysis	TLM Content	Chemistry Context in TLM
Learning Objective: Explain the principles of chemical urinalysis for urine glucose using the Benedict method	Benedict test procedure	• Measurement of liquid volumes and transfer of reagents and specimens during laboratory examinations (Taurusita et al., 2017) • Color change resulting from the reaction between analytes and reagents in urine glucose testing benedict method (Hernández-López et al., 2020; Zhang & Chen, 2020)
	Benedict reaction principle	• Oxidation of glucose and reduction of Cu^{2+} to Cu^{+} during the Benedict test for urine glucose examination (Hernández-López et al., 2020; Zhang & Chen, 2020)
Interview with Microbiology teacher: During microbiology practical sessions, students prepare culture media and sterilize laboratory solutions. While heat-resistant materials are sterilized by autoclaving, heat-sensitive solutions, such as antibiotic solutions and certain serum-containing media, are sterilized by membrane filtration. **Learning Objective:** To explain the principles of sterilization	Types of sterilization	• Properties of materials suitable for thermal sterilization (Mohapatra, 2017; Tantular et al., 2017)
	Membrane Filtration	• Removal of contaminants from heat-sensitive solutions through membrane filtration (Tantular et al., 2017)

One example identified from the analysis was the vocational content related to the Benedict method for urine glucose examination. As described by Taurusita et al. (2017), *"In an alkaline medium, glucose reduces cupric ions to cuprous ions, producing a brick-red precipitate."* During the examination, reducing sugars containing free aldehyde or ketone groups react with copper(II) ions (Cu^{2+}) in Benedict's reagent upon heating. In this reaction, the reducing sugar is oxidized, whereas Cu^{2+} is reduced to Cu^{+}, which subsequently forms a brick-red precipitate of copper(I) oxide (Cu_2O) (Hernández-López et al., 2020; Zhang & Chen, 2020). The progressive color change of the reagent from blue to green, yellow, orange, and finally brick red reflects the extent of the redox reaction and serves as the basis for interpreting the presence of glucose in the urine sample.

Another example illustrating the chemistry content identification process is the filtration content identified from the sterilization topic. The microbiology teacher explained that students prepare culture media and sterilize laboratory solutions during practical sessions. While heat-resistant materials are sterilized using an autoclave, heat-sensitive solutions, such as antibiotic solutions and serum-containing media, are sterilized by membrane filtration (Mohapatra, 2017; Tantular et al., 2017). However, students often perform the procedure by following instructions without understanding the underlying chemical principle of filtration as a mixture separation technique. This finding was supported by the learning objective, *"To explain the principles of sterilization,"* indicating that students are expected to understand the principle of sterilization.

The identified chemistry contexts were subsequently analyzed to determine the corresponding chemistry contents required to explain the underlying chemical principles represented in each vocational context. This process involved matching each identified chemistry context with the chemistry content that best explained the observed phenomenon or laboratory activity, using relevant scientific literature. The resulting chemistry contents are presented in Table 2, that illustrates the process of identifying chemistry content from the chemistry contexts identified in TLM learning activities.

Each chemistry context was analyzed to determine the chemistry content required to explain the underlying chemical principles represented in the vocational activity.

Table 2. Example of Chemistry Content Identification

Chemistry Contexts in TLM	Chemistry Content
Measurement of liquid volumes and transfer of reagents and specimens during laboratory examinations (Taurusita et al., 2017)	Laboratory equipment techniques
Color change resulting from the reaction between analytes and reagents in urine glucose testing benedict method (Hernández-López et al., 2020; Zhang & Chen, 2020)	Chemical changes
Oxidation of glucose and reduction of Cu^{2+} to Cu^{+} during the Benedict test for urine glucose examination (Hernández-López et al., 2020; Zhang & Chen, 2020)	Oxidation-reduction reaction
Selection of sterilization methods based on the boiling point and thermal stability of laboratory reagents (Mohapatra, 2017; Tantular et al., 2017)	Physical properties

For example, the preparation and mixing of Benedict reagent and urine samples was identified as requiring the content of laboratory equipment techniques because students are expected to perform accurate handling and transfer of reagents and specimens during the examination procedure. Likewise, the color change observed during the Benedict test was identified as representing the content of chemical changes, while the oxidation of glucose and the reduction of Cu^{2+} to Cu^{+} were identified as representing oxidation–reduction reactions (Petrucci et al., 2023; Whitten et al., 2013).

Based on the content and context needs analysis, this process resulted in 19 chemistry content s required to support the competency requirements of the TLM vocational program. The identified chemistry content s included: (1) chemical properties, (2) chemical changes, (3) physical properties, (4) colloidal properties (coagulation), (5) buffer solutions, (6) centrifugation, (7) laboratory equipment techniques, (8) oxidation–reduction reactions, (9) factors affecting reaction rate (temperature), (10) spectrophotometry, (11) factors affecting reaction rate (catalysts), (12) electrochemical cells, (13) periodic properties of elements, (14)

chromatography, (15) electrolytes and nonelectrolytes, (16) types of mixtures, (17) filtration, (18) pH, and (19) osmotic pressure.

Following the identification process, chemistry contexts associated with the same chemistry content were grouped together. This grouping was conducted to consolidate similar vocational contexts represented by a common chemistry content, thereby facilitating the organization and presentation of the identified chemistry content needs. The grouped chemistry contexts are presented in Table 3.

Table 3. Chemistry Content Identification

Chemistry Context in TLM	Chemistry Content
• Observation of urine color, turbidity, odor, during macroscopic urinalysis (Taurusita et al., 2017) • Selection of sterilization methods based on the boiling point and thermal stability of laboratory reagents (Mohapatra, 2017; Tantular et al., 2017)	Physical properties
• The use of chemical reagents with corrosive, irritant, toxic, or flammable properties in medical laboratorium (Taurusita et al., 2017; Whitten et al., 2013) • Measurement of urine pH as one of the parameters in macroscopic urinalysis (Parwati et al., 2020) • Measurement and control of pH in laboratory specimens and culture media (Djasang et al., 2024)	Chemical properties
• Observation of oxygen (O_2) gas production resulting from the metabolic activity of microorganisms during the catalase test (Nuryanti et al., 2021) • Observation of clot formation in plasma resulting from the metabolic activity of microorganisms during the coagulase test (Budiyanto et al., 2021) • Protein denaturation of microorganisms during sterilization using an autoclave (Ayu, 2025) • Color change resulting from the reaction between analytes and reagents in urine glucose testing benedict method (Hernández-López et al., 2020; Zhang & Chen, 2020) • Formation of blood clots in collected blood specimens (Ramadhani, 2022)	Chemical changes
• The process of blood coagulation in blood specimens after collection (Ramadhani, 2022) • The coagulation process of plasma during the coagulase test (Budiyanto et al., 2021)	Colloidal properties (coagulation)
• Regulation of blood pH through the bicarbonate buffer system (H_2CO_3/HCO_3^-) (Petrucci et al., 2023; Whitten et al., 2013)	Buffer solutions
• Preparation of plasma, serum, and urine sediment by centrifugation based on density differences (Setyadi et al., 2021; Winata et al., 2025)	Centrifugation
• Measurement of liquid volumes and transfer of reagents and specimens during laboratory examinations (Rohmatiningsih, 2021)	Laboratory equipment techniques
• Oxidation of glucose and reduction of Cu^{2+} to Cu^+ during the Benedict test for urine glucose examination (Hernández-López et al., 2020; Zhang & Chen, 2020) • Oxidation of free cholesterol by cholesterol oxidase (CHOD) during total cholesterol determination using the CHOD–PAP method (Desiana et al., 2024) • Oxidation of glucose by glucose oxidase (GOD) during blood glucose determination using the GOD–PAP method (Riyani et al., 2024) • Oxidation of glycerol-3-phosphate by glycerol phosphate oxidase (GPO) during triglyceride determination using the GPO–PAP method (McGowan et al., 1983; Taurusita et al., 2017)	Oxidation–reduction reactions
• Effect of temperature on protein denaturation during urine protein examination (Wolz & Kulozik, 2015)	Factors affecting reaction rate (temperature)
• Measurement of analyte concentration using spectrophotometry in clinical chemistry examinations (Maharani & Eka, 2020; Taurusita et al., 2017)	Spectrophotometry
• Enzyme-catalyzed glucose oxidation during blood glucose determination using the GOD–PAP method (Cooper, 2000; Taurusita et al., 2017)	Factors affecting reaction rate (catalysts)

Chemistry Context in TLM	Chemistry Content
• Enzyme-catalyzed cholesterol oxidation during total cholesterol determination using the CHOD–PAP method (Cooper, 2000; Taurusita et al., 2017) • Enzyme-catalyzed oxidation of glycerol-3-phosphate during triglyceride determination using the GPO–PAP method (Cooper, 2000; Taurusita et al., 2017) • Enzyme-catalyzed hydrolysis of urea during urea determination using the GLDH method (Cooper, 2000; Taurusita et al., 2017) • Enzyme-catalyzed decomposition of hydrogen peroxide during the catalase test for microorganism identification (Cooper, 2000; Tantular et al., 2017)	
• Conversion of oxidation–reduction reactions into electrical current during POCT-based analyte determination (Xu et al., 2023)	Electrochemical cells
• Ion formation of electrolyte elements (Petrucci et al., 2023; Whitten et al., 2013)	Periodic properties of elements
• Capillary-driven migration of analytes and antigen–antibody complexes during immunochromatographic testing (ICT) (Koczula & Gallotta, 2016; Slieman & Leheste, 2020)	Chromatography
• Differentiation of electrolyte and non-electrolyte substances in body fluids (Shrimanker & Bhattarai, 2025)	Electrolytes and nonelectrolytes
• Classification of blood as a heterogeneous mixture consisting of blood cells suspended in plasma (Salman et al., 2024) • Classification of urine as a heterogeneous mixture based on the presence of dissolved and suspended components (Siregar & Aryayuni, 2019; Taurusita et al., 2017)	Types of mixtures
• Membrane filtration for sterilization of heat-sensitive laboratory solutions (Mohapatra, 2017; Tantular et al., 2017)	Filtration
• Effect of pH on microbial growth in culture media (Djasang et al., 2024) • Factors affecting urine pH in urinalysis (Parwati et al., 2020)	pH
• Effect of osmotic pressure on erythrocytes in hypotonic and hypertonic solutions (Lopez & Hall, 2023; Zheng et al., 2024)	Osmotic pressure

Curriculum Suitability with Chemistry Content and Context Needs

The identified chemistry contents were subsequently evaluated against the chemistry content and contexts provided in the Proyek IPAS and Dasar-Dasar Teknologi Laboratorium Medik (DDTLM) subjects. This evaluation was conducted to determine the extent to which each required chemistry content had been accommodated in the existing curriculum. The evaluation results were used to identify contents that were already accommodated and those that should be retained as additional chemistry content needs. The results of accommodation analysis are presented in Table 4.

Table 4. Accommodation Analysis of the Identified Chemistry Content Needs in Proyek IPAS and DDTLM

Chemistry Content	Proyek IPAS		DDTLM		Decision
	Content	Context	Content	Context	
Physical properties	✓	-	-	-	Retain
Chemical properties	✓	-	-	-	Retain
Chemical changes	✓	-	-	-	Retain
Colloidal properties (coagulation)	-	-	-	-	Retain
Buffer solutions	-	-	-	-	Retain
Centrifugation	✓	-	✓	✓	Exclude
Laboratory equipment techniques	✓	✓	✓	✓	Exclude
Oxidation–reduction reactions	-	-	-	-	Retain
Factors affecting reaction rate (temperature)	-	-	-	-	Retain
Spectrophotometry	-	-	✓	✓	Exclude
Factors affecting reaction rate (catalysts)	-	-	-	-	Retain
Electrochemical cells	-	-	-	-	Retain

Chemistry Content	Proyek IPAS		DDTLM		Decision
	Content	Context	Content	Context	
Periodic properties of elements	-	-	-	-	Retain
Chromatography	✓	-	-	-	Retain
Electrolytes and nonelectrolytes	✓	-	-	-	Retain
Types of mixtures	✓	-	-	-	Retain
Filtration	✓	-	✓	✓	Exclude
Ph	-	-	-	-	Retain
Osmotic pressure	-	-	-	-	Retain

Based on the accommodation analysis, several chemistry content needs identified as relevant to TLM competencies were found to be accommodated in both Proyek IPAS and DDTLM. However, the accommodation of these contents varies in terms of scope, depth, and learning objectives. Some contents demonstrate conceptual continuity, in which Proyek IPAS provides foundational chemistry content, while DDTLM extends these contents into vocational laboratory contexts.

One example of this overlapping content is centrifugation. Interview findings indicated that Proyek IPAS emphasizes conceptual understanding, whereas DDTLM reinforces the content through practical application to support students' vocational competencies. In Proyek IPAS, centrifugation is introduced within the topic of mixture separation methods, focusing on the scientific principle of separating mixtures based on centrifugal force. This explanation provides students with a fundamental understanding of why centrifugation can be used as a separation technique. Meanwhile, DDTLM presents the content of centrifugation in relation to laboratory practices by explaining the operation and application of centrifuges in medical laboratory procedures. However, the presence of overlapping contents also highlights the importance of ensuring continuity between the two subjects so that foundational contents introduced in Proyek IPAS can effectively support students' understanding of vocational laboratory competencies.

While some chemistry contents demonstrate continuity between Proyek IPAS and DDTLM, several contents were accommodated only at the general chemistry level without sufficient connection to TLM applications. These contents included physical properties, chemical properties, chemical changes, chromatography, electrolytes and nonelectrolytes, and types of mixtures. Although these contents were introduced in Proyek IPAS, they were mainly presented as general chemistry knowledge and were not contextualized within authentic TLM settings. Consequently, students may understand the fundamental contents but have limited opportunities to relate them to laboratory procedures and clinical specimen analysis encountered in the TLM program.

In contrast, several chemistry contents, including oxidation–reduction reactions, buffer solutions, colloidal properties, factors affecting reaction rate, electrochemical cells, periodic properties of elements, and pH, were not accommodated in either the chemistry content or the vocational contexts of Proyek IPAS and DDTLM. Nevertheless, these contents were identified as essential through the content analysis of vocational subjects and interviews with vocational teachers because they are required to explain the chemical principles underlying laboratory examinations in medical laboratory. Therefore, these contents were retained as chemistry content needs despite their absence from the existing curriculum. The decision to retain these contents was based on their necessity for explaining laboratory phenomena and analytical principles encountered in TLM learning, rather than merely supporting laboratory procedures.

The results indicate that the limitation of the existing curriculum is not merely related to the absence of chemistry contents, but also to the limited integration of authentic vocational contexts in which these contents are applied. Several chemistry contents are introduced in Proyek IPAS as general scientific knowledge. However, they are not contextualized within Medical Laboratory Technology practices. This condition may reduce the relevance of chemistry learning for vocational students, as they have limited opportunities to understand how these

contents support laboratory procedures and clinical analyses in the TLM field.

Chemistry Content and Context Framework

Based on the findings of the accommodation analysis, the identified chemistry contents and their relevant Medical Laboratory Technology (TLM) contexts were compiled into a single framework to provide a comprehensive overview of the chemistry knowledge required in the TLM program. The framework is presented in Table 5.

Table 5. Chemistry Content and Context Framework

Chemistry Content	Chemistry Contexts in TLM
Physical properties	• Observation of urine color, turbidity, odor, during macroscopic urinalysis (Taurusita et al., 2017) • Selection of sterilization methods based on the boiling point and thermal stability of laboratory reagents (Mohapatra, 2017; Tantular et al., 2017)
Chemical properties	• The use of chemical reagents with corrosive, irritant, toxic, or flammable properties in medical laboratorium (Taurusita et al., 2017; Whitten et al., 2013) • Measurement of urine pH as one of the parameters in macroscopic urinalysis (Parwati et al., 2020) • Measurement and control of pH in laboratory specimens and culture media (Djasang et al., 2024)
Chemical changes	• Observation of oxygen (O_2) gas production resulting from the metabolic activity of microorganisms during the catalase test (Nuryanti et al., 2021) • Observation of clot formation in plasma resulting from the metabolic activity of microorganisms during the coagulase test (Budiyanto et al., 2021) • Protein denaturation of microorganisms during sterilization using an autoclave (Ayu, 2025) • Color change resulting from the reaction between analytes and reagents in urine glucose testing benedict method (Hernández-López et al., 2020; Zhang & Chen, 2020) • Formation of blood clots in collected blood specimens (Ramadhani, 2022)
Colloidal properties (coagulation)	• The process of blood coagulation in blood specimens after collection (Ramadhani, 2022) • The coagulation process of plasma during the coagulase test (Budiyanto et al., 2021)
Buffer solutions	• Regulation of blood pH through the bicarbonate buffer system (H_2CO_3/HCO_3^-) (Petrucci et al., 2023; Whitten et al., 2013)
Oxidation–reduction reactions	• Oxidation of glucose and reduction of Cu^{2+} to Cu^+ during the Benedict test for urine glucose examination (Hernández-López et al., 2020; Zhang & Chen, 2020) • Oxidation of free cholesterol by cholesterol oxidase (CHOD) during total cholesterol determination using the CHOD–PAP method (Desiana et al., 2024) • Oxidation of glucose by glucose oxidase (GOD) during blood glucose determination using the GOD–PAP method (Riyani et al., 2024) • Oxidation of glycerol-3-phosphate by glycerol phosphate oxidase (GPO) during triglyceride determination using the GPO–PAP method (McGowan et al., 1983; Taurusita et al., 2017)
Factors affecting reaction rate (temperature)	• Effect of temperature on protein denaturation during urine protein examination (Wolz & Kulozik, 2015)
Factors affecting reaction rate (catalysts)	• Enzyme-catalyzed glucose oxidation during blood glucose determination using the GOD–PAP method (Cooper, 2000; Taurusita et al., 2017) • Enzyme-catalyzed cholesterol oxidation during total cholesterol determination using the CHOD–PAP method (Cooper, 2000; Taurusita et al., 2017) • Enzyme-catalyzed oxidation of glycerol-3-phosphate during triglyceride determination using the GPO–PAP method (Cooper, 2000; Taurusita et al., 2017) • Enzyme-catalyzed hydrolysis of urea during urea determination using the GLDH method (Cooper, 2000; Taurusita et al., 2017) • Enzyme-catalyzed decomposition of hydrogen peroxide during the catalase test for microorganism identification (Cooper, 2000; Tantular et al., 2017)

Chemistry Content	Chemistry Contexts in TLM
Electrochemical cells	• Conversion of oxidation–reduction reactions into electrical current during POCT-based analyte determination (Xu et al., 2023)
Periodic properties of elements	• Ion formation of electrolyte elements (Petrucci et al., 2023; Whitten et al., 2013)
Chromatography	• Capillary-driven migration of analytes and antigen–antibody complexes during immunochromatographic testing (ICT) (Koczula & Gallotta, 2016; Slieman & Leheste, 2020)
Electrolytes and nonelectrolytes	• Differentiation of electrolyte and non-electrolyte substances in body fluids (Shrimanker & Bhattarai, 2025)
Types of mixtures	• Classification of blood as a heterogeneous mixture consisting of blood cells suspended in plasma (Salman et al., 2024) • Classification of urine as a heterogeneous mixture based on the presence of dissolved and suspended components (Siregar & Aryayuni, 2019; Taurusita et al., 2017)
pH	• Effect of pH on microbial growth in culture media (Djasang et al., 2024) • Factors affecting urine pH in urinalysis (Parwati et al., 2020)
Osmotic pressure	• Effect of osmotic pressure on erythrocytes in hypotonic and hypertonic solutions (Lopez & Hall, 2023; Zheng et al., 2024)

CONCLUSION

Based on the findings of this study, it can be concluded that the chemistry contents required to support learning in the Medical Laboratory Technology (TLM) context were only partially accommodated in the Proyek IPAS and Basic Medical Laboratory Technology (DDTLM) curriculum documents analyzed. While several chemistry contents were identified in both subjects, many were presented as general scientific knowledge or procedural laboratory skills without sufficient integration into authentic TLM contexts. In addition, several chemistry contents relevant to laboratory procedures and clinical examinations were identified as insufficiently accommodated. Based on these findings, a chemistry content and context framework was synthesized to summarize the chemistry contents and their relevant TLM applications identified within the scope of this study.

RECOMMENDATION

Future research is needed because the Learning Outcomes (CP) for the TLM VHS do not explicitly describe the detailed competencies content required to support those competencies. Consequently, the combination of vocational subjects offered by TLM programs may vary among vocational schools. So, additional needs assessments involving a wider range of TLM vocational schools are necessary.

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