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Designing Electronic Student Worksheets to Enhance Chemical Literacy and Collaborative Attitudes

Febri Nurason[1]*, Sri Atun[2], dan Hana' Fadhilah Retiyanto[3]

[1,2,3] Program Studi Pendidikan Kimia Universitas Negeri Yogyakarta
Jl. Colombo, No.1 Karangmalang, Yogyakarta 55281

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Abstract

This study investigates the feasibility of the integrated E-LKPD Chemo-entrepreneurship, its reception among students, and its impact on chemical literacy and collaborative attitudes. Employing the 4D Research and Development model with a quasi-experimental post-test only design, the research involved 72 randomly selected students from SMAN 9 Yogyakarta and was analyzed using MANOVA. The results demonstrate that the E-LKPD is highly valid according to experts, well-received by teachers and students, and exerts a significant influence on both chemical literacy and collaborative attitudes. Its effective contribution is 15% for chemical literacy (very high) and 6.1% for collaborative attitudes (moderate).

Keywords: *Buffer Solution; E-LKPD; TBL Strategy; Chemo-entrepreneurship; Chemical Literacy; Collaborative Attitude*

Introduction

According to the 2022 results of the Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Co-operation and Development (OECD), scientific literacy among Indonesian students remains categorized as low, with an average score of 383—slightly below the international average of 384. Indonesia occupies a subordinate position, ranking 67th in science, 71st in reading, and 70th in mathematics out of 81 participating countries (Kemdikbudristek, 2023). This underperformance is purportedly influenced by instructional patterns that prioritize rote memorization over conceptual understanding, the prevalence of lecture-based methods that inhibit student engagement, and a lack of contextual integration with the students' cultural backgrounds (Swanson et al., 2019). Although Indonesia's ranking in scientific proficiency ascended by six positions compared to 2018, the average score actually experienced a significant decline of 13 points, which is nearly commensurate with the 12-point decrease observed in the global average.

Electronic Student Worksheets (E-LKPD) can be integrated with the Chemo-Entrepreneurship (CEP) approach as a strategic effort to enhance student engagement in the learning process. Research conducted by Sumarti (2018) demonstrates that the implementation of CEP-integrated E-LKPD

effectively improves students' scientific literacy, as it encourages them to apply theoretical knowledge acquired in school to real-world scenarios and fosters an awareness of scientific principles in daily activities. Furthermore, chemical literacy can be systematically cultivated through the application of CEP-integrated E-LKPD (Sutarto et al., 2021).

Research by Le (2018) indicates that student collaborative attitudes remain deficient, characterized by a disparity in participatory engagement during discussions, where active involvement is limited to a subset of students while others remain passive. This condition underscores the necessity for instructional strategies capable of systematically cultivating collaborative skills (Pan & Liu, 2025). Furthermore, Hancock (2024) investigated the implementation of Team-Based Learning (TBL) strategies within E-LKPD, which was proven to facilitate students in conducting investigations, resolving problems, and generating artifacts (Sanders et al., 2025). The TBL strategy represents a 21st-century pedagogical model highly pertinent to fostering collaborative competencies (Lunt et al., 2025).

Chemistry is widely recognized as a discipline characterized by its relative difficulty and abstract nature (Darby et al., 2023). Within this field, buffer solutions represent a specific topic that presents significant challenges for students, frequently giving rise to misconceptions during the instructional process (Muntholib et al., 2020). Generally, pedagogical approaches to this subject continue to emphasize rote memorization over conceptual understanding and practical application in daily life, thereby contributing to suboptimal student learning outcomes (Harianto et al., 2025). To address these challenges, the Team-Based Learning (TBL) strategy can be implemented within the instruction of buffer solutions (Sanders et al., 2025).

Method

The research procedure adapts the 4D development model proposed by Thiagarajan (1974), which comprises four distinct stages: define, design, develop, and disseminate. The research subjects consisted of 72 students at SMAN 9 Yogyakarta, divided into an experimental group (n=36) and a control group (n=36), selected through a random sampling technique. The research trial was conducted utilizing a quasi-experimental approach, specifically a post-test only design, as delineated in Table 1.

Table 1. *Posttest Only Control Group Design*

Class	Treatment	*Posttest*
Experiment	X	Q1Q2
Control	Y	Q1Q2

Keterangan:

X : Treatment with CEP

Y : Treatment with Scientific Approach

Q1 : *Post-test* literacy chemistry

Q1 : Collaboration questionnaire

The assessment instruments, comprising test items for measuring chemical literacy and questionnaires for evaluating collaborative attitudes, underwent theoretical validation by two experts from Universitas Negeri Yogyakarta. Subsequently, construct validity was assessed by administering the instruments to 24 students at SMAN 3 Yogyakarta who had completed the topic of buffer solutions. The gathered data were then analyzed using SPSS software to determine the validity and reliability of the instruments. Furthermore, the influence of the independent variables on chemical literacy and collaborative attitudes was examined through a Multivariate Analysis of Variance (MANOVA) to ascertain the effective contribution of each variable.

Results and Discussion

1. Define

1.1 Preliminary Analysis

The interview results indicate that the availability of instructional materials specifically designed to bolster students' chemical literacy remains limited; furthermore, project-based learning is seldom implemented to assess collaborative attitudes during the instructional process. These findings underscore a critical need for the development of electronic student worksheets (E-LKPD) and the integration of project-based learning strategies. Such interventions are anticipated to enhance the efficacy of the learning process in fostering both chemical literacy and students' collaborative attitudes (Ridwan et al., 2025).

1.2 Student Analysis

A learner analysis was conducted to identify the target audience for the development of the electronic student worksheets (E-LKPD). This stage involved 36 grade XI students at SMAN 9 Yogyakarta and was executed through the distribution of a needs assessment questionnaire. The findings revealed that students encounter difficulties in comprehending chemical concepts when integrated with daily life phenomena. Consequently, there is a clear demand for instructional materials capable of facilitating conceptual understanding while maintaining relevance to real-world contexts (Mashami et al., 2025).

1.3 Task Analysis

A task analysis was performed to ensure that the construction of the research instruments aligns with the learning outcomes prescribed by the *Kurikulum Merdeka* (Independent Curriculum) for Phase F, Grade XI Chemistry at SMAN 9 Yogyakarta.

2. Design

2.1 Construction of the E-LKPD

The Electronic Student Worksheets (E-LKPD), based on the Team-Based Learning (TBL) strategy and integrated with Chemo-entrepreneurship, were constructed in accordance with the learning outcomes, learning objective flows, and specific learning objectives for Phase F, Grade XI, particularly within the topic of buffer solutions. Following the development phase, the E-LKPD was implemented as instructional material in the experimental class across three sessions. Subsequently, a post-test was administered at the conclusion of the final session to evaluate the intervention's efficacy.

2.2Draft construction of the E-LKPD

The initial draft of the electronic student worksheets (E-LKPD), based on a Team-Based Learning (TBL) strategy integrated with Chemo-entrepreneurship, was constructed prior to expert validation. The structural components of the E-LKPD include a cover page, preface, table of contents, lists of tables and figures, instructions for use, learning objectives, a concept map, three learning activities, a bibliography, and the author's profile. The development was executed using the Canva application, subsequently converted into a flipbook format via Heyzine to facilitate online access with an interface resembling a physical book. Furthermore, the E-LKPD is equipped with various instructional links, such as YouTube videos, illustrative images, downloadable worksheets, and practice exercises. These integrated features are intended to provide students with the opportunity to expand their academic references with greater flexibility (Sutiani et al., 2025).

2.3Design of the Research Instruments

This study assesses two dependent variables: chemical literacy and collaborative attitudes. Both variables were measured via a post-test administered at the conclusion of the sessions in both the

experimental and control classes. Chemical literacy was evaluated using 14 essay questions that had undergone feasibility testing by experts and were declared valid and reliable during the empirical testing phase. Similarly, collaborative attitudes were measured using a 10-item questionnaire, which was also expert-validated and proven valid and reliable through empirical analysis (Kim et al., 2022). Furthermore, a student response questionnaire regarding the E-LKPD was constructed, validated by experts, and administered to the experimental class at the end of the study. A practicality questionnaire was also developed for chemistry teachers to evaluate the E-LKPD utilized in the experimental class, employing an expert-validated instrument. Finally, the Lesson Plans (*Rencana Pelaksanaan Pembelajaran* or RPP) were designed using the Team-Based Learning (TBL) strategy for the experimental class and a scientific approach for the control class, following a rigorous expert validation process.

3. Develop

3.1 Theoretical Validation of the E-LKPD

The theoretical validation was conducted by subject matter and media experts, comprising faculty members from Universitas Negeri Yogyakarta. The recapitulation of the Aiken's V analysis results is presented as follows:

Table 2. Results of the Subject Matter Expert Validation

Aspects	Total Average Scores	Category
Content	0,88	Very Valid
Presentation of materials	0,83	Very Valid
Language	0,90	Very Valid

Table 3. Results of the Subject Media Expert Validation

Aspects	Total Average Scores	Category
Construction	0,83	Very Valid
Display	0,92	Very Valid

3.2 Teachers Response

Following the expert validation and subsequent revisions, the E-LKPD underwent an evaluative review by five chemistry teachers to assess its practicality. The comprehensive results of this practicality assessment are detailed in Table 4.

Table 4. Practicality Test Results

Aspects	Total Average Scores	Criteria
Content	86	Excellent
Construction	85	Excellent
Language	90	Excellent
Display	82	Excellent

3.3 Construct Validity of the Chemical Literacy Test and Collaborative Attitude Questionnaire

Table 5. Validity of the Chemical Literacy Instrument

Number	Score r	Criteria	Number	Score r	Criteria	Number	Score r	Criteria
1	0.435	Valid	7	0.766	Valid	13	0,589	Valid
2	0.673	Valid	8	0.453	Valid	14	0,553	Valid
3	0.673	Valid	9	0,541	Valid	15	0,387	No Valid
4	0.435	Valid	10	0,728	Valid	16	0,030	No Valid
5	0.499	Valid	11	0,728	Valid			
6	0.475	Valid	12	0,502	Valid			

Table 6. Validity of the Collaborative Attitude Instrument

Number	Score r	Criteria
1	0,511	Valid
2	0,657	Valid
3	0,731	Valid
4	0,750	Valid
5	0,533	Valid
6	0,573	Valid
7	0,771	Valid
8	0,674	Valid
9	0,463	Valid
10	0,911	Valid

Table 7. Reliability Results of the Dependent Variables

Chemical Literacy	Collaboration Attitude
0,79 > 0,60	0,85 > 0,60

4. Diseminate

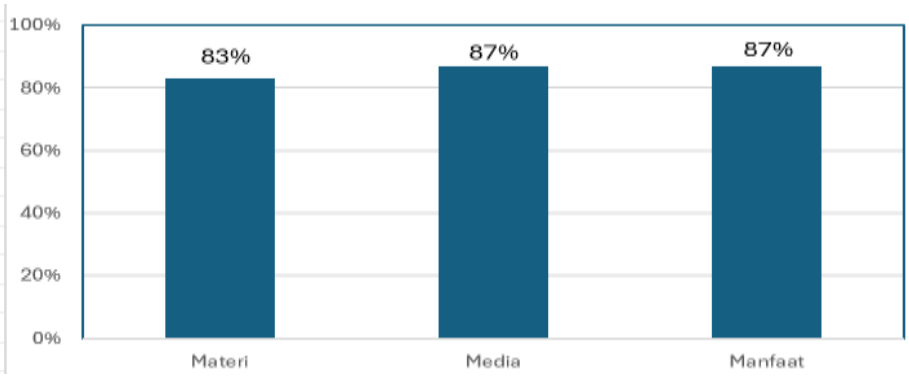
The subsequent phase in the product development sequence is the dissemination stage, which involves the distribution of the E-LKPD to chemistry teachers to support instructional processes and provide supplementary learning resources for students (Purnama et al., 2020). The dissemination of the E-LKPD was conducted at SMAN 9 Yogyakarta as the primary research site. Furthermore, the dissemination is manifested through the authorship of a scientific article based on the research findings, intended for publication in a reputable journal to ensure that the practical and theoretical benefits reach a broader academic audience.

5. Product Implementation Results

The field testing was conducted in the experimental class utilizing the E-LKPD based on the Team-Based Learning (TBL) strategy integrated with Chemo-entrepreneurship, while the control class employed a scientific approach (Ariffin, 2021). Each group participated in three sessions, followed by the administration of a post-test. The resulting post-test data are presented in Table 8.

Table 8. Total Average of Experiment and Control

Class	Total Average of Chemical Literacy	Total Average of Collaboration Attitude
Experiment	80,19	83,26
Control	74,03	78,89



The student response questionnaire results, illustrated in Figure 1, constitute a component of the E-LKPD feasibility study, following expert validation and practitioner review by chemistry teachers prior to field testing in the experimental class. The questionnaires were administered to 36 students in the experimental group at SMAN 9 Yogyakarta upon the completion of the post-test (Dewi & Mashami, 2019).

Table 9. *Test of Between-Subjects Effects*

Dependent Variabel	Sign	*Eta Squared*
Chemical Literacy	0,001	0,150
Collaboration	0,037	0,061

Table 9 demonstrates that all dependent variables yielded significance values below 0.05, thereby indicating that the implementation of the Team-Based Learning-based E-LKPD integrated with Chemo-entrepreneurship exerts a significant simultaneous influence on both chemical literacy and collaboration (Han et al., 2023). The magnitude of the effective contribution for each variable is delineated by the eta-squared values, where chemical literacy accounted for 0.15 (15%), classified within the very high category, and collaboration contributed 0.061 (6.1%), situated within the moderate category (Masadeh et al., 2024).

It is concluded that chemical literacy improves significantly through the utilization of the Team-Based Learning-based E-LKPD integrated with chemo-entrepreneurship. This finding is corroborated by the research of Muntholib (2020), which asserts that the integration of chemo-entrepreneurship into instructional processes—by leveraging local phenomena and establishing connections with scientific knowledge—serves as an effective strategy for enhancing chemical literacy. Furthermore, the authentic problems presented within the E-LKPD facilitate the development of chemical literacy, as students are systematically trained to solve real-world challenges (Harianto et al., 2025)

The E-LKPD facilitates student collaboration within teams, thereby enabling the reciprocal exchange of information during both laboratory practicals and collaborative projects. This observation aligns with the findings of Pan & Liu (2025), who posit that collaborative proficiency is a fundamental element of the learning process, as effective pedagogical frameworks facilitate interpersonal interaction and the mutual sharing of information among students.

Students are expected not only to synthesize products based on buffer solution principles within an academic setting but also to extrapolate these competencies into viable entrepreneurial opportunities through collaborative efforts. Furthermore, a collaborative attitude is pivotal in both instructional environments and the professional workforce (Ariffin, 2021).

Conclusion

The research findings demonstrate that the E-LKPD was categorized as highly valid by experts and met the "excellent" criteria according to chemistry practitioners. Furthermore, the E-LKPD elicited a highly positive response from students. Statistical analysis indicates a significant influence of E-LKPD implementation on chemical literacy and collaborative attitudes when comparing the experimental and control groups. Specifically, the effective contribution of the E-LKPD toward chemical literacy was 15.1%, falling within the "very high" category, while its contribution to collaborative attitudes was 6.2%, which is classified as "moderate.

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