The effectiveness of chemistry learning strategy in improving students’ learning process and achievement

I W Subagia* and I G L Wiratma

Department of Chemistry Education Universitas Pendidikan Ganesha, Indonesia

*Corresponding author: wayan.subagia@undiksha.ac.id

Abstract. This research aimed at describing and explaining the implementation results of learning strategy for senior high school chemistry based on starter experiment approach. This research was part of research and development conducted simultaneously in two different schools in the form of pre-experiment. Two chemistry teachers and 52 students were involved in this study. Mix methods consisted of observation and test were used to collect data. This study involved two topics of senior high school chemistry, namely Atomic Structure and Electron Configuration. This research focused on examining the effectiveness of learning process and learning achievement of students. The effectiveness of learning process was viewed from the involvement of students in learning obtained by observation techniques. The student learning achievement was viewed from the number of students achieving the minimum criteria of mastery learning set out by the schools. The result of this research revealed that learning process undergoes effectively which can be seen from students’ participation in learning, such as observing the starter experiment, promoting questions, discovering concepts, and applying concept to solve problems. In general, it can be stated that more than 90% students achieved the minimum standard of mastery learning set out by the schools.

1. Introduction

Through research and development, it has been developed a new learning strategy of senior high school chemistry which is called Chemistry Learning Strategy for Senior High School Students Based on Starter Experiment Approach. This learning strategy was developed based on the idea of starter experiment approach (SEA) promoted by Schönherr and an empirical abductive learning cycle promoted by Lawson. The starter experiment approach is used to begin the lesson encouraging students to learn chemistry by observing a demonstration of simple experiment. The empirical abductive learning cycle is used to develop learning stages helping students to construct knowledge of chemistry concepts connecting between macroscopic and microscopic phenomena of matters. Research results showed that many students still finding difficulties in learning chemistry. [1] reported several factors caused students’ difficulties in learning chemistry, such as poor background of knowledge, the absence of teaching aids, and misunderstanding of language.

The learning strategy developed is consisted of three main parts, namely: learning theories, social situation, and syntax. The learning theories used were behaviouristic learning theory, cognitive constructivist learning theory, and social constructivist learning theory. The behaviouristic learning theories (Pavlov, Thorndike, Skinner) explain how students change his or her behaviour during following a certain condition of learning process. This learning strategy provides complex stimulus in the form of starter experiment that should be responded by students regularly in beginning the lesson. The constructivist cognitive learning theory (Piaget) explains how students construct knowledge individually based on the interaction between his or her prior knowledge and current experiences. This knowledge construction is facilitated by giving opportunities to students to observe macroscopic
phenomena of matter, to formulate questions based on selected observation results, and to answer the question in group. The social cognitive constructivist theory (Vygotsky) promotes how students construct knowledge supported by their learning peers in groups learning. This learning activity is facilitated by tasks that should be completed by students in groups.

The social situation or social system of the learning strategy explains the role of teachers, students, and schools in the process of learning. In this learning strategy, the teacher plays the most important role in which he or she should plan, conduct, and assess as well as evaluate the process and product of learning [2, 3, 4]. In other word, the teacher plays role as a learning manager [5]. The students play a role as a subject of learning who constructs his or her knowledge along the process of learning. The school plays role as a place of learning which provides supports for learning or learning facilities [6], such as laboratory equipment and chemicals.

The syntax of the learning strategy mainly consists of three steps, namely observation of macroscopic phenomena of matters, concept formulation, and concept application. The whole learning strategy includes ten steps of learning as follows.

Step one: The demonstration of starter experiment by teachers.
Step two: The observation of starter experiment by students.
Step three: The selection and discussion of observation results.
Step four: The question formulation based on selected observation results.
Step five: The selection and discussion of formulated questions.
Step six: The presentation of the answer of questions.
Step seven: The discussion of task to discover concepts.
Steps eight: The presentation of task results
Step nine: The discussion of task to apply concepts.
Step ten: The collection and clarification of task results.

The starter experiment is used to begin students learning by observing the macroscopic phenomena of matter. This will help students to see the learning materials contextually and used this phenomenon to bridge the development of chemistry knowledge which is characterized by macroscopic, microscopic or sub-microscopic, as well as symbolic phenomena. Since chemistry knowledge is considered abstract, it is important to help students to develop understanding about chemistry concepts by using different approaches.

The observation step is used to train students to do observation as well as to write observation results. This primary learning activity should be conducted carefully because it is essential for further learning. Many students cannot perform observation well and lead to poor observation results due to poor knowledge and skills of doing correct observation and write observation results. [7] reported that the profile of scientific thinking abilities of students is in low category.

Observation should be done by utilizing all senses, either equipped or naked. Observation should be conducted closely to allow senses to gain correct facts. The quality of observation results can be classified into two, namely scientific observation and trivial observation results [8]. A scientific observation results is defined as observation that can be used to arise further questions. On the other hand, the trivial observation is referred to observation results that do not need further investigation. It is also called as non-investigative observation results.

The question formulation is used to enhance students’ critical thinking in which he or she formulates questions based on selected observation results. Formulating question could be seen the second important part of scientific processes. It is important to the students to be trained how to formulate questions. Good question will lead to further learning process. [7] found out that many students had problem on science question. It can be mentioned that the rest of scientific process can be conducted easily if the question formulation is clear.

The discussion and presentation provide opportunities to all students to speak, share ideas, evaluate his or her ideas, as well as appreciate other opinions, especially in small group. These activities will motivate students to learn in more pleasant ways and usually followed by better results of learning [9, 10, 6]. In general, students have less pressure to speak in small group compare to in large group. [11] reported that students were more enjoyable to work in group task and would like to work in group more often. In addition, it was found that the success of group work was also affected by the group formation.

Since high school chemistry learning aimed at developing factual, conceptual, procedural, and metacognitive knowledge, providing tasks for concepts formulation and concepts application are
essential. In this step, students are given opportunities to find concepts through literacy activity, i.e. reading textbook, and use the concepts to solve chemistry problems. In this case, teacher plays role as a learning facilitator to facilitate discussion process in each group. [12] reported that successful teachers consider these three aspects of teaching, i.e. develop knowledge of subject matter, content standards, and subject specific pedagogy; develop and apply knowledge of varied students’ needs; considered research and theory about how students learn; and reflect on and analyse evidence of the effects of instruction on students’ learning. [13] stated that some learning problems in chemistry caused by teacher’s limitation, such as asked successive questions, answered his or her questions, gave wrong information, made unclear and wrong analogy.

2. Methods
This research was part of research and development (R & D) aimed at developing a learning strategy for senior high school chemistry. In general, this study followed the idea of R & D from Borg and Gall focused on the field testing of the product. The aims of this study were to describe and explain the effectiveness of the learning strategy viewed from the quality of learning process and achievement of students in learning. The student’s participation in learning was used to view the quality of learning process. The participation of students in learning was obtained from their activities during learning process involving observation, questions formulation, discussion, presentation, and task collection activities. The achievement of students in learning was collected by using test and analysed descriptively and interpreted based on the number of students achieving the minimum criteria of mastery learning set out by the schools.

This study involved two senior high schools located in Singaraja City, Buleleng Regency, the Province of Bali. Two chemistry teachers and 52 students were involved in this study. The research design used was a pre-experiment using one shot case study design conducted simultaneously in two different schools. Two chemistry topics, i.e. Atomic Structure (SA) and Electron Configuration (EC) were involved in this study. The minimum criteria of mastery learning for Atomic Structure (AS) and Electron Configuration (EC) set out by the schools were 75 and 70, respectively.

The macroscopic phenomena of matters used as the starter experiment were “the heating process of water above a metal spoon” and “the electric static phenomenon produced by rubbing plastic ruler on wool materials.” The whole processes of learning for both topics were conducted similarly as follows. First, teacher demonstrated the starter experiment; Second, teacher asked students to observe the starter experiment and wrote the observation results in a piece of paper; Third, teacher asked students to discuss and select the best of observation result to be used to open questions; Fourth, teacher asked students to formulate questions based on the selected observation result; Fifth, teacher asked students to discuss and select the most appropriate question to be answered; Sixth, teacher asked students to work in group to answer the selected question; Seventh, teacher asked students to present the discussion results; Eighth, teacher gave students task consisted of conceptual questions and asked them to discuss in group; Ninth, teacher asked students to present their discussion result in front of the classroom; Tenth, teacher gave students task consisted of conceptual application problems and asked them to solve the problems in group; Eleventh, teacher asked students to collect the results and teacher clarified the solutions of the problems. Finally, teacher gave a test to the students to assess their learning achievement.

3. Results and Discussion
The results of this study were grouped into six, namely: 1) Students’ observation result, 2) Students’ questions formulation, 3) Students’ involvement during discussion, 4) Students’ task presentation, 5) Students’ task collection, and 6) Students’ achievement in learning.

3.1 Students’ observation results
There were two things recorded during observation of starter experiment demonstrated by teacher. The first was the way of student to do observation and the second was the result of observation. The way of students to do observation was varied. Some students observed the demonstration correctly and some students observed incorrectly. The correct way of observation is observing the starter experiment closely utilizing all senses. The incorrect way of observation is observing it from a distance. This way does not allowed students to see the experiment clearly. After collecting the results, teacher explained
the correct way of doing observation. It is seen that after the first demonstration, students showed better way of doing observation.

The examples of observation results obtained by the students for each starter experiment were as follows.

| Starter Experiment                          | Observation Results                                      |
|--------------------------------------------|----------------------------------------------------------|
| The heating of water above a spoon          | 1) Water evaporate (right)                               |
|                                            | 2) Temperature rising (wrong)                            |
|                                            | 3) Water bubbling over (write)                           |
|                                            | 4) Water change into water vapour (right)                |
|                                            | 5) Spoon conduct heat to water (wrong)                   |
| Electric static produced by rubbing plastic ruler on wool materials | 1) The papers stick on the ruler (write) |
|                                            | 2) The ruler pulls the pieces of paper (write)           |
|                                            | 3) Electric static pulls the piece of papers (wrong)     |
|                                            | 4) The negatively charged ruler pull the positively charged papers (wrong) |
|                                            | 5) The ruler is rubbed into wool in one direction (write) |

These results showed that there were right and wrong observation results written by students. Most of the observation result of students fell into the results number one and four of the first experiment and the results number one and two of the second experiment which were categorized as right observation results. Some students wrote wrong observation results, such as the results number two and five of the first experiment and the results number three and four of the second experiment. These results are not considered as observation results since students do not measure the temperature of water, do not touch the spoon, do not determine the charge of the ruler and the paper. So, those results can be mentioned as opinions or the product of thinking coming from their previous experiences. The result number five for the second experiment is considered right, but it is not appropriate because it is a trivial observation result or non-investigative observation result [8]. Based on these results, it can be mentioned that some students still having problems with observation. Therefore, they need to be trained how to do correct observation and write the results as well. Although the learning process spends more time, it can be mentioned that all students participate well in this learning process. It is believed that the time spend for this activity will be reduced when the students have more practice in doing observation.

3.2 Students’ question formulation
The observation results selected to be used for further process of learning were “water evaporate” and “the ruler pulls the pieces of paper.” Based on these observation results, the students formulated questions as follows:

| Observation Results          | Question Formulations                               |
|------------------------------|------------------------------------------------------|
| Water evaporate              | 1) Why does water evaporate? (right)                 |
|                              | 2) Why does water form bubbles? (right)              |
|                              | 3) What is happened to water molecules? (right)      |
|                              | 4) Why is the end of spoon hot? (wrong)              |
|                              | 5) What does the water molecule consist of? (write)  |
| The ruler pulls the pieces of papers | 1) How does the piece of papers stick on the ruler? (right) |
|                              | 2) What kinds of energy does the ruler obtain so it may pull the piece of papers? (right) |
3) Why does the ruler and wool produce electron after rubbing one to another? (right)

4) Why does the ruler become hot when it is rubbed on wool? (wrong)

5) What does the piece of paper stick on the ruler? (right)

Based on the formulated questions above, it can be mentioned that most students are able to formulate good questions. Wrong questions arise due to wrong observation result, such as the question number four of the first and the second experiment. Based on the number of questions arose or written by the students, it is seen that all students participated well in formulating questions. Since some students still having problem in writing questions, it is important to train students to develop question. This is in accordance with the result results mentioning that students have low skills in asking questions [7].

3.3 Students’ involvement during discussion
In general, students in each classroom were divided into six groups, respectively. Students in each group work together to answer the given questions or to solve the given problems. The conceptual questions given to each group for two different topics were as follows. The questions for Atomic Structure included: 1) What is an atom? 2) What does it mean by electron, proton, and neutron? 3) What is an atomic symbol? 4) What does it mean by atomic number and atomic mass? 5) What does it mean by isotope, isobars, isoton, and isoelectron? 6) What is the atomic model of Dalton, Thomson, Rutherford, Bohr, and wave mechanic? The questions for Electron Configuration included: 1) What is an electron configuration? 2) What is an orbital? 3) What is Aufbau’s Principle? 4) What is Pauli’s exclusion principle? 5) What is Hund’s role? 6) What does it mean by full orbital and half full orbital? 7) What is a quantum number? 8) What does it mean by principle (n), azimut (l), magnetik (m), and spin (s) quantum numbers?

During the discussion, not all students pay attention to the given task in group. Some students participated well in discussing and debating the answers. Some students waited the answer from his or her peer group and receive the answer as the result of discussion. This is the weaknesses of group learning. This situation needs to be controlled by the teacher to avoid students from ignoring the task and to encourage every student to take participation in learning [2].

3.4 Students’ task presentation
The presentation of students’ task was conducted by a sample group of students which was taken randomly. The presentation was conducted step by step as follows. First, students introduced their group members. Second, students presented their discussion results. Third, students offered questions to the class. Finally, teacher clarified concepts presented by the group. This activity gives an opportunity to all students to understand the concepts and to evaluate their discussion results.

An example of students’ answers with regards to the conceptual questions of Atomic Structure topics was as follows.

| Questions | Answers |
|-----------|---------|
| 1. What is an atom? | The smallest part of matter consisted of nucleus and electron cloud surrounding the nucleus. |
| 2. What does it mean by electron, proton, and neutron? | An electron is a negatively charged subatomic particle. A proton is a positively charged subatomic particles. A neutron is uncharged subatomic particle. |
| 3. What is an atomic symbol? | A symbol written in writing atoms, i.e. F for fluorine; C for carbon; Mg for magnesium, etc. |
4. What does it mean by atomic number and atomic mass?
   An atomic number is the number of proton in a nucleus.
   An atomic mass is the number of proton and neutron owned by atoms.

5. What does it mean by isotope, isobar, isoton, and isoelectron?
   Isotope are atoms having similar atomic number and different atomic mass.
   Isobar are atoms having similar atomic mass.
   Isoton are atoms having similar number of protons.
   Isoelectron are atoms having similar number of electrons.

3.5 Students’ task collection
The task that should be handed in by the students was the concept application task. In this case, the group of students was given problems to be solved. After collecting the task, teacher explained the solution of the given problems, so everyone evaluated his or her solutions. All groups of students participated well in doing and collecting task.

   An example of students’ solution with regards to the concept application task of Atomic Structure topics was as follows.

Table 4. Answers of Concept Application Problems

| Problems | Solution |
|----------|----------|
| 1. Draw the position of subatomic particle in an atom! | ![Diagram of atomic structure] |
| 2. How to write atomic notation? Give an example! | \( A_x^Z \)  
X is an atomic symbol  
Z is an atomic number  
A is an atomic mass  
Proton = electron = Z  
Neutron = A – Z |
| 3. How to determine the number of subatomic particles based on atomic notation? | Proton = electron = Z  
Neutron = A – Z |
| 4. What is the number of proton, neutron, and electron owned by the following atoms? a) \( ^{12}_{6}\text{Na} \); b) \( ^{35}_{17}\text{Cl} \); c) \( ^{56}_{26}\text{Fe} \). | a) Na has, 11 protons, 12 neutrons, and 11 electrons.  
b) Cl has 17 protons, 18 neutrons, and 17 electrons.  
c) Fe has 26 protons, 30 electrons, and 26 electrons.  |
| 5. Which of the following atoms represent isotope, isobar, isoton, and isoelectron? | Isotope: \( ^{12}_{6}\text{C}, ^{13}_{6}\text{C}, ^{14}_{6}\text{C}, ^{14}_{6}\text{N}, ^{13}_{6}\text{N}, ^{17}_{8}\text{O}, ^{16}_{8}\text{O} \).  
Isobar: \( ^{12}_{6}\text{C}, ^{13}_{7}\text{N}, ^{14}_{7}\text{N}, ^{14}_{7}\text{C} \).  
Isoton: \( ^{12}_{6}\text{C}, ^{13}_{7}\text{N}, ^{14}_{7}\text{N}, ^{14}_{7}\text{C}, ^{16}_{8}\text{O}, ^{16}_{8}\text{O} \).  
Isoelectron: \( ^{12}_{6}\text{C}, ^{13}_{6}\text{C}, ^{14}_{6}\text{N}, ^{14}_{7}\text{N}, ^{17}_{8}\text{O}, ^{16}_{8}\text{O} \).  |
| 6. What is the difference between Thomson and Rutherford atomic models? | The difference is on the description of electron and proton position. Thomson model the position of both particle is on the surface of atom, whereas Rutherford... |
model the position of proton in the nucleus and the position of electron outside the nucleus.

3.6 Students’ achievement in learning

Test was used to assess students’ achievement in learning. Examples of the problems given on test for the Atomic Structure topic were: 1) What are the particles composing matters? 2) Where is the position of each particle in an atom? 3) Write the notation of the following atoms: a) carbon (C) having atomic number 6 and atomic mass 12, b) natrium (Na) having atomic number 11 and atomic mass 23, and c) chlor (Cl) having atomic number 17 and atomic mass 35! 4) Determine the number of each particle of the following atoms: 14N; 20Ca; 36Ar! 5) The followings are hypothetical atomic notations: 6A; 6B; 6C; 6D. Determine which of them show a) isotop, b) isobar, c) isoton, and d) isoelectron! 6) What are the differences between Bohr and wave mechanic atomic models? The results of students’ achievement in learning for Atomic Structure (AS) and Electron Configuration (EC) were as follows.

|                      | First School |         | Second School |         |
|----------------------|--------------|---------|---------------|---------|
|                      | AS           | EC      | AS            | EC      |
| The number of students | 30           | 31      | 22            | 22      |
| Maximum score        | 84           | 100     | 100           | 100     |
| Minimum score        | 71           | 46      | 66            | 71      |
| Mean                 | 81           | 93      | 81            | 89      |
| Mastery Learning Criteria (MLC) | 75 | 75 | 70 | 70 | |
| ≥ MLC (%)            | 93           | 97      | 92            | 91      |

The distribution of students’ achievement for both topics at two schools is as follows.

![Figure 1. Students’ achievement distribution](image)

Based on the results presented above, it can be mentioned that the use of chemistry learning strategy based of starter experiment approach could improve students’ achievement in learning. Quantitatively, it is found that more that 90% students achieve the minimum criteria of mastery learning (75 and 70) set out by the schools. This result is the effect of the use of the learning strategy in which students learn step by step form observing the macroscopic phenomena of matter, formulating concepts, and applying concept to solve relevant problems. This finding is in accordance with the research results conducted by Jack [14]. It is reported that the use of learning cycle in chemistry learning enhanced students’ achievement in learning. Similarly, in the form of classroom action research (CAR), it was found out that the use of 5E learning cycle in learning improve students’ learning achievement in all aspects of learning, i.e. affective, cognitive, and psychomotor [15]. [16] reported that the use of inquiry learning enhanced student’s final learning results and inquiry activity, such as communicating.
4. Conclusion

The learning strategy for senior high school chemistry based on experiment approach enhances the quality of learning process and students’ achievement in learning. The participation of students in learning involves individual, class, and small group learning activities. The individual activities can be seen from students’ activity in observing starter experiment and formulating questions based on selected observation results. Classroom activities include discussion to select observation results and questions formulation. Group activities involve discussion to work on task for conceptual questions and concept application questions or problems. The student’s achievement in learning is viewed from the number of students achieving the minimum standard of mastery learning set out by the schools. It was found that more than 90 students achieve the minimum standard of mastery learning set out by the schools.

This learning strategy cannot be implemented directly by teacher without preparation. To implement this strategy in chemistry learning, teacher should prepare three things, namely: relevant macroscopic phenomena of matter to the materials or topic, task for conceptual questions, and task for concept application. In addition, teacher training with regards to this learning strategy is required on one hand. On the other hand, students need to be conditioned to learn through scientific processes to develop their scientific attitudes. Time spend for conducting this learning strategy will be reduced by practice, especially the time spend during observation dan discussion of observation results as well as questions formulation.

This learning strategy allows student to share his or her prior knowledge, particularly in terms of observation results, questions, and concept understanding. This will help teachers to see and counter students’ misconception if any.

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