Exploring Guided Discovery Learning: The Effect on Students’ Integrated Ability and Self-Regulated in Chemistry

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Abstract. The purpose of this study was to investigate the effect of a guided discovery learning (GDL) toward students’ integrated ability and self-regulated. The study was post-test only control group research design and the participants consisted of students in senior high school (N = 65). The topic of buffer solution was selected both the experimental class and control class, whereas the experiment class used GDL approach and control class used expository learning (EL). The ‘Integrated Assessment’ and ‘Self-Regulated Questionnaire Form’ were used as data collection tools in the research. Results of the descriptive analysis of post-test showed that the frequency of answers was the higher category for the experimental class than the control class students. In addition, results of the MANOVA test indicated that post-test scores were students in GDL class had significantly higher total integrated ability and self-regulated scores over their traditional counterparts. In this research, it was concluded that the GDL used in relation to the topic of buffer solution had significant effect toward students’ integrated ability.

Keyword: Guided discovery learning; Integrated ability; Self-regulated; Buffer solution.

1. Introduction

Learning requires deliberate process that tends to be permanent and creates a positive impact. Students’ learning outcomes are able to determine a learning quality [1]. Teachers’ qualification and capability in deciding the learning process will support the outcomes which will improve education quality and provides a positive impact to the students in preparing themselves to compete in the future. Through a proper learning process, students are able to practice required abilities in order to compete in the future. Abilities that are needed by the students can be trained through active learning by collecting, analysing, solving problems, and concluding any problems as in chemistry content. Chemistry studies natural phenomena in general, but it specifically studies structures, properties, and changes of chemical along the energy that is involved in chemical change [2]. To investigate natural phenomena makes chemistry be considered as a difficult subject. In a par with it, many chemical phenomena occur on molecular level which makes chemistry becomes harder, buffer solution topic, for instance [3].

Buffer solution, a general topic usually found in chemistry in high school, associate level, and undergraduate level, is a possibly topic faced by students in their daily life where they can find interesting science facts towards it. Buffer solution is related with other topics, for instance chemical equilibrium, acid and base, properties of particles of matter, chemical reaction, stoichiometry, solution chemistry [4]. Unfortunately, many students assume that a chemistry topic in buffer solution is difficult and do not understand the function and the importance of buffer solution topic. They also face
difficulties in solving calculations related to it [5]. According to the recent research conducted by [5] whom investigated college students’ perception and misconception about buffer, it was found that the students experience difficulties in writing chemistry equation and identify pH buffer systems, in defining weak acid / base and base / conjugate acid, and in explaining the relationship between pH, the concentration of hydronium ion, and $K_a$.

In their ground breaking paper of 2011, [6] whom investigate the effectiveness of active learning toward students’ comprehension in acid base reveals that there are more than 40% of students in control class have misconception in determining the form of buffer solution. This findings highlights the findings on recent research conducted by [7] about how capability of text book with scientific approach and inquiry learning model in buffer solution concept which claims that textbook learning only provides materials that are related to the materials itself. Therefore, guided discovery learning (GDL) approach is required in order to equip students with critical thinking so that it is sine qua non for the role key in chemistry learning.

The Guided Discovery Learning (GDL) approach is a learning process which students conduct to discover a new knowledge where it is supposed to be provided to the students through teachers’ instructions in the first place whom create a new knowledge from teachers’ possessed knowledge and active experience. The stage of learning process of discovery learning which involve pre-laboratory discussion which include discussion, observation, problems formulation, creating hypothesis, experimenting, and doing post-laboratory discussion which include observation, interpreting data, and finding a concept [8]. This approach will sharpen students’ thinking skill and self-regulated toward learning process. It is in line with previous finding in research conducted by [9] that reveals a combination effect on several representation approaches and collaborative learnings as an innovation in teaching of general biology is able to improve students’ scientific process skills and science development. Experts state that through practical work activity in form of discussion in pre-laboratory discussion which includes discussion, observation, formulating problems, creating hypothesis, doing experiment, post-laboratory discussion which includes observing, interpreting data, and discovering concept show significant improvement in understanding concept and analytical thinking ability to students who apply those activities [8, 10]. In their overview of GDL, GDL approach is useful for students, especially female and racial minority through learning experience as a process rather than promoting innate perception and enable students to experience almost all characteristics of pure discovery and it occurs in a realistic time frame [11].

Through learning process such as investigation which counts heavily on students will develop self-regulated and integrated skill. Independent students will set a target to achieve, do self-monitoring, plan proper steps, and do self-evaluation in learning process. More recent evidence [12] highlights that investigate effectiveness of independence training toward metacognition and high school students’ learning achievement which is reveal that the teacher must deliberately improve students’ learning process by integrating learning process and self-regulated process. The improvement of learning outcomes is expected to develop learning containing self-regulated and development of metacognition. Many attempts have been made [13] in order to give evidence about it which investigate the relationship between confidence in teaching and pedagogical content knowledge (PCK) which show PCK in vocational school is a dominant factor in strengthening teachers’ self-regulated and proper independence will develop the component of PCK for teachers. In a par with it, [14] reveals in his research that investigating relationship between self-regulated and students’ achievement in senior high school results in the components of independence such as performance approach against goal and time, the setting of learning environment influences the achievements in electrochemistry. The evidence from the recent research point towards the idea that there is a need to develop self-regulated along with attitude, metacognition, and thinking skill.

The process of chemistry learning which develops thinking skill, processing skills and communicating as an important aspect of life skill can be attained through investigation. Figure of critical thinking skills improvement of senior high school students by applying learning through reading combined with learning through investigation in science instruction reveals positive result shown by the
improvement of critical thinking skills [15]. Involving students in the process of investigation generates more complex thinking process and others ability. Science learning includes chemistry learning as a practical subject which facilitates experiences for the students to be involved in science process skills which benefits them to solve real life problems [16].

As we know that the research shows that GDL improves meaningful learning to the students, conceptual understanding, science process skills, analytical thinking ability, problem solving skills, developing positives attitudes in chemistry learning. Weighing up both sides of those arguments, this study addressed to determine the effect of guided discovery learning (GDL) toward integrated ability and self-regulated learning of the students in buffer solution. The research question is “is there any effect of guided discovery learning (GDL) toward integrated ability and self-regulated learning of students in buffer solution?”

The rest of this paper is organized as follow: Section 2 describes the proposed research method. Section 3 presents the obtained results and following by discussion. Finally Section 4 concludes this work.

2. Research Method

In this study posttest-only control quasi experiment design was applied as shown in Table 1. A total of 65 students of 11th grade took part (15–16 years of age) comprising a high school in Special Region of Yogyakarta, Indonesia. The participants were divided into two class, following are control class which experienced expository learning (EL) (N=32) and an experimental class which experienced guided discover learning (GDL) (N=31). The participants selected using simple random sampling.

| Table 1. Posttest-Only Control Design |
|---------------------------------------|
| Class      | Treatment | Post test |
| Experiment | X₁         | O₁O₂      |
| Control    | X₂         | O₂O₂      |

where

- O₁ Integrated Ability
- O₂ Self-regulated
- X₁ guided discovery learning (GDL) approach
- X₂ expository learning (EL) approach

This study consisted of three stages, following are designing research instrument which was validated by experts in the area of chemistry, applying guided discovery learning to experimental class and expository learning to control class, and conducting post-test in experimental and control classes which was analysed afterward.

In this study, the instrument of collecting data in this research was integrated assessment and self-regulated questionnaire.

2.1. Integrated assessment

Integrated assessment adapted by [17] is aimed at high school students in buffer solution. Integrated assessment consists of 5 essays which each item covers an indicator of analytical thinking and science process skills. Additionally, [17] explored the quality of the integrated assessment. The findings of their study ascertained that the developed integrated assessment has relatively high validity. The content validity of 5 items in integrated assessment was 0.87. The result of field trial showed that 9 items fit with the 1 PCM-1PL model. The difficulty level is in the range of -2.90 <b> 4.26. Function test information obtained 5.54 logit and standard error of measurement of 0.424. Integrated assessment test given to the students after the last treatment conducting in experiment and control class.
2.2. Self-Regulated Questionnaire
The indicator in the self-regulated questionnaire covered self-monitoring, motivation, and self-efficacy. The sample of students’ self-regulated questionnaire form was shown in Table 2.

| Aspect          | Indicator                                                                 |
|-----------------|---------------------------------------------------------------------------|
| Self-Monitoring | Regard teacher's explanation                                               |
|                 | Do the tasks given by the teacher                                          |
|                 | Complete the task given by the teacher                                     |
| Motivation      | Follow the lesson                                                          |
|                 | Trying to obtain information                                               |
|                 | Actively follow each learning process                                      |
| Self-Efficacy   | Answering questions given by the teacher                                   |
|                 | Do the questions given by the teacher                                      |
|                 | Give opinions during discussions                                           |
|                 | Convey of discussion results                                               |
|                 | Do the practicum independently                                             |

Logically, validating questionnaire was done by two experts who give suggestions to the learning activity and self-regulated learning questionnaire. Integrated assessment instrument was analyzed by using descriptive analysis which was interpreted based on the provided criteria. The result of integrated assessment instrument was obtained and categorized based on the result of each students. Self-regulated questionnaire form was analyzed by using descriptive analysis. Students’ answers were marked based on scoring guide which were categorized then. The category includes very high, high, moderate, low, very low [18]. Students’ answers to positive questions were marked 4 for always, 3 for often, 2 for rare, 1 for never. While for negative questions, the score was 1 for always, 2 for often, 3 for rare, and 4 for never. After analyzing the data using descriptive analysis, the data of integrated assessment instrument and data of students’ self-regulated questionnaire were calculated analyzed by using inferential statistic with multivariate analysis of variance (manova) which should comply multivariate normality test in the first place by using comparison of mahalanobis distance and chi square, homogeneity by using M-Box test, and correlation test by using Pearson test by using software Statistical Product and Service Solutions (SPSS).

3. Results and Discussion
The finding of this study was obtained using descriptive analysis and statistical analysis. The confidence interval was 95% which indicated significance level 0.05 applied in statistical analysis. Multivariate normality test of post-test for each group was calculated using value comparison of mahalanobis distance ≤ chi square value. The result of scatter-plot tended to draw a straight line, and was obtained more than or almost the half of the total comparison of mahalanobis distance value ≤ chi square value, thus it revealed that the data met the condition of population of multivariate normal distribution.

3.1 Result
3.1.1 Integrated ability
Learning process did not start with pre-test but it ended with post-test. After guided discovery learning (GDL) was applied, post-test was conducted to analyze integrated ability after following learning process. The result of descriptive statistic of post-test data of integrated ability yielded the average score, standard deviation, highest score as well as the lowest one in experimental and control class. The average score of students’ integrated ability post-test in experimental class was (M=71.54, SD=13.82) higher than the average score of control class (M=58.64, SD=11.38). Experimental class’
highest and lowest score were higher than control class. The percent of goal of students’ integrated ability in experimental and control classes based on the result of post-test were provided in Table 3.

| Integrated Ability | Number | Percentage (%) |
|--------------------|--------|----------------|
| Science Process Skill | Analytical Thinking Skill | Experiment | Control |
| predicting | differentiating | 1,2 | 72.21 | 78.06 |
| communicating | attributing | 1,3,5 | 81.77 | 76.56 |
| planning an experiment | organizing | 2 | 67.74 | 69.03 |
| applying the concept | attributing | 2 | 67.74 | 69.03 |
| predicting | differentiating | 2 | 67.74 | 69.03 |
| applying the concept | organizing | 3 | 89.68 | 90.96 |
| classifying | attributing | 3,4 | 78.71 | 64.64 |
| applying the concept | organizing | 4 | 67.74 | 51.61 |

As shown in Table 3, it revealed that there was a difference in student’s percentages of mastery analytical thinking skill and science process skill in experiment and control class. The highest percentage in experiment and control class, respectively were 81.77 and 78.06. Experiment class had the highest percentage on questions number 1, 3, and 5 with the indicator of science process skill is communicating, and the indicator of analytic thinking skill is attributing. In addition, control class had highest percentage on questions number 1 and 2 with the indicator of science process skill is predicting and the indicator of analytical thinking ability was differentiating. The lowest percentage of experiment and control class, respectively were 67.74 and 51.61. The lowest percentage of experiment and control class were on questions number 4 with the indicator of science process skill is applying concept and the indicator of analytical thinking ability is organizing.

Based on the result of post-test of analytical thinking skill and science process skill, the frequency distribution was known. Frequency distribution of post-test score of students’ integrated skill was presented in Table 4.

| Integrated Ability Frequency Distribution |
|------------------------------------------|
| No | Score Range | Category | Experiment | Control |
|----|-------------|----------|-------------|---------|
| 1. | $X > 30.3$ | Very High | 8 | 25.8 | 0 | 0 |
| 2. | $23.1 < X \leq 30.3$ | High | 19 | 61.3 | 11 | 35.48 |
| 3. | $15.9 < X \leq 23.1$ | Medium | 3 | 9.7 | 18 | 58.07 |
| 4. | $8.7 < X \leq 15.9$ | Low | 1 | 3.2 | 2 | 6.45 |
| 5. | $X \leq 8.7$ | Very Low | 0 | 0 | 0 | 0 |

Table 4 revealed the frequency distribution of integrated ability post-test result. The result of integrated ability post-test in experimental and control classes were in high category (61.3%) and in moderate category (58.07%). The result of analytical thinking ability and chemistry science process skills post-test of experimental and control class of low category were 3.2% and 6.45% respectively.

3.1.2 Self-Regulated
Students’ self-regulated was measured by using questionnaire. Previous learning self-regulated questionnaires was validated by two experts so that all 22 questions were confirmed to be valid. Self-
regulated questionnaire was given at the end of the learning process. Students’ self-regulated in experiment class was (M=64.52, SD=5.27) which is higher than control class (M=53.56, SD=7.17). Interestingly, according to self-regulated indicators in Table 5, experiment class’ motivation and self-efficacy were higher than control class. Experimental class (76.08%) and control class (66.41%) had the highest percentage for self-efficacy indicator. Students’ high motivation was clearly shown during the learning process. Students were more active in digging information through book as well as internet and actively participated in a discussion to solve problems.

Table 5. Result of Self-Regulated Questionnaire

| No. | Indicator Self-Regulated | Self-Regulated (%) |
|-----|--------------------------|---------------------|
|     |                          | Experiment         | Control          |
| 1.  | Self-Monitoring          | 69.74              | 63.82             |
| 2.  | Motivation               | 72.28              | 66.41             |
| 3.  | Self-Efficacy            | 76.08              | 56.14             |

Table 5 showed the percentage of self-efficacy indicator in experiment and control class, respectively were 76.08% and 56.14%. The indicator of self-monitoring in experiment class (69.74%) and the indicator of self-efficacy of control class (56.14%) had lower percentage compared to other indicators.

Table 6. Self-Regulated Frequency Distribution

| No | Score Range  | Category  | Experiment | Control |
|----|--------------|-----------|------------|---------|
|    |              | Sum       | %          | Sum     | %       |
| 1. | X > 74.8     | 1         | 3.23       | 0       | 0       |
| 2. | 61.6 < X ≤ 74.8 | 23      | 74.19      | 7       | 22.58   |
| 3. | 48.4 < X ≤ 61.6 | 7       | 22.58      | 17      | 54.84   |
| 4. | 35.2 < X ≤ 48.8 | 0       | 0          | 7       | 22.58   |
| 5. | X ≤ 35.2     | 0         | 0          | 0       | 0       |

The score of frequency distribution of students’ final learning self-regulated which was presented in Table 6 revealed that students’ self-regulated learning in experimental class had highest percentage in high category that was 74.19%. Self-regulated learning with moderate and very high category in experiment class were 22.58%, and 3.23%, respectively. The data of students’ final self-regulated learning in control class in high, moderate, and low category, respectively were 22.58%, 54.84%, and 22.58%.

3.1.3 Effect of Guided Discovery Learning (GDL) toward Integrated ability and self-regulated

a) Normality Test

The assumption of multivariate analysis is analysis data must be obtained from population with multivariate normal distribution and the matrix covariance among population is the same. Figure 1 showed the result of scatterplot which tended to draw a straight line and 48.39% was obtained value of mahalanobis distance which was less or equal to the value of chi square. It concurs well with the result of correlation coefficient 0.994 that showed relatively high correlation coefficient. The range of correlation coefficient was between -1 to +1. Sig. value was 0.000 < 0.05, thus highlighted the correlation was significant. In scatterplot, it meant that the data was taken from the samples with multivariate was in normal distribution.

Based on the result of scatter-plot in Figure 2, it tended to draw a straight line and 51.61% was obtained value of mahalanobis distance which was less or equal to the value of chi square. It concurs well with the result of correlation coefficient 0.946 which showed relatively high correlation coefficient. The range of correlation coefficient was between -1 to +1. Sig. value was 0.000 < 0.05, thus the correlation was significant. In scatter-plot, it meant that the data was taken from sample with
multivariate in normal distribution. The conspicuous result to emerge from the data comparison was the data from each group was taken from the sample with multivariate in normal distribution.

\[ \text{Figure 1. Distribution of Experiment Group’s Score} \]
\[ \text{Figure 2. Distribution of Control Group’s Score} \]

b) Homogeneity Test
Homogeneity test was conducted with Box’ M test. Table 7 provided the result of matrix variance homogeneity test with Box’ M test in the post-test of students’ integrated ability and self-regulated.

| Box’s M | F  | df1 | df2    | Sig. |
|---------|----|-----|--------|------|
| 5.576   | 1.791 | 3   | 648000 | 0.146 |

Based on Table 7, the result of matrix variance homogeneity test with Box’ M test revealed that the value of F was 1.791, and significance value of post-test of students’ integrated ability and self-regulated was 0.146 which meant that H₀ was accepted. It revealed that matrix variance of the data was already homogeneous.

c) Correlation Test
This test was used to examine relationships between students’ integrated ability and self-regulated by using Pearson test which was presents in Table 8.

| No | Dependent Variable | Pearson correlation value | Sig. | Category |
|----|--------------------|---------------------------|------|----------|
| 1. | Integrated Ability – Self-Regulated | 0.351 | 0.005 | Low |
| 2. | Self-Regulated – Integrated Ability | 0.351 | 0.005 | Low |

As shown in Table 8, the value of correlation coefficient of students’ integrated ability and self-regulated was 0.351. While significance value of both variables was 0.005. Sig. (0.005) < α (0.01), thus H₀ was rejected. Therefore, both dependent variables had a significant correlation.

From the conducted prerequisite test, the measurement data of integrated ability and self-regulated met the condition of parametric that was multivariate normal distribution data and variable group of data
were homogenous, thus the data continued to parametric hypothesis test using Multivariate Analysis of Variance (MANOVA). The result of parametric test using MANOVA shown in Table 9.

Table 9. Multivariate Analysis of Variance’s Result

| Effect       | Value  | Hypothesis Df | Sig.  | Partial Eta Squared |
|--------------|--------|---------------|-------|---------------------|
| Model        |        |               |       |                     |
| Pillai’s Trace | 0.506  | 2.000         | 0.000 | 0.506               |
| Wilks’s Lambda | 0.494  | 2.000         | 0.000 | 0.506               |
| Hoteling’s Trace | 1.025  | 2.000         | 0.000 | 0.506               |
| Roy’s Largest Root | 1.025  | 2.000         | 0.000 | 0.506               |

Based on Table 9, the result of MANOVA test revealed value Wilks’s Lambda that was 0.494. If the statistical value of Wilks’s Lambda was higher, thus the effect of integrated ability and self-regulated on GDL was stronger. As shown in Table 9, it showed significance value (0.000) < 0.05. Thus, $H_0$ was rejected. It revealed that there was an effect of integrated ability and self-regulated. The result of partial eta squared analysis was 0.506. It revealed that the use of GDL had significant effect toward students’ integrated ability and self-regulated which was 50.6%.

3.2 Discussion

The finding revealed that students who had Guided Discovery Learning (GDL) had higher integrated ability and self-regulated than students who had Expository Learning (EL). This finding correlate favourably with [7] who found that learning textbook only provided related materials to the students, thus GDL approach needs to equip students with critical thinking that has important role in learning chemistry. By GDL that encouraged students to be involved in learning process resulted in independence behaviour for the students. In a par with it, students who have active learning show less misconception in acid base topic, and improvement of achievements, prevention of misconception, increasing thinking skills such as analysing, attributing, synthesizing, analytical thinking skills that cannot be learnt in teacher centre learning style [6]. This also lend support to previous finding in the literature [19] that find students who present, observe other students, and try to imitate others give them help to finish their tasks. Students’ self-regulated leads them to plan their action, teacher as a guide helps in analysing the task and goal setting. At regulation level, teachers are success in supporting students when the students try to implement the behaviours they have learnt to finish the given task.

The most striking result to emerge from the data was GDL can significantly improve integrated ability and the result supported GDL to be one of approaches in developing integrated ability. Integrated ability in experiment class was higher than control class as shown in Table 5. In a par with it, robotics program based on guided discovery approach was successful give a positive impact on the ability of mathematics, the techniques that students have, attitudes towards science, technology, engineering and mathematics (STEM), and try to be better [11]. Indicator of applying concept and organizing on questions number three and four revealed different percentages. It was influenced by the categories of the questions, they were very easy and moderate. In a par with it, [20] state that the level of difficulty of question was not only influenced by the level of difficulty of the problem but also can be understood by the selection of words that are too difficult to understand and ambiguous instructions or bias in the presentation of the questions given.

Besides giving a significant effect toward integrated ability, GDL also had significant effect on students’ self-regulated as shown in Table 6 that the average of three indicators of self-regulated in experiment class were higher than control class. As reported by [21], the evidence we found points to GDL contributes positively like strengthening concept on biochemistry topic. Additionally, GDL is able to help them to be more motivated, develop flexible knowledge, and study about how knowledge is develop in certain domain [22]. Because of that, indicator of motivation in indicator of self-
regulated gave significant effect during the treatment of guided discovery learning. According to social cognitive theory about self-regulated learning, investigate relationship between college students’ homework, self-efficacy, self-regulated, and final score which reveal that highly self-efficacy students have intrinsic motivation and are involved in search of help and academic performances [19].

4. Conclusion
In conclusion, according to the result of descriptive analysis of integrated ability and self-regulated learning, the highest distribution of data frequency of post-test of experiment class classified in high category, while the highest frequency of post-test data distribution of control class classified moderate category. It revealed that GDL improved student’s integrated ability and self-regulated learning on buffer solution. The most remarkable result that GDL was able to affect students’ integrated ability and self-regulated compared to expository learning (EL) approach. Besides that, it was also found that applying concept in science process skills and organizing in analytical thinking ability was not really significant for question number four against GDL effect. Guided discovery learning (GDL) made students became involved in the investigation, like formulating problems, formulating hypothesis, collecting data, drawing a conclusion, therefore, on buffer solution topic, GDL was able to improve students’ self-regulated. This research focused on thinking ability of quantitative (symbol/systemic level) compositions of buffer solution, therefore, the data obtained from this research was able to be used in the future to be translated into various type of representation (symbolic, sub microscopic, and macroscopic).

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