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Development of Multiple-Representation-Based Student Worksheets and Their Effects on Senior High School Students' Cognitive Learning Outcomes and Scientific Attitudes in Colloid Systems

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Abstract: This study aimed to develop and evaluate multiple-representation-based student worksheets (LKPD) on colloidal system material and examine their effects on senior high school students' cognitive learning outcomes and scientific attitudes. Using Thiagarajan's 4D development model, which includes Define, Design, Develop, and Disseminate stages, the LKPD was designed, validated by expert lecturers, revised, and implemented with Class X students at SMA Negeri 2 Biak. A quasi-experimental posttest-only control group design was employed, with simple random sampling to assign experimental and control classes. Instruments included product practicality and feasibility assessments, cognitive learning tests, and scientific attitude questionnaires. Data were analyzed descriptively and inferentially using MANOVA and effect size calculations to determine the percentage of effective contribution. Results indicated that the LKPD was well-structured, printed in color on A4 paper, incorporated discovery learning syntax, and passed expert validation and readability tests. Students using the LKPD demonstrated significantly higher cognitive learning outcomes and scientific attitudes compared to the control group. MANOVA results revealed a very significant simultaneous effect of LKPD use on both variables ($p < 0.001$) with an overall effective contribution of 60.1%, a significant effect on cognitive learning outcomes ($p < 0.001$, 39.4%), and on scientific attitudes ($p < 0.001$, 54.3%). These findings suggest that multiple-representation-based LKPD is an effective instructional tool for enhancing both conceptual understanding and scientific attitudes in chemistry education.

Keywords: Cognitive learning outcomes; LKPD; Multiple representative; Scientific attitudes

Introduction

Education plays a fundamental role in preparing future generations to survive, adapt, and develop their potential in accordance with the demands of the times (Utami, 2020; Rohman et al., 2022). One of the main goals of education is to produce individuals who are faithful, of noble character, intelligent, and capable of contributing to society (Sujana, 2019). These goals are realized through learning processes that foster students' cognitive, affective, and psychomotor domains (Anderson et al., 2001).

In science learning, particularly chemistry, cognitive achievement is a key indicator of success as it

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relates to the understanding of abstract and complex concepts (Harahap & Siregar, 2020). However, numerous studies have reported that students still struggle to comprehend chemistry materials and to connect them with real-life phenomena (Priliyanti et al., 2021; Sariati et al., 2020; Sugiono & Widyaningrum, 2022). These difficulties are compounded by monotonous teaching methods, non-contextual learning resources, and limited availability of engaging materials, which in turn result in low cognitive learning outcomes (Lubis & Ikhsan, 2015; Suswati, 2021; Hakim et al., 2024).

Beyond cognitive achievement, scientific attitude also plays an essential role in successful chemistry learning. It encompasses curiosity, open-mindedness, accuracy, and honesty in decision-making (Rohaeti et al., 2020; Wahyudi & Wulandari, 2021, Shiddiqi, 2024; Walker et al., 2012; Aini & Silfianah, 2022). Nevertheless, empirical studies indicate that students' scientific attitudes remain underdeveloped, as reflected in passive classroom behavior, low self-confidence, and limited ability to express ideas critically (Murningsih et al., 2016; Parwati et al., 2020; Meutia et al., 2021).

In the 21st century, educational institutions are required to produce high-quality human resources through innovative, creative, and technology-based learning (Wijaya et al., 2016). The 2013 Curriculum emphasizes the importance of teachers providing learning materials that meet students' needs in order to create active and meaningful learning (Laksana, 2021). One instructional tool that can support this goal is the student worksheet (Lembar Kerja Peserta Didik, LKPD), which has been shown to increase student motivation, participation, and learning outcomes (Alam et al., 2023; Noor & Kurniasih, 2019).

The use of multiple representations in chemistry learning is considered effective in helping students understand concepts through the integration of macroscopic, microscopic, and symbolic levels (Prain et al., 2009). Several studies have demonstrated that learning materials based on multiple representations, including worksheets, can enhance conceptual understanding and critical thinking skills (Astuti & Mulyatun, 2019; Baptista et al., 2019; Dini & Dian, 2023). However, studies examining the effectiveness of multiple representation-based worksheets in the topic of colloid systems remain limited.

Interviews with chemistry teachers at SMA Negeri 2 Biak revealed that students have limited access to learning resources, teachers face difficulties in designing effective worksheets, and students' performance, both cognitively and in terms of scientific attitudes, remains low. This situation highlights the need for developing instructional materials that better support students' understanding. Therefore, this study was conducted to develop multiple representation-based worksheets on colloid systems and to analyze their impact on high school students' cognitive learning outcomes and scientific attitudes.

Method

Type of Research

The instructional product developed in this study is a multiple representation-based student worksheet (LKPD) designed to support the teaching and learning of colloid systems in high school chemistry. The development process was carried out using the 4D model proposed by Thiagarajan, which consists of four systematic stages: define, design, develop, and disseminate. Each stage was implemented to ensure that the resulting worksheet not only aligns with the curriculum but also addresses students' learning needs by integrating macroscopic, microscopic, and symbolic representations of chemical concepts.

Time and Place of the Research

The research was conducted at SMA Negeri 2 Biak during the 2024/2025 academic year, involving tenth-grade students as the participants.

Research Subject

The study population included all public senior high schools in Biak Regency implementing the 2013 Curriculum. The sample was drawn from tenth-grade students of SMA Negeri 2 Biak in the 2024/2025 academic year using simple random sampling, involving 60 students divided into experimental and control classes.

Procedure of Development

This study adopted the 4D development model consisting of four stages: Define, Design, Develop, and Disseminate. In the Define stage, needs, student, concept, task, and test analyses were conducted through literature review, field observation, and curriculum alignment to identify problems in chemistry learning and establish the foundation for product development. The Design stage involved preparing cognitive tests and scientific attitude questionnaires, selecting learning media and formats, and drafting the initial structure of the LKPD in accordance with curriculum standards. The Develop stage focused on creating the LKPD and instruments using Canva, followed by expert validation, teacher evaluation, readability tests, and empirical testing to ensure validity and reliability. Finally, the Disseminate stage was conducted through classroom trials to examine the effectiveness of the LKPD on cognitive achievement and scientific attitudes, as well as dissemination to teachers and students through instructional use, seminars, and scientific publications.

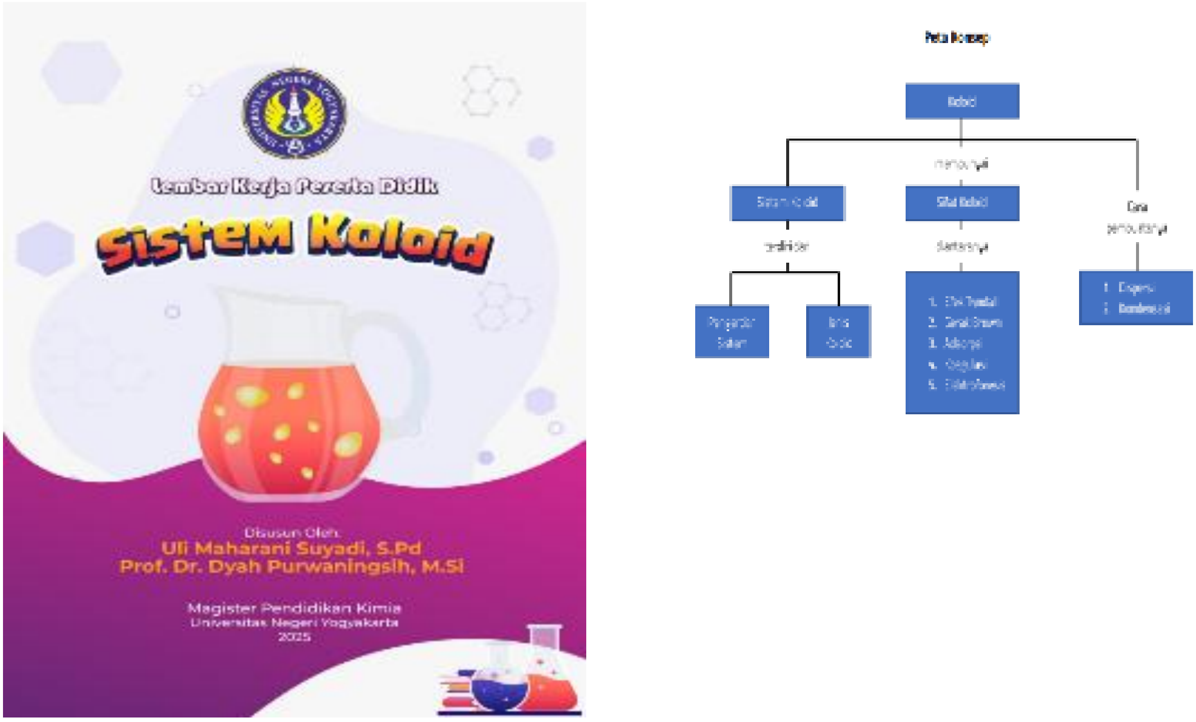

Figure 1. Initial cover page and concept map

Figure 2. Visual LKPD multiple representative

Instruments and Data Collection Techniques

Data were collected through test and non-test techniques. The non-test instruments consisted of questionnaires to measure students' scientific attitudes, evaluate the feasibility and quality of the developed LKPD by chemistry teachers, and assess its readability by students. Expert validation sheets for material and media included indicators of learning aspects, content accuracy, representational components, display, language, and product uniqueness. Teacher assessments covered material, language, media, and product specificity, while student readability focused on clarity and attractiveness. The test instrument was a multiple-choice achievement test developed based on the 2013 curriculum (KI and KD) and validated both theoretically and empirically. Altogether, the instruments ensured comprehensive data collection on cognitive learning outcomes, scientific attitudes, and the quality of the LKPD.

Data Analysis Techniques

The data analysis involved both qualitative and quantitative approaches. Instrument validation covered learning devices, cognitive achievement tests, and scientific attitude questionnaires, with theoretical validation carried out through expert judgment and empirical validation through pilot testing. The reliability of test items was examined using the Rasch model with INFIT MNSQ values (0.77–1.30) and Cronbach's Alpha (≥0.70). The quality of the developed LKPD was assessed by experts, teachers, and students, with scores converted from Likert scales into qualitative categories. Quantitative data from cognitive learning outcomes and scientific attitude tests were analyzed using multivariate analysis of variance (MANOVA) at a 0.05 significance level, while assumptions of normality, homogeneity, linearity, and multicollinearity were tested beforehand. Effect size was determined using partial eta squared to measure the effective contribution of the developed LKPD.

Result and Discussion

The LKPD development process in this study followed the 4D model (Define, Design, Develop, and Disseminate). In the Define stage, analysis revealed that students encountered significant difficulties in comprehending abstract chemical concepts, while the utilization of LKPD was still minimal. These findings emphasize the need for instructional materials that incorporate multiple representations to support conceptual understanding and foster active engagement. This is consistent with prior research demonstrating that multiple representations can enhance learning outcomes and reduce misconceptions in chemistry (Ainsworth, 2006; Treagust et al., 2018).

In the Design stage, the LKPD prototype was structured with supporting instruments such as attitude questionnaires, readability tests, teacher evaluations, and cognitive assessments. Canva was used to enhance the visual clarity of the worksheets and adjust the format to students' learning needs. Such design efforts align with studies indicating that materials developed with multiple representations improve both conceptual comprehension and students' self-efficacy compared to conventional approaches (Khajavi & Ketabi, 2012).

The Develop stage involved expert validation by subject-matter and media specialists, followed by practical assessments conducted by chemistry teachers. The LKPD obtained strong evaluations across content, language, media, and product uniqueness aspects (89.33% ideal score). However, the media aspect received a slightly lower evaluation (88%), suggesting a need for refinement in visual clarity and terminology. This process reflects iterative revisions that are characteristic of effective educational material development, which aligns with findings from studies that applied the 4D model to strengthen validity and classroom applicability (Thiagarajan et al., 1974; Maryani et al, 2025).

Finally, readability tests with students yielded very high scores: 93.75% for ease of understanding and 91.50% for attractiveness, resulting in an overall score of 92.62%. These results suggest that the use of multiple representations made the abstract concepts of colloids more accessible and engaging. Similar outcomes have been documented in studies reporting that multiple representation-based learning significantly improves problem-solving skills and conceptual mastery in science education (Chandrasegaran et al., 2007).

The research instruments, consisting of a cognitive posttest and a scientific attitude questionnaire, underwent expert validation and empirical testing. Analysis with the Rasch model via QUEST demonstrated that all 25 multiple-choice items on the cognitive test met the INFIT MNSQ criteria (0.77–1.33), while the 35 questionnaire items achieved an average INFIT MNSQ of 1.005, confirming strong item fit and construct validity. Reliability indices were satisfactory, with coefficients of 0.66 (moderate) for the cognitive test and 0.77 (good) for the attitude questionnaire, ensuring suitability for data collection. These outcomes align with prior studies emphasizing the value of Rasch modeling in establishing valid and reliable measurement tools in education (Boone, Staver, & Yale, 2014; Bond & Fox, 2015; Sumintono & Widhiarso, 2015).

Then the dissemination stage was carried out to test the effectiveness of LKPD based on multiple representatives on cognitive learning outcomes and students' scientific attitudes through trials in two classes X of SMA Negeri 2 Biak, namely the experimental class (X IPA 2) which used LKPD and the control class (X IPA 1) which did not use LKPD, while continuing with the distribution of products to chemistry teachers and publication of articles in journals in order to provide a wider contribution in the academic field. for the results of the product trial, see table 1.

Table 1. Average Scores of Experimental and Control Classes

Research Class	Number of Students	Average posttest cognitive learning outcomes	Average scientific attitude questionnaire
Experiment	30	87.33	89.77
Control	30	79.77	80.08

Table 1 shows that the average cognitive learning outcomes of students in the experimental class reached 87.33, higher than the control class at 79.77. Similarly, the average scientific attitude of students in the experimental class was 89.77, compared to 80.08 in the control class, indicating that the experimental class outperformed the control group in both domains. These results suggest that the implementation of multiple representation-based LKPD effectively enhanced students' conceptual understanding and scientific attitudes, as the use of varied representations provides multiple entry points for learners to construct meaning and reduce misconceptions (Shiddiqi et al, 2024). This finding aligns with research by Opona et al. (2022), who demonstrated that multiple representation approaches in chemistry learning significantly improved comprehension and engagement, thereby reinforcing the value of such strategies in supporting both cognitive and affective learning outcomes.

Then, MANOVA hypothesis testing was performed using Pillai's Trace statistics to determine significant differences between variables simultaneously. If the significance value is <0.05, then H0 is rejected, meaning there are significant differences in the measured variables. The test results are shown in Table 2.

Based on table 2, a significance value of 0.000 < significance value of 0.05 was obtained; therefore, H0 was rejected. This indicates a significant difference in students' cognitive learning outcomes and scientific attitudes simultaneously after using multiple representative-based LKPD on colloidal system material in the experimental class with control class students without using LKPD. Then for the percentage of effective contribution simultaneously based on the partial eta square value of 0.601, it can be concluded that multiple representative-based LKPD on colloidal system material provides a high effective contribution to cognitive learning outcomes and scientific attitudes simultaneously.

Table 2. MANOVA Test Results

Effect		Sig.	Partial Eta Square
Class	Pillai's Trace	0.000	0.601

Subsequently, a hypothesis test was conducted to examine the significant differences in students' cognitive learning outcomes and scientific attitudes between those who used the multiple representation-based worksheets and those who learned without them, analyzed separately (partial test). The results are presented in Table 3.

Table 3. Tests of Between-Subjects Effects

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Cognitive Learning Outcomes	858,.817	1	858.817	37.735	0.000	0.394
Scientific Attitude	1410.089	1	1410.089	68.885		

Based on Table 3, the obtained significance value of 0.000, which is lower than the 0.05 threshold, indicates that the null hypothesis (H0) is rejected. This finding demonstrates a significant difference in cognitive learning outcomes between students in the experimental class who used multiple representation-based worksheets (LKPD) on the colloid system material and those in the control class who did not. The partial eta squared value of 0.394 further suggests that the intervention contributed approximately 39.4% to the variance in students' cognitive scores, reflecting a strong effect size and confirming the substantial influence of the learning strategy.

The application of multiple representations in chemistry instruction provides students with opportunities to understand concepts from macroscopic, microscopic, and symbolic perspectives, enabling a deeper and more integrated comprehension. This approach has been reported to enhance conceptual mastery, facilitate connections across representational modes, and minimize misconceptions (Putri, 2015; Tima & Sutrisno, 2020; Arif & Muthoharoh, 2021). Such representational flexibility is particularly critical for abstract topics like colloids, where linking observable phenomena with particle-level explanations plays an essential role in knowledge construction.

Empirical evidence from previous studies also supports the current findings. Panie (2023) showed that blended learning incorporating multiple representations improved students' problem-solving abilities, while Puspitasari (2024) emphasized the role of representational switching in stabilizing students' conceptual structures. Similarly, Abdurrahman et al. (2019) highlighted that multiple representation-based worksheets stimulate diverse cognitive pathways, making knowledge more durable, and Sudiatmika et al.

(2016) found that interactive multimedia with multiple representations reduced misconceptions in learning colloids. Moreover, Huda et al. (2021) reported positive student responses to such learning designs, as they enable learners to connect chemical concepts with real-world phenomena. Collectively, these insights confirm that multiple representation-based worksheets are an effective pedagogical tool to significantly improve cognitive learning outcomes in chemistry education.

Based on Table 3, the statistical test revealed a significance value of 0.000, which is below the 0.05 threshold, indicating that the null hypothesis (H_0) is rejected. This demonstrates a significant difference in students' scientific attitudes between the experimental class, which received instruction using multiple representation-based worksheets (LKPD) on the colloid system, and the control class, which did not. The partial eta squared value of 0.543 further indicates that 54.3% of the variance in scientific attitudes can be attributed to the use of multiple representation-based LKPD, highlighting its substantial pedagogical contribution in shaping students' scientific dispositions, such as curiosity, openness to evidence, critical evaluation of information, and honesty in scientific processes (Sunyono et al., 2018; Andriani & Gazali, 2025).

Field implementation at SMA Negeri 2 Biak showed that the average scientific attitude score in the experimental class reached 89.77, compared to 80.08 in the control class. This difference suggests that multiple representations actively engage students in scientific activities such as observation, discussion, and data-based conclusion drawing. Previous research has shown that integrating narrative, graphical, and visual simulations strengthens students' scientific character through direct exploration (Reyes & Villanueva, 2024). The LKPD facilitated not only content delivery but also active student participation in constructing meaning from scientific activities.

Furthermore, the use of diverse representational forms allows students to develop systematic, reflective, and critical thinking skills (Oz & Memis, 2018). Conceptual diagrams, scientific narratives, and molecular models support internalization of scientific principles, while flipbooks and visual worksheets enhance engagement and curiosity, reinforcing scientific attitudes (Ardiyah et al., 2023; Sari & Ulianas, 2021). Inquiry-based approaches using multiple representations also cultivate objectivity and perseverance in observing and analyzing colloid phenomena (Panie, 2023; Termini, 2023). Collectively, these findings indicate that LKPD based on multiple representations significantly contributes to the development of scientific attitudes, emphasizing both academic skills and the cultivation of essential scientific values such as accuracy, honesty, and open-mindedness.

The final product developed in this study is a multiple representation-based student worksheet (LKPD) on colloid systems, designed using the 4D model (define, design, develop, and disseminate). Each stage was implemented systematically to ensure the worksheet is feasible, practical, and effective for classroom use. During the develop phase, material and media experts from FMIPA Universitas Negeri Yogyakarta validated the product, focusing on content accuracy, alignment with learning objectives, clarity of language, visual presentation, and the integration of multiple representations. Feedback from these experts guided revisions, resulting in an LKPD structured to support both pedagogical and didactic principles. Dissemination involved testing the effectiveness of the LKPD in SMA Negeri 2 Biak with an experimental class using the worksheet and a control class without it, followed by distribution to chemistry teachers and publication in academic journals to extend its educational impact.

Practicality and readability assessments confirmed the LKPD's effectiveness and usability. Three chemistry teachers evaluated four aspects, namely content, language, media, and uniqueness, resulting in an overall ideal score of 89.33 percent, indicating very high practicality. Students' readability assessments further supported this finding, with an average score of 92.62 percent, reflecting clear, structured language, organized visual layout, and engaging content that facilitated independent understanding. Systematic revisions based on expert and practitioner feedback, including enhancements to instructions, conceptual maps, Bloom's taxonomy alignment, and illustration completeness, ensured the LKPD effectively guided students through exploration, analysis, and reflection activities. These results align with previous studies demonstrating the benefits of multiple representation-based worksheets in improving conceptual understanding and scientific skills (Sutamiati et al., 2015; Arta & Azhar, 2019; Fauziyah & Susatyo, 2022).

Despite these strengths, the study acknowledges several limitations. The implementation was constrained by school time allocations, limiting the full execution of designed activities, especially conceptual representation stages. The study was conducted in a single school with a relatively homogeneous student population, restricting the generalizability of findings across diverse academic, social, and cultural contexts. Additionally, variations in students' learning styles, prior knowledge, and representational thinking skills were not broadly accommodated, which may influence the LKPD's effectiveness in more heterogeneous settings. Future research should expand testing across multiple schools and diverse student populations to validate and refine the application of multiple representation-based worksheets in chemistry education.

Conclusion

Based on the research and development findings, the multiple-representation-based student worksheet (LKPD) on colloid systems, produced as a colored A4 print integrating discovery learning syntax and macroscopic, microscopic, and symbolic representations, was deemed suitable for use by experts, teachers, and students. The product proved effective in enhancing both cognitive learning outcomes and scientific attitudes, with a significance value of 0.000 and a simultaneous effect contribution of 60.1%, including 39.4% for cognitive outcomes and 54.3% for scientific attitudes, while receiving positive feedback on readability and practicality. This LKPD can be applied to other chemistry topics, developed into a digital version for broader access, and used as a contextual teaching resource in inquiry-based or problem-based learning, with follow-up actions including the publication of research results and further development to support scientific literacy, conceptual understanding, and students' exploratory, analytical, and reflective activities.

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Conceptualization, U.M.S. and D.P.; methodology, U.M.S.; software, U.M.S.; validation, U.M.S. and D.P.; formal analysis, U.M.S.; investigation, U.M.S.; resources, U.M.S.; data curation, U.M.S.; writing—original draft preparation, U.M.S.; writing—review and editing, D.P.

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Conflicts of Interest
The authors declare no conflict of interest.

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