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Application of 4STMD Method in Developing Colloid Chemistry Materials for Agricultural Product Processing Vocational Schools

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Abstract: *Chemistry learning in Vocational High Schools (SMK), particularly in the Agribusiness Processing of Agricultural Products (APHP) expertise program, has not been fully integrated with vocational contexts, leading to students' low motivation and limited understanding of chemistry concepts. This study aims to develop a contextual chemistry learning module on colloidal systems using the Four Steps Teaching Material Development (4S-TMD) method. The research employed a Research and Development (R&D) approach following the DDE model (Design, Develop, Evaluate). The process included the design and initial development phases, namely selection and structuring stages. The selection phase resulted in five competency achievement indicators and ten concept labels compiled from 14 reference sources. The structuring phase produced a concept map, macro structure, and multi-level representations (macroscopic, sub-microscopic, and symbolic), all designed to enhance students' comprehensive understanding. The developed module shows potential in improving the relevance of chemistry instruction to vocational practices in SMK. Further research is recommended to proceed with the characterization and didactic reduction stages to optimize the readability and accessibility of the learning materials.*

Keywords: *chemistry module; 4S-TMD; colloidal systems; vocational education; contextual learning*

INTRODUCTION

Teaching materials play a critical role in enhancing the effectiveness of learning processes. As learning media, they support teachers in delivering content and serve as internal motivators for students to engage in independent study (Aisah et al., 2020). Teaching materials are generally categorised into printed and non-printed formats. The diverse use of such materials aims to provide varied and engaging learning experiences, which in turn make the learning process more meaningful and effective (Susilaningsih et al., 2019). One of the most widely used printed teaching materials is the module. Modules are systematically developed based on the curriculum and equipped with learning instructions that support self-directed learning. In the context of chemistry education, modules function as supplementary learning resources that help students understand material independently. Moreover, their use promotes a pedagogical shift from teacher-centered to student-centered approaches, thereby encouraging learner autonomy (Andriani & Ayu Dewi, 2019; Nalarita & Listiawan, 2018) This shift also fosters critical thinking and greater student engagement with the subject matter.

Vocational High School (SMK) is an educational institution that aims to equip students with the knowledge and skills needed in life (Afinda et al., 2023; Haryani et al., 2021). Learning that takes place effectively will support the creation of graduates who are competent and ready to face the world of work. One of the supporting facilities in the learning process is the use of teaching materials, which play an important role in supporting the smooth running of learning activities (Haryani et al., 2022)

Chemistry is one of the core subjects taught in SMKs, including within the Agribusiness of Agricultural Product Processing's (APHP) expertise competency (Kusnandar, 2019). Chemistry learning resources must be adapted to vocational contexts to ensure they align with the needs and professional realities of students. Integrating chemistry with productive vocational subjects allows learners to apply theoretical knowledge in practical settings, thereby enhancing competency development (Ariyani et al., 2020; Haryani et al., 2021)).

However, current chemistry instruction in SMKs often mirrors the general high school (SMA) model, lacking vocational contextualisation that aligns with students' specific skill areas. Observations conducted in several SMKs in Semarang, including SMK Negeri Jawa Tengah, SMK Negeri 3, SMK Negeri 4, SMK Negeri 8, SMK Muhammadiyah 2, and SMK Texmaco, revealed that instructional materials fail to reflect the vocational context. One of the major issues is the absence of learning resources that link chemistry concepts to practical work-based competencies (Herlina et al., 2023).

This lack of context negatively impacts students' motivation. Chemistry is frequently perceived as difficult and irrelevant, leading to disengagement and suboptimal academic performance. Many students fail to see the relevance of chemistry in their future professional activities, further reinforcing negative attitudes toward the subject (Haryani et al., 2022)

One key topic in the APHP expertise competency is the colloid system. According to interviews with chemistry and productive subject teachers, relevant materials include types of colloids, their properties, and manufacturing processes. These topics are vital when linked to vocational applications such as food processing, coagulation techniques, and emulsification processes. The relevance of colloids in improving product stability and quality underscores the need to integrate these concepts with hands-on vocational practice.

Nevertheless, the chemistry textbooks currently used in SMKs still fall short of meeting vocational requirements. They lack relevance to real-world applications in APHP, necessitating the development of materials that align with industrial needs. Such materials must also fulfil academic quality standards in language, presentation, content, and graphic design, ensuring clarity and appeal for learners.

We have applied several instructional design models to develop teaching materials. The ADDIE model (Analysis, Design, Development, Implementation, Evaluation) by Reiser and Mollenda is widely used in instructional design but does not specifically target material development. Thiagarajan's 4D model (Define, Design, Develop, Disseminate) is commonly adopted in educational R&D but lacks detailed procedural guidance for preparing independent teaching materials. In contrast, the Four Steps Teaching Material Development (4S-TMD) model developed by Sjaeful Anwar consists of four systematic stages: Selection, Structuring, Characterisation, and Reduction. This model offers detailed procedures specifically aimed at creating effective, contextualised, and autonomous teaching materials suitable for vocational education settings.

Based on the aforementioned issues, it is essential to develop relevant chemistry teaching materials that support students in the Agribusiness Expertise Competency of

Agricultural Product Processing (APHP). We expect these materials to enhance students' chemistry understanding through practical and contextual applications. Therefore, this study aims to develop a contextual colloid module for SMK APHP using the Four Steps Teaching Material Development (4S-TMD) model

LITERATURE REVIEW

Teaching Materials and Their Characteristics

Good teaching materials are those that pay attention to quality in terms of content, language, graphic elements, illustrations, and development methods (Susilaningsih et al., 2019) According to the module writing guidelines issued by the Directorate of Vocational High School, Directorate General of Primary and Secondary Education, Ministry of National Education in 2003, teaching materials have several characteristics: self-instructional, self-contained, stand-alone, adaptive, and user-friendly (Yuberti, 2024)

Five characteristics of teaching materials according to (Yuberti, 2024) (1) Self-instructional: Teaching materials enable students to learn independently with clearly defined objectives and content organized into specific units. (2) Self-contained: all content for a single competency unit is fully presented within one teaching material. (3) Stand-alone: Users can utilize the material independently, eliminating the need for other teaching resources. This independence allows educators to implement the material in various settings, catering to different learning styles and paces. As a result, students can engage with the content at their convenience, fostering a more personalized educational experience. (4) Adaptive: the material can adapt to developments in science and technology. (5) User-friendly: easy to use and understand, providing information in a helpful and accessible manner. This ensures that learners can engage with the material effectively, enhancing their educational experience. By incorporating features that promote interactivity and ease of navigation, these teaching materials can significantly improve knowledge retention and comprehension.

The 4STMD Method

According to Anwar (2023) the 4STMD (Four Step Teaching Material Development) teaching material development method is a method that can, in detail, guide how the stages of developing teaching materials should be carried out..

The selection step of teaching materials is the process of selecting information that is in accordance with the curriculum and student needs. The main criteria include conformity to the curriculum, scientific truth, and development of the material context (substance and pedagogical). Selection steps include: (a) Determining indicators and concepts based on basic competencies. (b) Developing material from concepts with reliable sources. (c) Adjusting the context of the material to the characteristics and environment of the students.

The structuralization stage is the preparation of teaching materials logically and scientifically based on the right order. This process involves organizing content in a way that enhances understanding and retention for students. By aligning the materials with educational objectives, instructors can create a more effective learning environment. The goal is that learning does not occur partially between concepts. We structure the material by organizing it into three forms: concept maps, macro structures, and three levels of text representation.

The characterization stage is the process of identifying the level of difficulty of each concept or text in the teaching materials, from easy (concrete, simple) to difficult (abstract, complex). The didactic principles used include teaching from simple to complex, near to far, and concrete to abstract. This characterization allows for the adjustment of teaching materials to enhance student understanding.

The didactic reduction stage is the process of qualitatively and quantitatively simplifying teaching materials to suit the level of student understanding. The aim is to make the material easier to understand without losing the core meaning. Several methods are used: (a) Qualitative presentation: Replacing complex data with simple explanations. (b) Ignorance: Simplifying complex concepts, such as Dalton's atomic model. (c) Visual media: Using images, animations, videos, and simulations to aid understanding. (d) Analogy: Likening difficult concepts to things students are already familiar with.

Based on the aforementioned background, it is assumed that the contextual colloid module developed using the 4S-TMD model will meet the eligibility criteria for chemistry learning materials in accordance with the APHP vocational context and will enhance students' understanding and motivation to learn independently. With a direct linkage between colloid concepts and vocational practices, this module is expected to serve as an effective and relevant learning medium to support the achievement of vocational high school students' competencies.

METHODS

The study involved students from a vocational high school (SMK APHP) in Bandung, specializing in the agribusiness processing of agricultural products. It aimed to evaluate effective teaching methods to enhance students' understanding and skills in agricultural product processing through practical, hands-on learning. The research used the Development Research (DR) method based on Richey and Klein (2014), following the DDE framework: Design, Develop, and Evaluate. The development of chemistry teaching modules uses the Four Steps Teaching Material Development (4 STMD) method described by Anwar (2023). The following is the DR method associated with the steps for developing teaching materials using the 4STMD method, as shown in Figure 3.1.

Design step

Based on Figure 3.1, the design stage involves planning teaching materials tailored to learning objectives. This process begins with selecting appropriate topics, followed by analysing the curriculum and learning needs using textbooks. Curriculum analysis includes identifying the key skills that students must possess in accordance with the APHP vocational school curriculum, setting learning objectives for colloid system materials, and determining the main points of the material to be delivered based on these objectives.

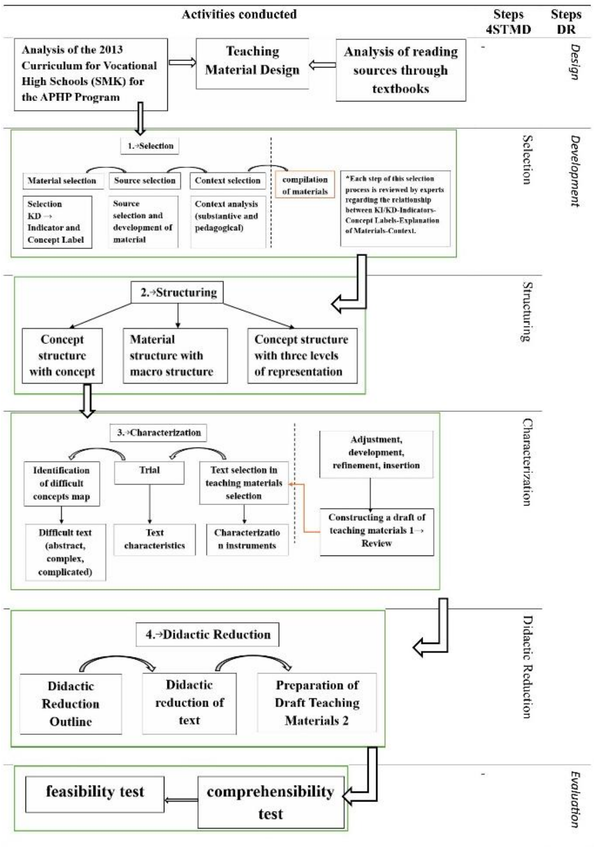

Figure 3.1. Research flow chart

Development step

The development step in the 4STMD method consists of four interrelated sequential stages. The first stage is selection, which includes the development of indicators and concept labels, development of material from concept labels, and contextual development. The final output of this stage is a collection of materials developed based on relevant concepts and contextual analysis. The structuring stage involves compiling concept maps, determining the macro structure, and selecting three levels of representation macroscopic, microscopic, and symbolic that facilitate meaningful learning. The information gathered is then reviewed by experts and compiled into the first draft of the teaching material. The third stage is characterisation, which is the process of identifying parts of the text that are difficult for students to understand using a characterisation instrument. This analysis also includes identifying the nature of the concepts—whether they are abstract, complex, or intricate. The final stage is didactic reduction, which refers to the simplification of the material both qualitatively and quantitatively to improve student comprehension. Strategies used include the use of analogies, visuals, experiments, and historical concept development. The final result of all these stages is teaching material that is easier to understand and aligned with the characteristics of vocational students.

Evaluation step

The evaluation stage involves assessing the feasibility of the developed teaching materials and testing their comprehensibility. We conduct the comprehensibility test using a comprehension test instrument to gauge the students' understanding of the developed teaching materials. The feasibility assessment is carried out based on the BSNP (National Education Standards Agency) guidelines for teaching material standards, which include content feasibility, language use, presentation, and visual design.

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Data Analysis

The instrumental analysis of the selection stage was carried out by descriptively presenting the results of the chemistry lecturer's review regarding the alignment of the basic competencies with the developed learning indicators, as well as the alignment of the indicators with the concept labels. In addition, the validation of the selection stage was also conducted to assess the consistency between the concept labels and the content, as well as the relevance of the content to the context (whether substantive or pedagogical). Any parts requiring revision were adjusted based on input from the chemistry lecturer. The assessment instrument used in the selection stage is shown in Figure 3.2.

No	Concept Label	Concept/Material Description (UK)	LK's compatibility with the UK		Suggestions for Improvement
			Yes	No	

Figure 3.2. Table Review of the Validity of the Concept

The instrumental analysis of the structuring stage included the validation of the concept map, macrostructure, and the three levels of representation. The results of this analysis were used as input to improve the concept map, macrostructure, and the three levels of representation that were still considered unsuitable based on the chemistry lecturer's review.

RESULT AND DISCUSSION

The design phase concentrated on creating chemistry instructional materials tailored to the contextual learning requirements of vocational high school students specializing in agribusiness or agricultural product processing (APHP). The procedure commenced with the identification of pertinent themes, succeeded by a study of curriculum and learning requirements grounded in conventional chemistry textbooks. The curriculum analysis sought to identify the requisite abilities students must attain per the vocational curriculum, establish learning objectives for the colloidal system topic, and ascertain critical content points that facilitate the attainment of these competencies. We subsequently conducted a requirements analysis to identify any discrepancies between students' prior knowledge and the anticipated learning objectives (Sönmez, 2019) The findings of this research informed the selection of content, the design of the syllabus, and the identification of suitable teaching methods and approaches (Haque, 2014)

The chemical content created at this level is based on updated Basic Competencies (KD) that have been adjusted to meet the needs of the agricultural industry. The primary emphasis was on integrating fundamental chemistry principles with vocational practices to create relevant and practical learning experiences. This technique aims to combine theoretical concepts with practical abilities, facilitating students' comprehension of the direct relationship between chemistry and agricultural product processing. We anticipate that the educational design will comprehensively facilitate both academic success and vocational skill enhancement. Table 4.1 illustrates the comprehensive structure of the formulated chemistry content.

Tabel 4.1. Composition of chemistry content taught in SMK Agribusiness Processing of Agricultural Products

Code	Chemistry content	Relevant productive subjects
Kim 1	Chemicals contained in fruits and physical and chemical quality of fruits	2 KD in PPHN
Kim 2	Chemicals contained in vegetables and the physical and chemical quality of vegetables	2 KD in PPHN
Kim 3	Chemicals contained in tubers and the physical and chemical quality of tubers	2 KD in PPHN
Kim 4	Chemicals contained in beans and the physical and chemical quality of beans	2 KD in PPHN
Kim 5	Physical and chemical properties of ingredients contained in chicken eggs and chemical principles in chicken egg processing	2 KD in PPHH
Kim 6	Chemicals contained in chicken eggshell waste. and reutilization of eggshells with chemical principles	2 KD in PPHH
Kim 7	Chemicals contained in herbal foods, chemical principles in the processing of herbal food products, and production of herbal foods with chemical principles.	2 KD in PPKPH
Kim8	Chemicals contained in herbal drinks, chemical principles in the processing of herbal drink products, and production of herbal drinks with chemical principles	2 KD in PPKPH
Kim 9	Chemical and physical properties of foodstuffs to be tested or sampled and plan for sampling of foodstuffs.	2 KD in KPPP
Kim 10	Pesticide chemical content and control of pests, sugar diseases in crops	2 KD in KPPP

Table 4.1 illustrates a comprehensive alignment between chemistry content and vocational subjects in the Agribusiness of Agricultural Product Processing specialization at vocational high schools (SMK). The content units (Kim 1–Kim 10) are thoughtfully structured to embed fundamental chemical principles within practical vocational contexts, such as the processing of fruits, vegetables, tubers, legumes, animal-derived products, herbal ingredients, along with key areas of food safety, warehousing, and pest management. This structure facilitates a balanced integration of chemistry

across multiple Basic Competencies (KD), equipping students with the ability to apply theoretical chemical knowledge in hands-on settings. Embedding chemistry into these vocational courses strengthens interdisciplinary connections and deepens both conceptual understanding and procedural skills, thus reinforcing the relevance of chemistry in vocational learning.

The chemistry content, developed based on the updated competencies proposed by (Adji et al., 2024) has been affirmed as suitable for supporting skill development in the agribusiness sector. By integrating chemistry with vocational content, this strategy helps bridge the divide between theoretical science education and its practical applications, while also responding to the commonly reported lack of perceived relevance of chemistry among vocational students (Haryani et al., 2022) The mapping also fosters synergy between adaptive subjects that focus on scientific theory and productive subjects that emphasize applied skills, offering a solid framework for developing contextual learning resources that align with industry demands. These insights echo the conclusions drawn by (Wahyuni et al., 2021), who found that contextualized chemistry instruction has a positive impact on student engagement and competency development in vocational education.

The researcher conducted a comprehensive mapping of essential chemical substances used in the processing of agricultural and livestock products, including their types, characteristics, and relevant chemical principles in food and beverage processing. The results of this mapping indicate that colloidal principles—such as emulsions, suspensions, and gels—are extensively applied in vocational practices, particularly in the processing of horticultural products, animal-based products, and plantation and herbal commodities. These colloidal interactions significantly influence product quality, safety, and nutritional value, making them crucial content for students in vocational schools specializing in Agribusiness of Agricultural Product Processing.

Furthermore, the integration of colloidal content is clearly reflected in the Basic Competencies (KD) of various productive subjects, including PPHN, PPHH, PPKPH, and KPPP, as presented in Table 4.1. Given the strong contextual relevance, the researcher selected colloidal systems as the primary topic for developing chemistry teaching materials. The development process adopted the *Four Steps Teaching Material Development (4S-TMD)* model, aiming to contextualize chemical concepts within real-world agribusiness practices. This approach is intended to enhance students' applied competencies and bridge the gap between theoretical understanding and vocational application, in line with the objectives of contextual and meaningful learning in vocational chemical education.

Using the Four Steps Teaching Material Development (4S TMD) method, the selection stage for teaching materials on colloidal systems within the context of agricultural product processing begins with a thorough review of the 2013 Curriculum, particularly the relevant Core Competencies (KI) and Basic Competencies (KD). This ensures alignment between the teaching materials and the intended learning outcomes, while also supporting students' conceptual understanding of colloidal systems.

The selected content refers specifically to KD 3.10 and KD 4.10 for Grade X, which require students to analyze the formation of various colloidal systems using materials commonly encountered in daily life. Based on these competencies, the researchers developed a series of Competency Achievement Indicators (GPA) to guide the formulation of concept labels within the instructional materials.

Table 4.2 presents a detailed mapping of these indicators, outlining the relationship between the KD, the expected learning outcomes, and the relevant colloidal concepts**.** This mapping serves as the foundation for the next stages of teaching material development, ensuring that the content is both pedagogically sound and contextually appropriate for vocational chemistry education in the field of agribusiness.

During the teaching material review phase, the supervisor identified and evaluated four indicators for Basic Competency (KD) 3.10 and one indicator for KD 4.10, as outlined in Table 4.2

Tabel 4.2. Development of indicators and concept labels

Basic Competency (KD)	Competency Achievement Indicator (GPA)	Concept Label (LK)
3.10 Analyze the preparation of various colloidal systems with materials around us	3.10.1 Classify solutions, suspensions, and colloids	Differences in solutions, suspensions, and colloids
	3.10.2 Classify colloids based on dispersing and dispersed phases	Types of colloids
	3.10.3 Explain the properties of colloids	Adsorption Coagulation Tyndall effect Lyophobic colloids Lyophile colloids Emulsification
	3.10.4 Explain how colloids are made	How to make colloids by dispersion method How to make colloids by condensation method
4.10 Develop the manufacture of various colloidal systems with materials around us	4.10.1 Processing agricultural products into food products	Types of colloids

This evaluation aimed to ensure coherence between the basic competencies and the competency achievement indicators, aligning them with the learning objectives for colloidal systems in vocational chemistry education. One of the supervisor's review results is illustrated in Figure 4.1, which includes several suggestions and revisions for Indicator 3.10.3 concerning the properties of colloids. Based on this review process, the researcher then formulated concept labels that represent the core ideas of each indicator, to serve as the foundation for developing relevant and contextual teaching materials.

No	Basic Competencies (KD)	Competency Achievement Indicators (GPA)	KD's Suitability with GPA		Suggestion
			Yes	No	
1	3.10. Analyze the manufacture of various colloidal systems with the materials that are around us	3.10.1 Classifying solutions, suspensions, and colloids	√		
		3.10.2 Classifying colloids by dispersing and dispersing phases	√		
		3.10.3 Explains the properties of the colloidal	√		Describe the properties associated with the processing of agricultural products

Figure 3.2. Table Review of KD's Suitability with GPA

The next step in developing teaching materials is to create resources based on concept labels that have passed the assessment stage. To explain each concept label, various relevant reference sources were collected during the process of preparing teaching materials, especially regarding colloidal systems. The concept labels were then defined and explained using textbook content, resulting in a relevant and in-depth learning resource on colloidal systems.

The sources referenced in this study include high school and vocational chemistry textbooks, internationally recognized texts such as *Principles of Colloid and Surface Chemistry* by Paul C. Hiemenz and Raj Rajagopalan (1997), as well as books on food science. These sources serve to explain the concept labels, which are then summarized into fundamental ideas that form the foundation of the material development. According to Anwar S. (2023), each concept should be compared with textbook content to maintain scientific validity. As these references are widely used internationally, they are deemed suitable as primary sources for developing instructional materials. Table 4.4 presents an example of the results of developing sample concept explanations derived from textbooks. These explanations are designed to clarify complex ideas in a way that is accessible to students, ensuring that the teaching materials are both informative and engaging. By utilizing these foundational concepts, educators can create a curriculum that is grounded in established research and provides a solid framework for student learning.

Tabel 4.4. Development of Concept/Material Description

Concept Label (LK)	Description of Concept/Material	Source
Differences in solutions, suspensions, and colloids	Teks Asli *Some substances appear to initially dissolve in a solvent, but over time, the substance separates from the pure solvent. For example, finely divided clay particles dispersed in water eventually settle out because of gravity. Gravity affects the clay particles because they are much larger than most molecules, consisting of thousands or even millions of atoms. In contrast, the dispersed particles in a true solution (ions in a salt solution or glu- cose molecules in a sugar solution) are small. Between these extremes lie dispersed par- ticles that are larger than typical molecules but not so large that the components of the mixture separate under the influence of gravity. These intermediate types of dispersions are called either colloidal dispersions or simply colloids. Colloids form the dividing line between solutions and heterogeneous mixtures. Particle size can be used to classify a mixture as colloid or solution. Colloid particles range in diameter from 5 to 1000 nm; solute particles are smaller than 5 nm in diameter.*	Brown, L.T. (2020). *Chemistry the Central Science 14th Edition*. United States: Pearson

The development of teaching materials in the selection stage, using the Four Steps Teaching Material Development (4S TMD) method, involves identifying relevant content and appropriate learning contexts, particularly for the topic of colloidal systems. Evaluation of the material's depth and scope ensures alignment between chemical concepts and real-world applications. The substance context plays a crucial role in connecting the content with everyday phenomena, allowing students to better understand colloidal concepts through familiar situations. This approach enhances student engagement and deepens conceptual understanding.

In addition, the application of varied pedagogical strategies aims to accommodate different learning styles and foster critical thinking skills, enabling students to appreciate the practical relevance of colloidal systems (Anwar, 2023). This approach is supported by (Harahap & Roza, 2020) who developed a chemistry module based on Pedagogical Content Knowledge (PCK). Their study showed that modules structured with appropriate pedagogical design—through illustrations, examples, and structured content—significantly improved students' learning outcomes, with a gain score of 0.80, categorized as high. The module also included real-life phenomena, making the material more meaningful and accessible to students. This aligns with the integration of substance and pedagogical contexts as illustrated in Table 4.5, which aim to support students' conceptual comprehension in a relevant and engaging manner.

The effectiveness of contextual integration in chemistry learning is supported by several previous studies (Widodo, 2017) found that applying a contextual approach to electrochemistry materials improved both motivation and academic performance among vocational high school students by aligning the content with their field of expertise. Similarly (Wiyarsi et al., 2020) reported that

Context-Based Learning (CBL) enhances students' chemical literacy and scientific attitudes through real-life cases. In line with this, (Afrida & Sinaga, 2019) demonstrated that contextual teaching materials significantly improved student learning outcomes (gain = 0.71). Furthermore, (Nainggolan et al., 2019) showed that a project-based practicum guide incorporating real-life contexts effectively enhanced cognitive, psychomotor, and affective domains. Together, these findings emphasize that integrating both substance and pedagogical contexts into teaching materials is a key strategy for making chemistry learning more meaningful and relevant, especially in vocational education settings.

Tabel 4.5. Substance Context Related to Concept/Matter

Description of Material	Substantial Context	Substance Context Development Description
Colloids A colloid is a type of mixture where very small particles (5–1000 nm) are evenly dispersed in another substance. These particles are larger than those in a solution but small enough that they don't settle quickly. Colloids scatter light, which makes them appear cloudy or opaque, and they remain stable without forming sediment.	 Gambar susu Sumber: https://res.cloudinary.com	Did you know there's one drink almost everyone has enjoyed since they were babies? Yes, it's milk! Loved by all ages for its great taste and rich nutrients—like fat, protein, vitamins, and minerals—milk is also fascinating from a scientific view. It's a type of colloid, specifically an emulsion. Proteins and phospholipids in milk act as stabilizers to keep the fat evenly dispersed. Its tiny particles (1–100 nm) stay suspended in the liquid, which is why milk has a smooth texture and doesn't easily separate.

In the structuralization step of creating learning materials, the goal is to help students understand content more easily by organizing concepts systematically. A concept map is developed to illustrate the relationships between macro- and micro-concepts in colloidal system material, allowing students to see how ideas are connected and structured. This breakdown helps learners grasp complex topics by building knowledge step by step. Additionally, three levels of representation—macroscopic, submicroscopic, and symbolic—are included to deepen understanding. This approach supports the development of a strong cognitive framework, enabling students to absorb new material more effectively.

Concept maps are effective tools for connecting ideas and improving memory retention (Setyaputri & Destya, 2022) These visual representations help individuals organize information in a way that highlights relationships between concepts, making it easier to recall and apply knowledge. By structuring information visually, learners can enhance their understanding and facilitate deeper learning experiences. They also enhance critical thinking by helping students visualize relationships between concepts. The maps are structured with general concepts at the top, followed by specific concepts linked through connecting words to form clear propositions. This layout helps clarify meaning and supports deeper understanding. Concepts are placed in rectangular boxes, with connecting words positioned along the linking lines. The concept map is arranged as a network tree, starting from the main concept of colloidal systems. This approach promotes meaningful learning and strengthens long-term memory retention (Anwar, 2023). The completed concept map was reviewed by two assessors and is presented in Figure 4.3.

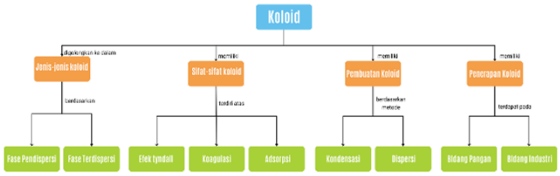


Figure 4.3. Concept map of colloid system material for APHP vocational school students

The macro structure aims to facilitate understanding of teaching materials by organizing the material as a whole based on two dimensions: progression (flow of material presentation) and elaboration (depth of content).

This structure contains concepts, theories, and principles that are interrelated, helps teachers prepare additional materials, and provides an overview of the sequence of materials that students will learn. This overview not only aids in lesson planning but also ensures that students can connect new information with prior knowledge, enhancing their overall learning experience. By utilizing the macrostructure, educators can create a more cohesive and engaging curriculum that meets diverse learning needs. In addition, the macrostructure clarifies the relationship between parts of the text to make it easier to understand.

In the development of teaching materials, the macro structure guides the preparation of material didactically and shows the integration of argumentation to emphasize the truth of the content (Anwar, 2023).

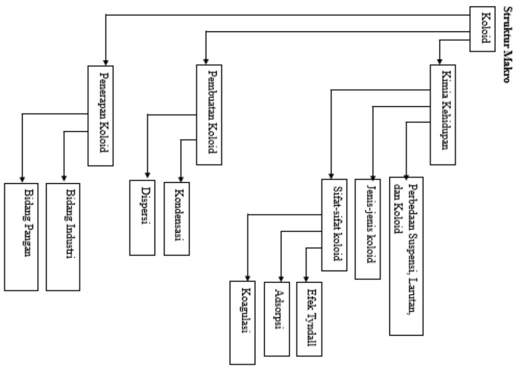
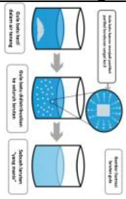


Figure 4.4. Macro structure

Stage three representations include macroscopic, microscopic, and symbolic representations (De Oliveira et al., 2015; Tippett, 2016) that are arranged to make it easier for students to understand the concepts in the teaching materials. At the macroscopic level, concepts are presented through phenomena that can be observed and felt, such as written reports, discussions, and graphs. The microscopic level points out concepts at the molecular level that cannot be observed directly, while the symbolic level simplifies explanations using symbols, chemical formulas, diagrams, reaction equations, and calculations (Drastisianti & Alighiri, 2021) These three levels aim to help students form the correct mental model of chemistry. The results of the three levels of representation were then compiled into a draft of teaching materials that were reviewed by two assessors. Examples of the three levels of representation can be seen in the table 4.6.

Tabel 4.6. Multiple Representation

Concept Label	Multiple Representation macroscopic	microscopic	symbolic
Differences in solutions, suspensions, and colloids	**Solution**  Sugar water **source:** cdn.idntimes.com/	 Sumber: diadaptasi dari https://shorturl.asia/qbp0c	

This colloidal system learning module was specifically developed to address the needs of vocational students in the Agribusiness Processing of Agricultural Products (APHP) program. The module is printed in A4 format to ensure readability and a neat layout, thereby facilitating optimal self-directed learning. The content is presented systematically through conceptual explanations, examples of colloidal system applications in agricultural contexts, practice exercises, and summaries that reinforce students' understanding.

Additionally, the module cover is designed with an engaging visual theme aligned with the topic of colloids, aiming to enhance visual appeal and support students' information retention. This module is intended not only as a self-learning resource but also as a teaching aid for instructors in contextualizing chemical concepts within real-world issues related to agricultural product processing. The colloid-themed cover design is illustrated in Figure 4.5.

Figure 4.5. Front cover of colloid system module for APHP vocational school students

Figure 4.6 presents a visual representation of the structure and content of the colloidal system learning module. It illustrates the organization of the material, the number of page views, and the types of presentation designed to support students' understanding of colloid concepts. Part (a) displays the content of the module, which includes conceptual explanations, application examples, and learning evaluations. Part (b) shows one of the practicum activities aimed at distinguishing between solutions, suspensions, and colloids by observing the physical characteristics of each dispersion system. Meanwhile, part (c) documents a practicum on tofu production as an example of applying the principle of coagulation in forming colloidal systems from agricultural products. These three components support a contextual and practical approach to chemistry learning in vocational schools, aiming to enhance both conceptual understanding and students' procedural skills.

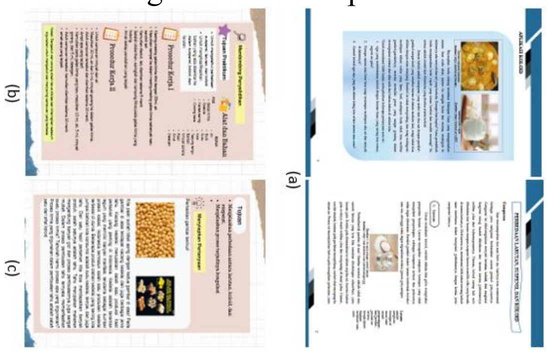


Figure 4.6. (a) Module content, (b) Practicum to differentiate between solutions, suspension, and colloids, (c) Practicum on making tofu colloidal products with coagulation principle.

The learning module developed in this study employed the Four Steps Teaching Material Development (4S-TMD) approach by systematically integrating substance and pedagogical contexts. During the selection phase, researchers constructed indicators, concept labels, and relevant content on colloids gathered from 13 different sources, which then formed the foundation for the module's content. The subsequent structuring phase produced a concept map, macrostructure, and multi-level representations (macroscopic, submicroscopic, and symbolic), all of which proved effective in helping students build comprehensive conceptual understanding. This strategy not only provided visualization of complex chemical concepts but also supported meaningful and contextual learning tailored to the needs of students in the Agribusiness Processing of Agricultural Products (APHP) vocational program.

Previous studies have emphasized the importance of context in chemistry learning. Research by (Wiyarsi et al., 2020) demonstrated that context-based learning in vocational schools significantly improved students' chemical literacy and scientific attitudes. Additionally, studies by (Demelash et al., 2024; Geerdink-Klink, 2019) found that using real-life examples and different ways to show information helps students link complex ideas to everyday situations, which improves their critical thinking and problem-solving skills. These findings highlight the significant potential of contextually grounded modules to enhance the quality of chemistry education in vocational settings.

In practice, this module enriches students' learning experiences by presenting chemistry content that is directly relevant to their future professions, particularly in the field of agricultural product processing. The module also supports teachers in designing more applicable and curriculum-aligned instruction. However, we are still in the development stage of this study, having not yet completed the characterization and content reduction phases. Research by (Damanik et al., 2024) showed that using a Project-Based Learning (PjBL) e-module significantly improved student activity and learning outcomes in the topic of electrolyte and nonelectrolyte solutions, with the experimental group achieving an average post-test score of 85.83—higher than the control group's 73.19. This demonstrates that systematically developed, context-based modules can effectively support student competency.

Meanwhile (Sinaga & Sagala, 2021) developed a thermochemistry module validated for content, presentation, language, and visuals, with average scores ranging from 3.26 to 3.50, categorized as highly appropriate. Their research highlights the importance of developing modules that are not only content-appropriate but also contextually relevant to students' lives and needs.

Together, these studies affirm that even at early stages, module development holds significant potential for improving learning effectiveness, especially when aligned with vocational contexts and students' future career demands. This limitation represents a challenge that should be addressed in future research, especially in assessing text readability, material suitability for students' characteristics, and the effectiveness of the module in actual classroom implementation.

Thus, while initial results show promising potential, further evaluation and refinement are necessary to ensure that the module can truly serve as an innovative, effective, and contextually relevant learning resource in vocational education.

CONCLUSION

The results of module development using the Four Steps Teaching Material Development (4S-TMD) method were carried out through two stages, namely the selection stage and the structuralization stage. During the selection stage, we obtained five competency achievement indicators and ten concept labels related to the topic of colloidal systems. The materials used in the module development were sourced from 14 references, consisting of 10 international books and 4 local books, to ensure the validity and relevance of the module content. The context of the substance developed in this module raises the process of making soy milk and tofu using various types of coagulants, which are aligned with the field of expertise in the agribusiness processing of agricultural products. During the structuring stage, we created concept maps, main outlines, and detailed descriptions that were organized clearly, following the properties of chemical materials related to colloidal systems.

The developed module shows potential in enhancing the contextual understanding of students in vocational schools, especially in aligning chemical concepts with real-world applications in agricultural product processing. However, this study was limited to the selection and structuring stages. Further research is recommended to continue with the next phases of the 4S-TMD method, namely characterizing and didactic reduction, in order to improve content accessibility and pedagogical effectiveness. Additionally, this approach may be adapted for other vocational competencies in SMK, offering opportunities for broader implementation and innovation in contextual teaching materials.

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