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Enhancing Critical Thinking in Chemistry Education Through Differentiated LKPD Design

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Abstract

This research aims to enhance students' Critical Thinking Skills in chemistry learning by using differentiated LKPD. Based on the initial observation, it was found that the CTS of students was still in the low category, as the learning media used had not taken into account the learning styles of students. This type of research is quasi-experimental with a Control Group Pre-Test-Post-Test Design. The sample in this study consisted of students from X.E-8, the experimental class, who were treated with differentiated LKPD, and the control class X.E-6, which was treated with undifferentiated LKPD. The research sample consisted of 76 students. The data collection employed a description test, consisting of five questions. Normality, homogeneity, and the One-Way ANOVA test were employed to analyze the data. The results of the feasibility test of differentiated LKPD, in terms of presentation, content, language, and writing, obtained an Aiken index of 0.87 and an Inter-Rater Agreement of 0.617, indicating that LKPD is valid and reliable. So, it is feasible to use as a chemistry learning medium. Based on the one-way ANOVA test analysis, it was found that there was a significant difference in the improvement of critical thinking skills between students taught using differentiated LKPD in the experimental class and those taught using undifferentiated LKPD in the control class.

1. Introduction

Critical thinking (CT) is one of the 21st-century competencies needed by students in the globalization era to help students face future challenges [1–3]. The development of critical thinking abilities has become one of the highest educational priorities and public needs in modern societies [4–6]. Critical thinking is a cognitive process that involves analyzing and evaluating information, arguments, and evidence logically and systematically [7]. Through the development of critical thinking, students are encouraged to consider diverse perspectives, assess evidence, and form well-justified conclusions [8, 9]. This skill allows them to logically analyze and evaluate issues, fostering their ability to create innovative and effective solutions.

To develop successful critical thinkers, critical thinking skills (CTS) must be incorporated into the curriculum content and teaching approaches, and sequenced at all grade levels [10]. CTS was first analyzed by John Dewey in 1916, who discussed the concept of CTS skills in education [11]. Dewey viewed CTS as a process that begins with a problem and ends with a solution and selfinterpretation. Then, Bean [12] elaborates on this by stating that such problems should 'evoke students' natural curiosity and stimulate learning and critical thought. The National Council for Excellence in Critical Thinking describes CTS as a disciplined intellectual process involving the active and skillful conceptualization, application, analysis, synthesis, and evaluation of information obtained or derived from observation, experience, reflection, reasoning, or communication, to guide one's beliefs and actions [13]. In essence, CTS involve reflective and rational thought processes that allow individuals to assess multiple justifiable arguments or viewpoints and determine which is the most well-founded [14, 15]. By applying the concept of critical thinking, students are expected to connect their thoughts and ideas with contextual aspects of life [16].

CTS is a high-level thinking skill that plays a role in the development of science [17]. The Association of College and Research Libraries (ACRL) and the American Chemical Society (ACS), as leading scientific organizations, have made efforts to develop and implement a framework for CTS [18, 19]. The Framework for Information Literacy for Higher Education and Chemical Information Skills, respectively, discuss the specific skills associated with critical thinking, such as identifying key references on related topics and evaluating the quality and usefulness of the information. Although these documents do not directly address the broad idea of critical thinking itself, they do outline the specific skills associated with it. Furthermore, there are dimensions in critical thinking that include critical analysis of information, decision-making, and understanding [20].

Chemistry is a fundamental subject in science education as it explains the composition, properties, behavior, and transformation of matter [21]. Chemistry is often considered a challenging subject by students, especially because its content involves abstract concepts that require understanding at various levels, namely macroscopic, microscopic, and symbolic [22]. Many students struggle to connect these representations, which are crucial for understanding chemical phenomena [23]. These difficulties can lead to confusion and a decline in interest and academic performance in the subject of chemistry. When teachers use teaching methods that are the same for all students, without considering individual differences in how students learn, it tends to exacerbate this problem [24]. To help resolve this problem, one approach that has been given attention is differentiated instruction [25].

Differentiated Instruction is an approach that tailors instruction to meet students' needs in terms of their readiness, interests, and learning profiles, differentiating content, process, and product [26]. Differentiated learning is a learning process where learners can acquire subject matter according to their abilities, preferences, and needs, ensuring they do not feel like failures in their learning experience [27–29]. In this context, learning instructions play a role in realizing the principles of differentiated teaching. One such instruction or learning tool is the student Worksheet (LKPD), which is designed to improve learning outcomes by aligning activities with students' needs and abilities [30]. The LKPD can be tailored to suit the varied learning preferences of students [31]. A practical way to start implementing differentiated teaching is to recognize students' learning styles, such as visual, auditory, and kinesthetic learning styles [32, 33]. For example, worksheets intended for kinesthetic learners can incorporate practical, hands-on experiments. When teachers design lessons that align with these preferences [34], students are more likely to participate and stay motivated in class actively [35].

Differentiated learning begins with diagnostic assessment. Diagnostic assessment is the most fundamental stage in a differentiated learning process. The results of the diagnostic assessment reveal differences in the learning styles of each student in chemistry classes at SMAN 1 Langsa. A learning style represents the distinctive way a person prefers to understand, absorb, and retain new knowledge. Neil Fleming introduced the concept of various learning styles, which include visual, auditory, reading/writing, and kinesthetic modes [36]. Students often favor different methods of learning, and many use a combination of styles. For instance, visual learners grasp concepts more effectively through images and diagrams, auditory learners learn best through spoken instruction or discussion, while kinesthetic learners prefer engaging in practical, hands-on experiences [37]. To enhance learning effectiveness, educators and institutions should recognize and accommodate the diverse learning preferences of their students [38].

The identification of students' learning styles at SMAN 1 Langsa is conducted through the use of the VARK (Visual, Auditory, Reading/Write, and Kinesthetic) learning style questionnaire, version 8.01. The VARK model is widely used to review students' learning styles [39, 40]. Based on the results of the diagnostic assessment, the variations in students' learning styles include 26 % visual, 29% audiovisual, 11% reading/writing, and 34% kinesthetic. The results of this assessment serve as a reference in developing LKPD that meets the needs of students.

Based on the results of preliminary observations at SMAN 1 Langsa, it is evident that the critical thinking skills of students in learning chemistry, particularly in the material of chemical reaction equations, remain low. In science education, particularly in chemistry, where students must grasp complex and abstract concepts, differentiated learning with customized student worksheets can support students in understanding key concepts and develop critical thinking and problem-solving skills [41, 42]. Some research results indicate an increase in concept understanding and CTS among students through differentiated learning [43–45]. Other research shown that the development of differentiated LKPD is very effective to use in math learning [46, 47].

Differentiated learning in this study is implemented through the application of LKPD, which focuses on aspects of process differentiation and is based on the learning styles of students. Based on these problems, this study aims to use differentiated LKPD on chemical reaction equations to realize learning that is proactive, rooted in assessment, and learner-oriented. This differentiated LKPD is designed according to the learning style of students to enhance their understanding of chemical concepts related to reaction equations, as well as improve students' CTS. With improved learning outcomes and CTS, students will be better equipped to solve problems and make informed decisions based on logical analysis and accurate data, thereby supporting their success in navigating academic challenges and real-life situations. This research question in this study concerns the feasibility of the Differentiated LKPD in chemistry learning and its impact on enhancing students' CTS in chemistry learning.

2. Materials and Methods

This study used a quantitative approach with a quasi-experimental design. According to Sugiyono [48], quasi-experimental research is conducted to examine how independent variables influence dependent variables under controlled conditions. This study utilized a Control Group Pretest-Posttest Design. The research population consisted of class X students from SMAN 1 Langsa during the even semester of the 2024/2025 academic year. Two out of ten classes were chosen as samples: class X.E-8 served as the experimental group, and class X.E-6 as the control group, with each class comprising 38 students. The sampling technique applied was simple random sampling, meaning participants were selected randomly without considering any stratification within the population [48]. In this study, the population was regarded as homogeneous because all students were at the same grade level, followed an identical curriculum, and there were no specialized or advanced classes that differentiated them.

The research instrument used was a CTS question description consisting of 5 questions, guided by the CTS indicator. The questions were validated by an expert from the Department of Chemistry at Syiah Kuala University, who confirmed that all items demonstrate high validity. This indicates that they effectively measure the intended indicators, are conceptually sound, and are free from ambiguity. In addition, all test items have also been empirically tested and have fulfilled the appropriate criteria of validity, reliability, discriminating power, and difficulty level [49].

Data was collected using a CTS question description about chemical reaction equations at the pre-test and post-test. The pre-test measures students' initial knowledge before being given the treatment. The treatment consisted of applying differentiated LKPD to the experimental group, whereas LKPD was not differentiated in the control group. Then, the students were given a post-test to measure the knowledge after the treatment.

Furthermore, the collected data were examined for normality and homogeneity. Following the normality test, the data homogeneity test is performed. This stage seeks to determine if the data from the control and experimental classes are homogeneous or not. Analysis of critical thinking skills improvement using normality gain [50], Normality test with Shapiro-Wilk [51], and the One-Way Anova to find out the significant difference between the experimental class taught using differentiated LKPD and the control class taught using undifferentiated LKPD. Normality, homogeneity, and One-way ANOVA tests were performed using SPSS.

3. Results and Discussion

By the objectives of the study as formulated in the introduction, the data displayed are related to (1) the feasibility of the Differentiated LKPD Design in chemistry learning and (2) the treatment effect on enhancing students' CTS in chemistry learning.

3.1. The Feasibility of Differentiated LKPD Design in Chemistry Learning

The differentiated LKPD, as shown in Figure 1, is developed to meet students' needs in learning chemistry. The preparation of LKPD is based on the results of curriculum, student, teacher, and infrastructure analyses. Differentiated LKPD in this research refers to the Merdeka curriculum on chemical reaction equation material. This LKPD focuses on the differentiation aspect of the process based on the learning style of students.

Figure 1. Differentiated LKPD design.

Table 1. Validity and reliability of Differentiated LKPD design.

Category	Aiken' Index	Validity Standard	Inter-Rater Agreement (IRA)	Reliability Standard
Media & Materials	0.87	Valid	0.617	Good agreement beyond chance

Table 2. Result of normality test on CTS.

Class	Shapiro-Wilk Test			
	Statistic	df	Sig	
			Pre-Test	Post-Test
Experiment	0.959	38	0.266	0.069
Control	0.939	38	0.283	0.084

Table 3. Result of N-gain on CTS.

Class	Pre-Test	Post-Test	N. Gain
Experiment	38.63	85.48	0.73
Control	35.46	72.70	0.52

Table 4. Result of homogeneity test on CTS.

Class	Lavene's Statistic	df1	df2	Sig.
Experiment	0.196	1	74	.714
Control	0.054	1	74	.830

Process differentiation is learning in which the teacher adjusts the way students understand the subject matter (process) through different LKPD. The results of the diagnostic assessment show a variety of learning styles of students, including 26% visual, 29% audiovisual, 11% reading/writing, and 34% kinesthetic. This differentiated LKPD contains teaching materials for students with visual, auditory, reading/writing, and kinesthetic learning styles.

The feasibility of the Differentiated LKPD Design is assessed by a media and material expert [48]. Assessment of Differentiated

LKPD is based on aspects of presentability, content feasibility, language, and writing feasibility. The results of the validity test using the Aiken Index and the reliability test using the Inter-Rater Agreement (IRA) on the differentiated LKPD are presented in Table 1. Based on Table 1, the result of calculating the Aiken Index is 0,87, and it can be concluded that the Differentiated LKPD was Valid. Furthermore, the calculation result of the IRA is 0.67. This result indicates that the differentiated LKPD was reliable, as evidenced by the agreement among experts, which is not coincidental (excellent agreement beyond chance [52]).

3.2. The Treatment Effect on Enhancing Students' CTS In Chemistry Learning.

The implementation of the research began with a pre-test administered in the experimental and control classes to determine the initial students' CTS. Then, they continued with the treatment, specifically explaining the chemical reaction using differentiated LKPD in the experimental class and undifferentiated LKPD in the control class. At the end of the lesson, all students were required to complete the post-test to assess the enhancement of their CTS.

Table 2 summarizes the normality test results, showing that both the experimental and control classes obtained sig values greater than 0.05, indicating that the data are normally distributed. As presented in Table 3, the N-gain for the experimental class was 0.73 (high) and for the control class was 0.52 (medium). Following the normality test, a homogeneity test was conducted to determine the similarity of variance between the two groups.

Based on Table 4, it is known that the homogeneity test results obtained are significant. > 0.05. This means that the data is homogeneous.

After verifying that the CTS test data is normal and homogeneous, hypothesis testing was conducted using One-Way ANOVA to determine the significant difference between the experimental class taught using differentiated LKPD and the control class taught using undifferentiated LKPD.

Table 5. Result of one-way ANOVA test.

Class	Mean Square	Sig
Pretest of Experiment & Control	86,621	.496
Posttest of Experiment & Control	58,488	.024

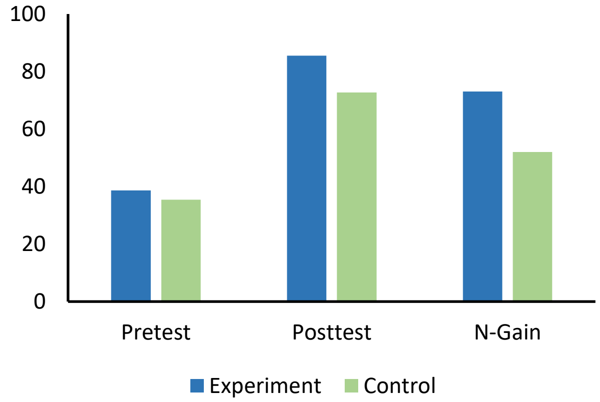

Figure 2. N-gain test results on students' CTS.

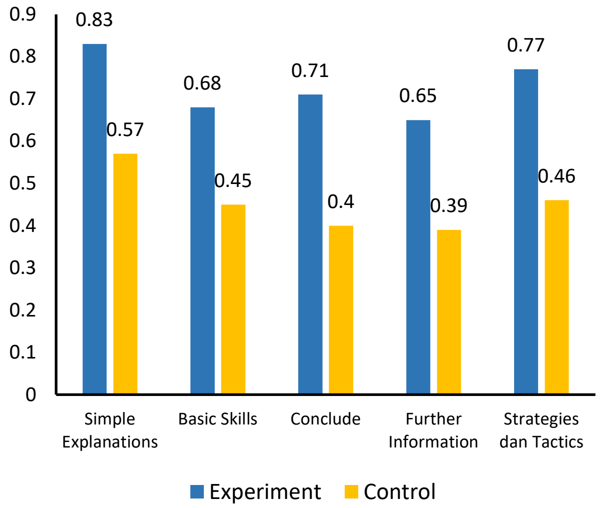

Figure 3. N-gain of students' CTS based on CTS indicators.

Based on Table 5, it can be seen that the pre-test significance is greater than 0.05. This indicates that, in the initial test (pre-test), there is no difference in the students' CTS scores between the experimental and control classes. While in the post-test, a significant result was obtained. <0.05. This indicates a difference in the improvement of students' CTS in the experimental class, which was taught using differentiated LKPD, and the control class, which was taught using undifferentiated LKPD. Figure 2 shows the results of the N-gain test in the experimental and control classes on students' CTS.

Some previous research results that support improving students' CTS through differentiated learning include those by Goyibova et al. [53], Dimas et al. [46], Tirtawati [54], Wulan et al. [47], and Apriyantini & Sukendra [55]. The results of their research indicated that differentiated learning, as implemented through LKPD can enhance students' CTS, learning outcomes, and learning activities. Furthermore, the implementation of differentiated learning can enhance learning motivation by tailoring learning instruction, content, and assessment to meet the diverse needs of students.

Analysis of students' CTS was also carried out based on N-gain per indicator, which aims to clarify differences in the improvement of students' CTS on each question. The indicators of students' CTS consist of: (I) Providing simple explanations, (II) Building basic skills, (III) Concluding, (IV) Providing further explanation, and (V) Developing strategies and tactics.

Based on the N-Gain results of each CTS indicator in Figure 3, students in the experimental class experienced a greater improvement in CTS compared to those in the control class. This means that the use of differentiated LKPD is more effective than undifferentiated LKPD [56–58].

4. Conclusions

Based on the study results, it can be concluded that the Differentiated LKPD is feasible for use in chemistry learning, with a validity and reliability value of 0.87 and an Inter-Rater Agreement of 0.617. can increase students' CTS. In addition, Differentiated LKPD can increase students' CTS in chemistry learning, especially in chemical reaction equations. The limitation of this research is time constraints in implementing differentiated learning.

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Informed Consent Statement: This study has obtained permission from SMA Negeri 1 Langsa and Syiah Kuala University. The school and university have approved all procedures by the applicable research policies.

Data Availability Statement: The data supporting this study are available upon request from the corresponding author.

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