STEM Activity Prototype on Solubility Product Subject

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Abstract: Research on the development of STEM activity prototype on the solubility product (K_{sp}) subject has been done. The purpose of this study is to develop STEM activity on solubility product subject. Research is a type of development research with the ADDIE model. Research was carried out until the development stage. STEM is education as an effort to combine some or all of the four discipline of science, technology, engineering, and mathematics into one class that is based on a connection between the subjects and real-world problems. The sample used in STEM activity is calcium hydroxide. Because it sparingly soluble in water and is widely used in daily life. A STEM activity was done by titration because of calcium hydroxide basic so that can be determined by acid. The result of this study is the determination way of the solubility product constant is conducted by titration of calcium hydroxide with hydrochloric acid. The percentage error of K_{sp} value in this experiment at 29^{o}C is 43.25%. Although this value is quite large, it can be applied in learning on the subject of solubility product.

Keywords: STEM; solubility products

1. Introduction

Chemistry is the study of matter and the changes it undergoes (Chang, 2010). Solubility and solubility product (K_{sp}) is a subject in chemistry. This subject has an important role in the industry, medicine, and everyday life (Chang, 2010). The problem that is commonly found in chemistry learning, especially Ksp, is that students are only given theoretical learning in the classroom without an experiment. Therefore learning is less interesting and not contextual. This is because all this time Ksp learning is only focused on calculations both at school and at the university. It is rarely thought by teachers how to get ksp values in selected data tables. Teachers should be innovative to do learning by combining Ksp calculations with Ksp determination experiments in the laboratory so that it is more challenging and can improve students' higher-order thinking skills (HOTS) and skill. One way to do this learning can be achieved by implementing integrated STEM learning

STEM is education as an effort to combine some or all of the four disciplines, technology, engineering, and mathematics into one class, unit, or subject based on the relationship between subjects and real-world problems (Moore, et al.,2014). Kelley & Knowles (2016) defines STEM as an approach to teaching STEM content from two or more STEM domains to enhance student learning. STEM learning is perfect for training HOTS students because it combines several disciplines (multidisciplinary) knowledge to solve problems.

Research on the development of STEM activities in chemistry has been carried out by various researchers. Tunkham, et al. (2016) have been the development of STEM activities in chemistry on protein to enhance 21st-century learning skills for senior high school students in Thailand. They found that students' academic achievement and innovation skills on creativity was significantly higher at .05 level. Damanhuri and Karpudewan (2019) have studied evaluating the effectiveness of Integrated STEM-lab activities to improving students' understanding of electrolysis. The study revealed that

Integrated-STEM lab activities are suitable to address the limitation of the existing laboratory for knowledge construction.

Based on the literature review, there is no research on the development of STEM activities for the K_{sp} subject. Therefore, the authors are interested in developing a prototype of STEM activities on Ksp subject for undergraduate students.

2. Methodology

2.1. Research Methods and Procedures

This research is a type of development research. This study aims to develop and produce a product in the form of a STEM experimental prototype on the subject of solubility and solubility product. The design of the STEM experimental prototype development in this study was adapted from the ADDIE development model (Figure 1) which consists of five stages of development namely Analysis, Design, Development, Implement, and Evaluate.

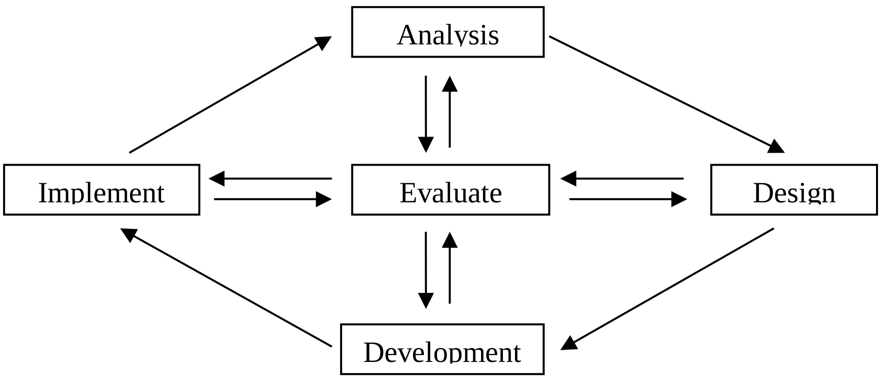

Figure 1. ADDIE Model Design

(Branch, 2009)

Procedure STEM experiment prototype development research done through 3 stages ADDIE model based on the following :

(1) Analysis
The analysis was carried out on the 3 development components as follows:

(a) Analysis of the development of a prototype STEM experiment
Analysis of chemical experiments on the subject of integrated chemistry STEM was carried out by conducting library studies from various books and journals about the components, characteristics, and procedures needed in developing STEM integrated scientific prototype projects.

(b) Curriculum Analysis
Curriculum analysis is carried out by reviewing the curriculum used, namely the Indonesian National Qualification Framework (KKNI) curriculum. This is intended so that the modules developed can be used by various tertiary institutions and are not fixed in the curriculum of certain tertiary institutions. The things analyzed in the curriculum

are competency standards, expected basic competencies, and indicators that must be achieved by students on the subject of rectangular formulas.

(c) Analysis of student characteristics
Analysis of the characteristics of prospective chemistry student is done by examining relevant theories, interviews with chemistry lecturers, and observations when learning activities in class. This analysis is conducted to find out in detail the psychological condition of students psychologically and physically who will use the module being tested. The results of this analysis will serve as a guide for developing and developing modules. Characteristics of students to be analyzed are the characters of prospective teacher students. This is considered important to do because it is to determine the level of ability and motivation of students.

(2) Design
At this stage, the STEM integrated experimental prototype began to be developed which will be developed according to the results of the analysis conducted previously. Next, the design phase is carried out by determining the elements needed in the integrated STEM prototype experiment. Researchers also collect references that will be used in developing integrated STEM experiment prototypes.

(3) Development
The development stage is the stage of product realization. At this stage, the development of an integrated STEM prototype experiment was carried out in accordance with the design. At this stage, the researcher also analyzes data on the results of the STEM integrated prototype assessment.

2.2. Equipment and material

The equipment used are an analytical balance, thermometer, filter paper, burette, graduated cylinder, beaker glass, drop pipette, watch glass, funnel, and stirring rod. The chemicals used are calcium hydroxide ($Ca(OH)_2$), hydrochloric acid, distilled water, and phenolphthalein.

3. Result and Discussion

3.1. Result

The STEM experimental design for determining the solubility product that has been successfully developed according to the ADDIE model is given in Figure 2. While the results of the successfully developed STEM prototype experiments are given in Table 1 and assessment rubrics are given in Table 2.

Title: Determining K_{sp} of $Ca(OH)_2$
Objective: Determination of $Ca(OH)_2$ K_{sp} value
Principle: Equilibrium reactions in saturated solutions and acid-base neutralization reaction
Material: beaker 100 mL, burette 50 mL, Erlenmeyer 100 mL, funnel, filter paper, phenolphthalein (PP), HCl 0.05 M, $Ca(OH)_2$ solid, and distillate water.
Procedure :

1. Weigh 1 gram of $Ca(OH)_2$ solids
2. Dissolve $Ca(OH)_2$ in a 100 mL beaker with distilled water to a volume of 50 mL
3. Stir until part of the $Ca(OH)_2$ is dissolved
4. Leave the mixture for about 5 minutes
5. Decantation and filter the solution using a funnel and filter paper. The resulting filter is a saturated solution of $Ca(OH)_2$
6. Measure the temperature of the saturated solution of $Ca(OH)_2$ with a thermometer.
7. Take 20 mL of $Ca(OH)_2$ saturated solution and transfer it to the Erlenmeyer flask.
8. Add the PP indicator (you can also use a natural indicator, such as Asian melastome extract) into the saturated solution of $Ca(OH)_2$.
9. Rinse and fill the burette with a 0.05 M HCl solution
10. Titrate carefully and slowly
11. Pay attention to the indicator's color change from pink to clear
12. Record the 0.05 M HCl volume used
13. Experiment up to 3 times and find the average volume of 0.05 M HCl used
14. Calculate the error percentage of the $Ca(OH)_2$ Ksp according to this experiment and standard data.

Figure 2. STEM Experimental Design

Table 1. Result of the Experiment of STEM Prototype

	Test 1	Test 2	Test 3
Temperature (T)	29^0C	29^0C	29^0C
$Ca(OH)_2$ weight	1.0065 gr	1.0073 gr	1.0047 gr
The volume of $Ca(OH)_2$ saturated	20 mL	20 mL	20 mL
solution	16,5 mL	17 mL	16 mL

Table 2. Assessment Rubrics of STEM experiment

Assessment component	Scale			
	1	2	3	4
Designing experimental equipment				
Weighing of $Ca(OH)_2$				
Measuring of saturated solution				
Titrating				
Filtering the solution				
Accuracy of $Ca(OH)_2$ Ksp value				
Cleanliness and neatness				

3.2. Discussion

Calcium hydroxide ($Ca(OH)_2$) is sparingly soluble in water (around 1.2 g/L at 25^oC) (Euler, et.al., 2000). It is a white odorless powder with the chemical formula $Ca(OH)_2$ and a molecular weight of

74.08. It is widely used in various fields of life, including agriculture, health, and industry. $Ca(OH)_2$ will establish an equilibrium between solid and aqueous if it is dissolved in water according to equation 1.

$$Ca(OH)_{2(s)} \leftrightarrow Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \qquad \text{(eq. 1)}$$

Based on equation 1, a saturated solution of $Ca(OH)_2$ have molar solubility (s) equals half of $[OH^-]$. Therefore, we can determine of $Ca(OH)_2$ solubility product constant by titrate it with hydrochloric acid based on neutralization reaction (equation 2.)

$$Ca^{2+}_{(aq)} + 2OH^-_{(aq)} + 2H^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow Ca^{2+}_{(aq)} + H_2O_{(l)} + 2Cl^-_{(aq)} \qquad \text{(eq. 2)}$$

Moles HCl used will be the same as moles OH^- (2s) and half of moles Ca^{2+} (s) in the saturated solution of $Ca(OH)_2$. Therefore, the value of $Ca(OH)_2$ Ksp can be calculated by equation 3

$$Ksp = [Ca^{2+}][OH^-]^2 = (s)(2s)^2 = 4s^3 \qquad \text{(eq. 3)}$$

Based on data in Table 1.2 it is found that the average volume of 0.05 M HCl used is 16.5 mL and the volume of $Ca(OH)_2$ saturated solution is 20 mL, then the value of Ca $(OH)_2$ Ksp is:

Moles HCl = 0.05 x 16.5 = 0.825 mmol
Moles OH^- = mol HCl = 0.825 mmol
$[OH^-]$ = 2s = 0.825 mmol / 20 mL =0.04125 M
$[Ca^{2+}]$ = s = 0.04125/2 = 0.020625 M
$Ksp = [Ca^{2+}][OH^-]^2 = (0.020625)(0.04125)^2 = 3.5095 \times 10^{-5}$

The value of $Ca(OH)_2$ Ksp according to literature is 5.02×10^{-6} (at 25^0) and 2.45×10^{-5} (30^0C) (Lide, 2000). Because this experiments were carried out at 29^0C (room temperature experiment carried out), then to calculate the percentage error of Ksp Ca $(OH)_2$ compared to the Ksp data at 30^0C. So, the relative error percentage (REP) of the Ksp Ca $(OH)_2$ value is:

$$REP = \frac{|experiment\ value\ of\ Ca(OH)_2\ Ksp\ -\ literature\ value\ of\ Ca(OH)_2\ Ksp\ |}{literature\ value\ of\ Ca(OH)_2\ Ksp} x100\%$$

$$REP = \frac{3.5095\ x\ 10^{-5} - 2.45\ x\ 10^{-5}}{2.45\ x\ 10^{-5}} x100\%$$

$$REP = 43.245\%$$

Based on calculations that have been done, it was found that the REP of Ksp $Ca(OH)_2$ was 43.245%. Although this value is quite large, it can still be tolerated. Because this experiment is not the exact determination of the solubility product of calcium hydroxide, but just to the understanding concept of the solubility product constant by chemistry students.

A quite large REP value can be caused by several sources including the following:

1. $Ca(OH)_2$ solution reacts with atmospheric carbon dioxide (CO_2)
   $Ca(OH)_2$ is a strong base solution that can react with acidic carbon dioxide gas in the atmospheric to form calcium carbonate ($CaCO_3$) according to the reaction equation 4:
   $$Ca^{2+}_{(aq)} + 2OH^-_{(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)} \qquad (4)$$

The reaction of $Ca(OH)_2$ with atmospheric CO_2 can be minimized in a way boiling the distilled water before adding the solid $Ca(OH)_2$ (Euler, et al., 2000) and do all the experimental procedures related to $Ca(OH)_2$ solution quickly. This is done because the gas will reduce its solubility if the temperature is raised (Chang, 2010).

2. Error in titrating
   Errors in titrating can be caused by three types of errors as follows:

   (a) Systematic Errors
   Systematic errors are errors that arise from mistakes made consistently during the analysis. This error causes consistently wrong or slightly floated results.
   Common systematic titration errors include calculation formulas, weighing a substance, titrant concentrations, titration speed, and titration endpoint.

   (b) Random Errors
   Random errors are components of overall errors that vary in unpredictable ways. These titration errors include material handling, inadequate equipment, gas bubbles in the burette, ineffective rinsing glassware after use, and inadequate environmental conditions (such as temperature and humidity).

   (c) Gross Errors
   Gross errors are easily recognized and can be avoided. Common gross errors include calculation errors, mixing of samples and reagents, incorrect sample sizes, and poor instrument operation.

(Mettler-Toledo, 2015)

4. Conclusion

The STEM activity prototype on solubility product subject for Ksp $Ca(OH)_2$ determination developed has a fairly large percentage of errors. However, this can be tolerated because it only aims to understand the concept of Ksp for chemistry students. Errors can be caused by reactions between $Ca(OH)_2$ with atmospheric CO_2 and error in titrating. Experiments should be conducted in a CO_2 free space and 25^0C temperature to get the Ksp value according to the actual value.

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