

EFFECTIVENESS OF FLIPPED LEARNING WITH DEEP LEARNING FRAMEWORK BASED ON MULTIPLE REPRESENTATIONS IN ACID-BASE MATERIAL TO IMPROVE SCIENTIFIC PROCESS SKILLS

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Abstract

This study aims to describe the effectiveness of flipped learning with a deep learning framework based on multiple representations on acid-base material to improve science process skills. The population in this study were all grade XI students of SMA Negeri 1 Bandar Lampung in the 2025/2026 academic year. The research sample was taken using a purposive sampling technique and obtained class F.1 as the experimental class and class F.2 as the control class. In the experimental class, flipped learning with a deep learning framework based on multiple representations was applied and the control class was applied with conventional learning. This study is a quasi-experimental study with a non-equivalent control group design. The instrument used was a science process skills pretest–posttest test. Supporting data on student activities were collected using observation sheets. Data analysis in this study included analysis of primary data, supporting data, and hypothesis testing. Hypothesis testing used was a test for differences in two means with an independent sample t-test. The results showed that the average N-gain of students' science process skills in the experimental class was significantly higher than the control class, with the average N-gain of students' science process skills in the experimental class being categorized as moderate. It can be concluded that flipped learning with a deep learning framework based on multiple representations on acid-base material is effective in improving students' science process skills.

Keywords: flipped learning, deep learning, multiple representations, acid base, science process skills

INTRODUCTION

Science is not only oriented towards products or mastery of concepts, but also how the process must be taken to produce a scientific product [1]. One branch of science is chemistry, which has two main dimensions, namely chemistry as a product and chemistry as a process [2]. So in chemistry learning that involves scientific work, mastery of science process skills, such as observing, grouping, interpreting, predicting, proposing hypotheses, applying concepts, and communicating the results of investigations is one of the competencies that need to be developed [3]. Science process skills play an important role in helping students understand chemical concepts, develop logical and systematic thinking skills, and improve problem-solving skills needed in everyday life [4,5].

However, the results of the 2022 Programme for International Student Assessment (PISA) show that Indonesia scored 383 points in scientific literacy, significantly lower than the OECD average of 485 points, by 102 points. Students still experience difficulties in explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting scientific data and evidence. These competencies assessed in PISA are closely related to students' science process skills, as achieving them requires students to master fundamental science process skills, such as observing, classifying, interpreting data, designing investigations, and drawing evidence-based conclusions [6]. Therefore, the low achievement of Indonesian students in the PISA science assessment indicates that the science process skills underlying these competencies still need to be strengthened.

This is also in line with information obtained through interviews with chemistry teachers and 11th grade students, where in the learning process, various activities that can train students' science process skills are not practiced enough. Therefore, in science learning, including chemistry, it is very important to optimize learning so that learning is not only oriented towards mastering concepts, but also able to facilitate the development of students' science process skills through various learning experiences [7].

The need to address chemistry learning issues aligns with the independent curriculum policy, which emphasizes the importance of in-depth learning, a framework focused on enhancing the learning process through the creation of a conscious, meaningful, and enjoyable learning environment [8]. Through these learning experiences, students can build knowledge through the learning process, providing students with the opportunity to develop science process skills [9].

The implementation of the deep learning framework relies heavily on pedagogical practices that support the creation of meaningful learning experiences for students throughout the learning process [10]. To facilitate these learning experiences, learning strategies should provide students with opportunities to engage in learning both inside and outside the classroom. One pedagogical approach that supports the implementation of the deep learning framework is the flipped learning strategy, which organizes learning into two phases: out class and in class activities [11]. Both out class and in class activities are integrated with the stages of the guided inquiry model, enabling students to actively construct knowledge and develop their science process skills [12].

In chemistry learning, particularly on the topic of acids and bases, many concepts are abstract, making them difficult for students to understand [13]. Therefore, multiple representations consisting of macroscopic, submicroscopic, and symbolic representations are essential for helping students connect observable phenomena with particle-level explanations and symbolic representations, thereby facilitating a

deeper understanding of chemical concepts [14]. The integration of multiple representations can be effectively facilitated through the phases of flipped learning. During out class activities, students are introduced to macroscopic representations through instructional videos, enabling them to build an initial understanding before classroom learning. During in-class activities, students deepen their conceptual understanding through guided inquiry activities by connecting macroscopic observations with submicroscopic explanations and symbolic representations. This learning process encourages students to observe, classify, interpret data, and draw evidence-based conclusions, thereby supporting the development of science process skills [11,14].

Various previous studies have shown that flipped learning can improve students' conceptual understanding and learning readiness compared to conventional learning [12,15]. The application of a deep learning framework has also been reported to support more meaningful, reflective, and student-centered learning [16,17]. Then, other studies have shown that the use of multiple representations can help conceptual understanding while also helping to train students' science process skills [14]. These three approaches have complementary roles in supporting the development of students' science process skills. The deep learning framework provides meaningful learning experiences, flipped learning extends learning opportunities through out-of-class and in-class activities, and multiple representations help students understand abstract chemical concepts while engaging in scientific processes. Therefore, integrating these approaches has the potential to better facilitate the development of students' science process skills.

However, previous research generally examines flipped learning, the deep learning framework, and multiple representations separately or only combines the two approaches. Furthermore, most studies focus more on learning outcomes and conceptual understanding. Research integrating the deep learning framework as a foundation for learning experiences, flipped learning as a pedagogical practice, and multiple representations as a basis for learning activities to improve science

process skills in acid-base topics is still limited. Therefore, this study offers a novelty in the form of integrating these three components into a single learning design to provide a more meaningful learning experience while simultaneously improving students' science process skills.

Based on this description, this study aims to describe the effectiveness of implementing flipped learning with a deep learning framework based on multiple representations on acid-base material to improve students' science process skills.

METHOD

This study uses a quasi-experimental method with a non-equivalent control group design presented in Table 1.

Table 1. Research Design

Class	Pretest	Treatment	Posttest
Experimental	O	X	O
Control	O	C	O

[18]

Description:

- O = Pretest and posttest of students' science process skills
X = Implementation of flipped learning with a multiple representation-based deep learning framework
C = Implementation of conventional learning

This research was conducted at SMA Negeri 1 Bandar Lampung. The population consisted of all eleventh-grade students from nine classes. The sample was selected using a purposive sampling technique. This technique resulted in class XI F.1, consisting of 36 students, being designated as the experimental class, while class XI F.2, consisting of 36 students, was designated as the control class.

Both research classes were given a pretest to measure students' initial science process skills. Next, both research classes were given a treatment: the experimental class implemented flipped learning with a multiple representation-based deep learning framework, and the control class implemented conventional learning. After the treatment was completed, both research classes were given a posttest to measure students' final science process skills.

The research instrument consisted of pretest and posttest questions on science process skills in the form of five essay questions measuring three indicators: observing, classifying, and interpreting. Supporting data were collected using observation sheets of student activities during learning activities out class, such as expressing opinions, and during in class activities, such as asking questions, expressing opinions, and collaborating. The science process skills instrument underwent content validation through expert judgment by the supervising lecturer. Based on the expert's feedback, the instrument was revised until all items were considered appropriate for measuring students' science process skills and deemed suitable for use in this study.

Data analysis was conducted through several stages. First, calculating the average pretest and posttest scores for students' science process skills. Second, calculating the N-gain of each student's science process skills. Third, calculating the average N-gain. And fourth, calculating the average N-gain for each science process skill indicator. The results of the average N-gain calculation were then interpreted using the N-gain criteria presented in Table 2.

Table 2. N-gain Criteria

N-gain value	Criteria
$\langle g \rangle \geq 0.7$	High
$0.3 \leq \langle g \rangle < 0.7$	Moderate
$\langle g \rangle < 0.3$	Low

[19]

Next, supporting data analysis was conducted, namely student activities in both out class and in class activities, by calculating the percentage of each activity for each meeting. The percentages obtained were interpreted using the student activity criteria presented in Table 3.

Table 3. Student Activity Criteria

Persentase (%)	Kriteria
81-100	Very High
61-80	High
41-60	Moderate
21-40	Low
0-20	Very Low

[20]

Hypothesis testing was conducted using statistical analysis to determine whether the average N-gain of students' science process skills in the experimental class was significantly higher than that of the control class. Prior to hypothesis testing, the assumptions of normality and homogeneity were examined using the Kolmogorov–Smirnov test and Levene's test, respectively. If the data met the assumptions of normality and homogeneity, the Independent Samples t-test was used. Otherwise, the Mann–Whitney U test was employed as a non-parametric alternative [21]. The hypothesis was formulated as follows:

- $H_0 = \mu_1 \leq \mu_2$ = The average N-gain of students' science process skills in the experimental class using flipped learning with a deep learning framework based on multiple representations was lower or the same as the average N-gain of students' science process skills in the control class using conventional learning on acid-base material.
- $H_1 = \mu_1 > \mu_2$ = The average N-gain of students' science process skills in the experimental class using flipped learning with a deep learning framework based on multiple representations was higher than the average N-gain of students' science process skills in the control class using conventional learning on acid-base material.

The hypothesis decision was based on the one-tailed significance value as follows:

- If Sig. (1-tailed) < 0.05, H_0 is rejected and H_1 is accepted.
- If Sig. (1-tailed) > 0.05, H_0 is accepted and H_1 is rejected.

RESULTS AND DISCUSSION

Students in the experimental and control classes were given a pretest before the learning treatment and a posttest after the learning process to assess improvements in science process skills following the treatment. Based on the pretest and posttest results for both classes, there was a clear difference in the in the average scores pretest and posttest. The average pretest and posttest scores for science process skills and the average N-gain of

science process skills in the experimental and control classes are presented in Figures 1 and 2.

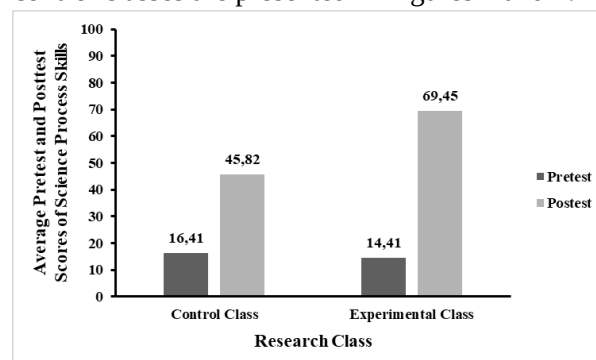


Figure 1. Average Pretest Posttest Score

Figure 1 shows an increase in scores in both research classes. The average pretest scores for science process skills in both research classes were relatively similar, indicating that the students had comparable initial science process skills before the treatment. After the treatment, both classes experienced an increase in their average scores. However, the increase in the average post-test score in the experimental class that implemented flipped learning with a multiple representation-based deep learning framework was higher than the control class that implemented conventional learning.

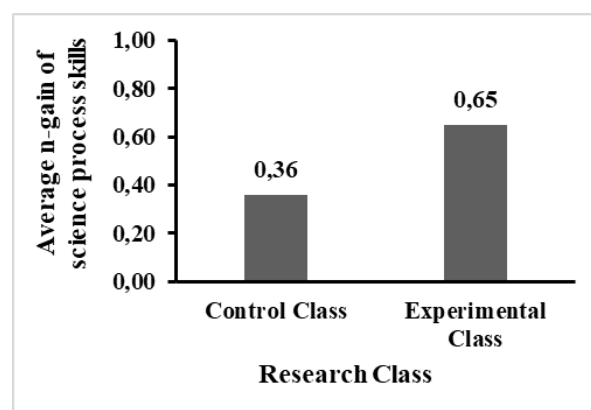


Figure 2. Average N-gain of Science Process Skills

Figure 2 presents a comparison of the mean N-gain scores of students' science process skills in the experimental and control classes. The experimental class achieved a higher mean N-gain score than the control class, with both classes falling into the medium category according to Hake's criteria. However, the experimental class showed a greater improvement, with a difference

of 0.29 in the mean N-gain score. Furthermore, the proportion of N-gain students achieving was higher in the experimental class compared to the control class presented in Table 4, indicating that the applied learning facilitated greater improvement in students' science process skills.

Table 4. Percentage of N-gain of Students' Science Process Skills

N-gain Criteria	Experimental Class	Control Class
High	50%	0%
Moderate	47%	69%
Low	3%	31%

In addition, the N-gain was also analyzed for each indicator of science process skills, namely the indicators of observing, classifying, and interpreting in both research classes showed in Figure 3.

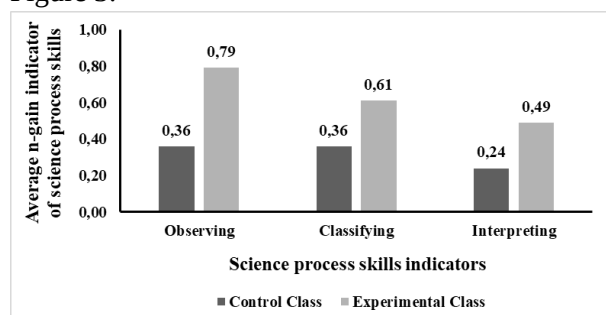


Figure 3. Average N-gain of Each Science Process Skill Indicator

Based on Figure 3, all indicators of science process skills in the experimental class showed a higher N-gain increase compared to the control class. This increase occurred due to differences in the implementation of the learning carried out, where in the experimental class students were given more opportunities to practice various science process skills ranging from observing, grouping, to interpretation through the application of flipped learning with a deep learning framework based on multiple representations on acid-base material, while in the control class conventional learning was applied which did not provide many opportunities for students to practice science process skills.

Improvement in observation indicators is linked to both in class and out class activities. In the out class question-asking stage, students observe acid-base phenomena through learning

videos, images, and contextual discourse as representations at the macroscopic level. These activities reflect the principles of awareness and meaning, and help students build initial knowledge (understanding), in accordance with deep learning experiences. In in-class activities, through practicums at the experiment stage, students provide learning experiences in applying them according to deep learning [8]. Then, observations of animations or submicroscopic images, and the use of symbolic representations in the form of reaction equations at the knowledge synthesis stage, encourage students to practice their observation skills. This series of activities provides students with broader opportunities to practice their observation skills, thereby improving them.

The improvement of classifying indicators is linked to in class activities, particularly at the knowledge synthesis stage. Through analyzing observation results by identifying similarities and differences in the characteristics of each solution, students can group them based on their acidic and basic properties. This activity provides students with the opportunity to develop the ability to classify objects based on certain characteristics, which is an important aspect of grouping skills [3]. This activity is in line with the principle of meaningfulness and helps students build a learning experience that understands according to the deep learning framework, because students build conceptual understanding through analyzing and processing observation results, not simply memorizing information.

The improvement in interpreting indicators is associated with in class activities at the knowledge synthesis stage. Through various activities analyzing practicum results and discussing questions in LKPD compiled using submicroscopic and symbolic representations, students are encouraged to connect observation results with various representations so they can draw conclusions based on the evidence obtained. This is in line with Arrofa who stated that learning using multiple representations can improve students' science process skills [14]. This process aligns with the learning experience of understanding and applying through analysis of

observation results to draw conclusions based on the knowledge that has been obtained. These activities reflect the meaningful principle in the deep learning framework because students actively build conceptual understanding.

Improvements in science process skills across each indicator were also supported by increased student activity during the implementation of flipped learning with a deep learning framework based on multiple representations, both in out class and in class activities. During the out of class activities, the observed student activity was expressing opinions through the assigned learning tasks based on the learning videos provided before class. During the in-class activities, the observed student activities included asking questions, expressing opinions, and collaborating in group discussions. Student activity data were analyzed by calculating the percentage of each observed activity. The results are presented in Figures 4 and 5.

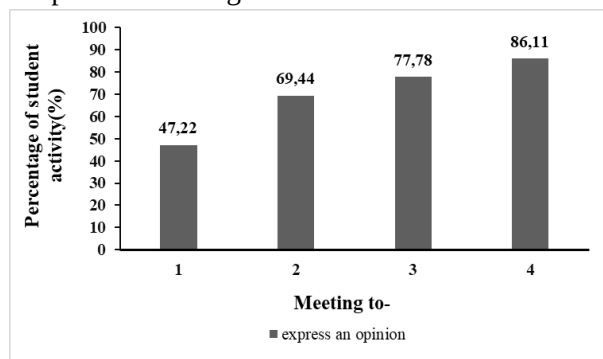


Figure 4. Percentage of Student Activity in Out Class Activities

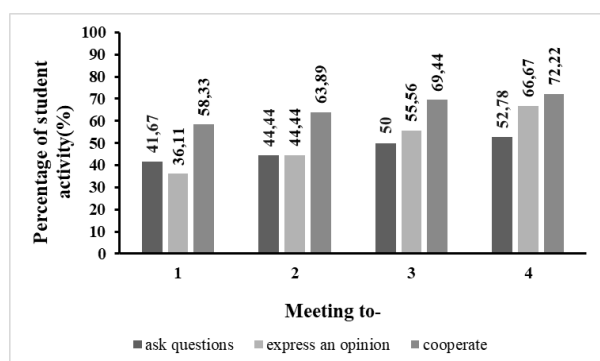


Figure 5. Percentage of Student Activity in Class Activities

Based on Figures 4 and 5, the percentage of student activity increased at each meeting during

both in-class and out-of-class learning. The activities observed during out-of-class learning focused on students expressing their opinions based on information obtained from learning videos through pre-class learning assignments. In contrast, in-class learning emphasized interactive activities, where students asked questions, expressed their opinions, and collaborated with their group members during practical work and when completing student worksheets during the learning process. In out class activities, the activity of expressing opinions increased from moderate criteria in the first meeting to very high criteria in the fourth meeting. Improvements also occurred in in-class activities, which reached a moderate to high criterion in the fourth meeting. This increase in student activity indicates that the implementation of flipped learning with a deep learning framework based on multiple representations can encourage active student involvement, thereby supporting the improvement of students' science process skills.

The effect of the treatment on the sample was demonstrated through hypothesis testing using statistical analysis. Prior to hypothesis testing, the data were first tested for normality and homogeneity are presented in Tables 5 and 6.

Table 5. Results of Normality Test

Class	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Experimental	0.136	36	0.088
Control	0.082	36	0.200

Based on Table 5, the experimental and control classes show a significance value > 0.05 , thus concluding that both research classes come from a normally distributed population.

Table 6. Results of Homogeneity Test

		Levene			
		Statistic	df1	df2	Sig.
Ngain	Based on mean	1.792	1	70	0.185
	Based on median	1.451	1	70	0.232
	Based on median and	1.451	1	67.436	0.233

	Levene Statistic	df1	df2	Sig.
with adjusted df Based on trimmed mean	1.699	1	70	0.197

Table 6 shows the results of the homogeneity test, which obtained a significance value > 0.05 , thus concluding that both research classes have homogeneous variances. Based on the results of the normality and homogeneity tests, namely the data are normally distributed and have homogeneous variances, the assumptions of both tests have been met. Therefore, proceed to the hypothesis testing stage, by testing the difference between two means using the Independent Sample t-Test presented in Table 7.

Table 7. Results of the Independent Samples t-Test

Test Criteria	Test Result	Decision
H_0 is rejected if the Sig. (1-tailed) < 0.05	Sig. (1-tailed) < 0.001	H_0 is rejected

Based on Table 7, the results of the independent sample t-test show a significance value (1-tailed) of < 0.001 , which was lower than the significance level of 0.05. Therefore, H_0 was rejected and H_1 was accepted. These results indicate that the average N-gain of students' science process skills in the experimental class that implemented flipped learning with a deep learning framework based on multiple representation was significantly higher than the control class that implemented conventional learning. Thus, the application of flipped learning with a deep learning framework based on multiple representation in acid-base material is effective in improving students' science process skills.

CONCLUSION

Based on the findings of this study, it can be concluded that the implementation of flipped learning with a deep learning framework based on

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multiple representation in acid-base material is effective in improving students' science process skills. Students who learned through this learning showed a significantly greater improvement in science process skills compared to students who received conventional learning. These findings indicate that the integration of flipped learning through out class and in class learning activities, supported by a deep learning framework based on multiple representation, provides a learning experience that actively engages students in the scientific process and facilitates the development of science process skills. Therefore, this learning can be considered as an alternative to chemistry learning to support the development of students' science process skills.

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