pISSN 2685-0761
eISSN 2685-0850

JURNAL INOVASI PEMBELAJARAN KIMIA
(Journal of Innovation in Chemistry Education)
https://jurnal.unimed.ac.id/2012/index.php/jipk
email: Jinovpkim@unimed.ac.id

Recieved : 17 July 2025
Revised : 22 October 2025
Accepted : 25 October 2025
Published : 31 October 2025
Page : 348 – 356

The 4STMD Method for a Contextual Colloid Module on Tofu Waste Coagulation

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Abstract: *The abstract nature of chemistry often leads to low student comprehension, a problem exacerbated by a lack of teaching materials that connect concepts to real-world situations. This research aimed to develop a valid, practical, and effective contextual teaching module on the colloid system using Four Steps Teaching Material Development (4STMD) method. The research following the stages of Design, Development, and Evaluation (DDE). The module's unique context is the application of colloid chemistry principles to the treatment of tofu liquid wastewater using Moringa oleifera seeds as a natural coagulant. The development process followed the four stages of 4STMD: Selection, Structuring, Characterization, and Didactic Reduction. The module's quality was evaluated by three expert chemistry teachers and tested for understandability with 63 high school students. The results of the expert validation indicated that the module is Very Feasible, with high scores in content (95.2%), language (85.7%), presentation (93.7%), and graphical feasibility (85.3%). Furthermore, the student understandability test yielded an average score of 93.33%, categorizing the module as "High" and suitable for independent learning. It is concluded that the 4STMD method successfully produced a viable and effective contextual module that bridges the gap between abstract chemical concepts and their practical, sustainable applications.*

Keywords: *Contextual Teaching and Learning; Four Steps Teaching Material Development; Colloid System; Tofu Wastewater; Moringa oleifera.*

INTRODUCTION

Chemistry education is often perceived as difficult by students due to the abstract nature of its concepts (Ristiyani & Bahriah, 2016). This challenge is exacerbated by teaching practices that tend to be theoretical and focus on rote memorization, leading to students struggling to connect material with real-world applications (Hanum et al., 2017).

To address this issue, educational researchers suggest for Contextual Teaching and Learning (CTL), which connects academic content to students' lived experiences (Minata et al., 2022). Studies show CTL positively impacts student achievement and engagement by making learning more meaningful (Rismawati, 2022).

Despite the proven benefits of CTL, a significant gap remains: the lack of high-

quality, validated teaching materials designed specifically for contextual learning (Misbah et al., 2018). This gap is particularly evident for complex topics like the colloid system. A preliminary analysis of widely used chemistry textbooks revealed that colloid properties are often taught theoretically, lacking clear links to practical applications. This creates a clear need for innovative, context-rich teaching materials.

To address this need, this research developed a contextual module focused on a unique and locally relevant issue: the treatment of tofu liquid wastewater using Moringa oleifera seeds as a natural coagulant (Haslinah, 2020; Firmansyah, 2022). This context makes abstract colloidal principles (such as coagulation) relevant and introduces the concept of green chemistry, providing a green and sustainable solution for wastewater treatment (Gutierrez Herrera et al., 2024).

Furthermore, this study addresses a methodological gap in material development. Common development models like ADDIE or Borg & Gall are often too broad for re-engineering complex scientific knowledge. This research employed the Four Steps Teaching Material Development (4STMD) method (Anwar, 2023). The 4STMD method is specifically designed to transform scientific content into comprehensible materials through four stages: (1) Selection, (2) Structuring, (3) Characterization, and (4) Didactic Reduction. The "Characterization" and "Didactic Reduction" stages create a crucial student-centered feedback loop, empirically identifying and simplifying difficult concepts, which is often missing in other models. The hypothesis was that the systematic use of 4STMD, combined with the relevant tofu wastewater context, would produce a learning module meeting very high criteria for validity (feasibility) and practicality (understandability).

The novelty of this research lies in the combination of the 4STMD method with the specific and sustainable context of tofu wastewater treatment in colloidal teaching materials. Therefore, this study aims to develop a contextual teaching module for colloidal systems and evaluate its quality based on validity, practicality, and understandability.

LITERATURE REVIEW

Contextual Teaching and Learning (CTL)

Contextual Teaching and Learning (CTL) is a pedagogical philosophy grounded in the constructivist perspective that learning occurs when students can process new information in a way that makes sense to them within their own frames of reference. This approach emphasizes connecting academic content to tangible contexts in students' personal, social, and cultural lives (Agil & Pratiwi, 2015). The core principle of CTL is that by situating learning in real-world problems, students are better able to find meaning in the material, which enhances motivation, comprehension, and knowledge retention (Hasibuan, 2014).

A systematic literature review by Minata, Rahayu, & Dasna, (2022) confirmed that context-based chemistry learning has a positive effect on improving students' cognitive, affective, psychomotor, and social outcomes. Recent studies published also confirm the effectiveness of CTL, particularly for challenging topics like colloid systems, by helping students connect abstract concepts to daily life contexts (Siregar et al., 2024). The versatility of the CTL approach is evident in its successful application across various media and topics, including the development of video-based learning for acid-base chemistry, where it proved to be both valid and practical (Gustina & Yasthophi, 2022).

Developments in Chemistry Module

The development of teaching modules is an important research area within chemistry education (Anwar, 2023). Recent studies have focused on developing modules using various approaches, such as Problem-Based Learning (PBL) for acid-base materials (Dalimunthe & Ginting, 2022), project-based learning for alkenes (Purba & Fitri, 2021), and the

integration of Pedagogical Content Knowledge (PCK) for reaction rates (Harahap & Roza, 2020). These studies highlight a continuous effort to create effective, student-centered, and valid teaching materials (Adita & Sugiharti, 2025). This study uses 4STMD as a method for developing teaching materials which is different from more common R&D models such as 4D or ADDIE used in previous studies.

Colloid System

A colloid is a type of mixture intermediate between a true solution and a suspension. Its dispersed particles, ranging in size from 1 to 100 nm, are too small to settle under gravity but large enough to scatter light, an effect known as the Tyndall effect (Whitten, K. W., et al., 2014). The stability of colloids is often due to electrostatic repulsion between particles that have adsorbed ions of the same charge on their surfaces (Zumdahl, S. S., & Zumdahl, S. A. (2018). The central property of colloids to this study's context was the coagulation. This is the process of destabilizing a colloid, causing the dispersed particles to aggregate and form larger masses that can precipitate. Coagulation can be induced by heating or, more relevantly, by adding an electrolyte that neutralizes the surface charges on the colloidal particles, allowing them to clump together (Zumdahl, S. S., & Zumdahl, S. A. (2018). This topic is often considered difficult for high school students, necessitating innovative learning approaches, such as contextual learning, to improve problem-solving skills (Rahayu & Jahro, 2024). The central property of colloids to this study's context was the coagulation. This is the process of destabilizing a colloid, causing the dispersed particles to aggregate and form larger masses that can precipitate.

Moringa oleifera as a Natural Coagulant

The treatment of industrial wastewater, such as that from tofu production, often involves coagulation to remove suspended colloidal impurities (Firmansyah, 2022). While chemical coagulants like alum are effective, there is growing interest in sustainable, "green" alternatives. *Moringa oleifera* seeds have been identified as a highly effective natural coagulant that is biodegradable, inexpensive, and safe for human health (Sulaiman et al., 2017). The coagulation mechanism of *Moringa oleifera* is attributed to a water-soluble cationic protein found in the seeds. This protein acts as a polyelectrolyte, neutralizing the negative surface charges of colloidal particles in the wastewater through a process of adsorption and charge neutralization, which leads to particle aggregation (flocculation) and subsequent sedimentation. The efficiency of this process can be influenced by factors such as pH and temperature, with studies showing optimal performance in slightly acidic to neutral pH ranges (Manab, A., & Andriani, R. D., 2023; Katayon et al., 2006). The use of *Moringa oleifera* in an educational context provides a powerful example of applying green chemistry principles to solve real-world environmental problems (Gutierrez Herrera et al., 2024).

METHODS

Research Design

This study uses the Developmental Research (DR) methodology, following the three-phase Design, Development, and Evaluation (DDE) model as described by Richey, Klein, & Nelson (2004). The research was conducted in Bandung, Indonesia. The DDE model guided the overall research flow, starting with the Design Phase for curriculum analysis and preliminary laboratory experiments to optimize the module's practical activity. This was followed by the Development Phase, focusing on the systematic creation of the module using the 4STMD method. The final stage was the Evaluation Phase, which assessed the product's quality through expert feasibility (validity) and student understandability tests.

Participants

The research involved three distinct groups of participants. The first group consisted of three experienced senior high school chemistry teachers who served as

expert validators for the module's feasibility. The second group included 72 eleventh-grade students who participated in the initial draft testing (the Characterization stage of 4STMD). The third group comprised 63 eleventh-grade students who participated in the final evaluation of the revised module's understandability.

4STMD Procedure

The module was developed following the four systematic stages of the 4STMD method (Anwar, 2023). The Selection stage involved aligning module content with curriculum standards (Core Competencies) and ensuring scientific accuracy by synthesizing material from eight authoritative chemistry textbooks. The substance context (tofu wastewater treatment) and pedagogical contexts (e.g., environmental awareness) were integrated. Subsequently, the Structuring stage organized the content logically by creating a concept map, a macro structure (defining the learning path), and three-level representations (macroscopic, sub-microscopic, symbolic) for key concepts. The Characterization stage empirically tested the first draft with 72 students, who were tasked to identify the main idea of each text segment to pinpoint specific concepts perceived as difficult to understand. Finally, the Didactic Reduction stage systematically simplified the identified "difficult" texts using didactic techniques, such as adding visual aids (diagrams, images) and reformulating complex sentences.

Research Instruments

Two primary instruments were used to evaluate the final module's quality. The Feasibility Questionnaire was a validation instrument administered to the three expert teachers. This questionnaire was adapted from the feasibility standards set by the Ministry of Education (Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2022) and covered four aspects: content, language, presentation, and graphics. The Understandability Test Instrument was a "main idea identification test" administered to 63 students. This instrument, adapted from the 4STMD characterization procedure, required students to write the main idea of each text segment to assess their ease of understanding.

Data Analysis Techniques

The feasibility data from the expert teacher questionnaire were analyzed using descriptive percentages to determine the module's validity. The feasibility percentage was calculated using the formula adapted from Slavin (2011):

$$\% = \frac{Total\ Score\ Obtained}{Maximum\ Posible\ Score} \times 100\%$$

The resulting percentage was then categorized according to the criteria in Table 1.

Table 1. Module Feasibility Criteria (adapted from Slavin, 2011)

Score Interval	Criteria
81% - 100%	Very Feasible
61% - 80%	Feasible
41% - 60%	Fairly Feasible
21% - 40%	Infeasible
0% - 20%	Very Infeasible

The understandability data from the student "main idea identification test" were analyzed to determine the module's practicality. The understandability score (K) was calculated based on the percentage of students who correctly identified the main idea of each text. The resulting overall percentage was categorized using the criteria in Table 2, which was adapted from Arifin & Anwar (2016).

Table 2. Module understandability criteria (adapted from Arifin & Anwar, 2016)

Score Interval	Criteria
60% - 100%	High (Suitable for independent study)
40% - 59%	Medium (Suitable for instructional study)
0% - 39%	Low (Difficult)

RESULT AND DISCUSSION

This section presents the findings of the module development process, which followed the Design, Development, and Evaluation (DDE) model. The results are presented in three parts: the final characteristics of the module after the 4STMD

process, the results of the expert feasibility (validity) test, and the results of the student understandability (practicality) test. Finally, these findings are discussed and compared with relevant research to situate the study's contribution.

Module Characteristics

The application of the 4STMD method resulted in a well-structured and didactically refined module. The Characterization stage successfully identified four text segments (out of 58) that were conceptually difficult for students. The subsequent Didactic Reduction stage effectively addressed these difficulties by incorporating targeted visual aids and reformulating complex sentence structures to improve clarity.

The application of 4STMD method resulted in a contextual module on colloidal systems. This process successfully addressed conceptual difficulties through empirical testing. The Characterization phase, which tested the initial draft on 72 students, identified four specific text segments (out of 58) as “difficult”. The subsequent Didactic Reduction phase effectively addressed these difficulties. Based on analysis of student feedback, the reduction techniques implemented included reformulating complex sentences into clearer language and adding directed explanatory images and diagrams to make abstract processes (such as the Cottrell precipitator function and the Bredig Arc method) more concrete and understandable.

Module Feasibility

The module's feasibility (validity) was evaluated by three expert chemistry teachers using a questionnaire adapted from the Indonesian Ministry of Education (Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan, 2022) standards. The evaluation covered four key aspects: content, language, presentation, and graphics. The aggregated results of this validation are presented in table below.

Table 3. Expert validation results of module feasibility

Feasibility Aspect	Score (%)	Criterion
Content	95.2	Very Feasible
Language	85.7	Very Feasible
Presentation	93.7	Very Feasible
Graphics	85.3	Very Feasible

For a clearer visualization of the validation results, the data from Table 3 is also presented in the bar graph in Figure 1.

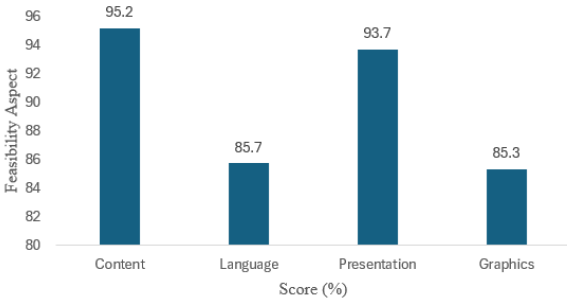

Figure 1. Module feasibility test results

Module Understandability

Following the expert validation, the module's understandability was evaluated from the students perspective. The final revised module was tested on 63 eleventh-grade students using the 'main idea identification test' described in the methods section. This test measures the percentage of students who can correctly understand and state the main idea of the module's texts. The results are summarized in table below.

Table 4. Summary of student understandability test result

Parameter	Value
Number of Text	58
Number of Student Participants	63
Understandability Score	93.33%
Understandability Category	High

Data shows an exceptionally high understandability score of 93.33%. Based on the criteria established by Arifin & Anwar (2016) (where a score above 60% is "High"), this result categorizes the module as highly suitable for independent student learning.

Discussion

The strong quantitative results, which show the module to be both highly feasible and exceptionally comprehensible, are not

incidental. They are a direct outcome of the systematic and rigorous methodology employed in its creation. This discussion interprets these results by linking them to the specific strengths of the 4STMD method and the nature for the context.

The most significant finding, is the module's high "Understandability" score. This result provides evidence for the 4STMD method's most innovative feature, its empirical, student-centered feedback loop. Unlike more linear development models (Omoregie et al., 2024), 4STMD has the Characterization and Didactic Reduction stages. This process ensures that the teaching material is understandable and also empirically tests the material with the target student population to identify specific points of confusion. High understandability scores are a direct validation of this process, confirming that the module was successfully refined to meet student needs.

These findings are consistent with other module development research, which also confirms the high feasibility of R&D products (Harahap & Roza, 2020). This work also aligns with other recent studies that have successfully used the 4STMD method to produce high-quality, contextual teaching materials (Permana et al., 2023) and project-based modules (Darmilah et al., 2025). While previous research validated modules using PBL (Dalimunthe & Ginting, 2022) or multimedia (Purba & Fitri, 2021), this study specifically confirms the efficacy of the 4STMD method's empirical feedback loop in achieving high understandability scores.

Furthermore, the module's success cannot be separated from its unique context. The application of colloid chemistry to the treatment of tofu wastewater with *Moringa oleifera* aligns perfectly with the principles of CTL (Berns & Ericson, 2001; Minata, Rahayu, & Dasna, 2022). By framing the topic as a real-world environmental problem with a sustainable, green chemistry solution (Firmansyah, 2022), the module makes abstract concepts tangible. This synergy between a rigorous development method (4STMD) and a meaningful context (tofu wastewater) confirms the module as a viable and effective teaching materials.

CONCLUSION

This research successfully developed a contextual teaching module on the colloid system using the 4STMD method, contextualized in the treatment of tofu wastewater with *Moringa oleifera* seeds. The 4STMD method proved to be a highly effective framework, producing a module that was validated by expert teachers as "Very Feasible" and demonstrated a "High" level of understandability among students.

The primary implication of this study is that the developed module is a viable, validated, and practical resource that can be immediately implemented by chemistry educators to teach the colloid system in a more engaging and meaningful way. Furthermore, this research provides a replicable, evidence-based model for other practitioners and researchers seeking to develop high-quality contextual teaching materials for other complex scientific topics.

ACKNOWLEDGEMENT

The author extends sincere gratitude to Dr. paed. Sjaeful Anwar and Dr. Ijang Rohman, M.Si., for their invaluable guidance and motivation throughout this research. Appreciation is also extended to the Universitas Pendidikan Indonesia, the leadership and chemistry teachers of SMA Laboratorium-Percontohan UPI, and all the students who participated in this study. The authors declare that this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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