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Development of a Contact Process Demonstration Tool n the Production of Sulfuric Acid to Improve Students' Learning Motivation on Chemical Equilibrium Concepts

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Abstract

This study aimed to; (1) develop a teaching aid for the contact process of sulfuric acid production in chemical equilibrium materials; (2) to find out the influence of contact process teaching aids on increasing learning motivation. This study used a mixed-method research design with product development using R&D methods (Research and Development) using ADDIE (Analyze, Design, Development, Implement, Evaluation) model of product implementation and used a quasi-experimental method to test the effectiveness of the product. The contact process props are in the form of four sets of tools consisting of reactor 1 as a place for oxygen production, reactor 2 as a place for SO_2 production, a balance shift pipe as a place for SO^3 production, and SO^3 Absorption as a place where SO_3 meets H_2O to produce H_2SO_4. Contact process props provide students with visualizations of shifts in chemical equilibrium affected by pressure and volume. The feasibility test of material and language experts was 88.44% and the media feasibility test of 91.33% showed that contact process teaching aids on chemical equilibrium materials are very feasible as practicum media. The results of the independent t-test stated that there was an influence of the product on learning motivation with a significance value of 0.012. Contact process teaching aids provide learning with macroscopic representations to students, thus making learning about chemical equilibrium material interesting.

Keywords: Teaching Aids, Contact Process, Learning Motivation, Chemical Equilibrium

INTRODUCTION

There are three levels of representation in chemistry learning, namely macroscopic, submicroscopic, and symbolic (Zidny, 2015). Macroscopic representations are concerned with phenomena that can be observed and experienced directly in the real world, such as discoloration or sediment formation. Submicroscopic representations refer to the levels of particles (atoms, molecules, ions) that cannot be directly seen but are the basis for macroscopic phenomena. Meanwhile, symbolic representation involves the use of chemical formulas, reaction equations, and models to represent chemical concepts (Talanquer, 2017). Contemporary research consistently highlights that students' difficulties in understanding chemistry are often rooted in their inability to connect these three representations effectively. For example, a student may be able to write a reaction equation (symbolic) but fails to explain what happens at the molecular (microscopic) level or how it manifests in an experiment (macroscopic) (Rahayu et al., 2018). Students' difficulties in understanding chemistry are due to a lack of experience at the macroscopic level, misconceptions at the submicroscopic level, and a lack of information about the agreements on the use of terms at the symbolic level (Gilbert & Treagust, 2009). In studying chemistry, the study revealed that 47.96% of students had difficulty understanding the concept of chemical equilibrium (Basyiroh et al., 2022).

Meanwhile, 41% of students experienced misconceptions and 18% did not understand chemical equilibrium material (Mayasri et al., 2023).

The use of props in the chemistry learning process is important because students need concrete and easily observable events so that it becomes an impressive learning experience (Lubis, 2021). The availability of adequate teaching aids plays a vital role in chemistry learning, especially in abstract and complex chemical equilibrium materials. Concepts such as equilibrium shifts, equilibrium constants, and the factors that affect them are often difficult for students to visualize through theoretical explanations or mathematical formulas alone. The lack of props, such as molecular models, equilibrium reaction experiment sets, or interactive simulations, can hinder students' conceptual understanding and make learning feel boring. A study Purwati & Haryani (2019) highlights that limited laboratory facilities and lack of teaching aids are often the main obstacles in the implementation of active and experimental learning, especially in chemistry topics that require real visualization.

Teaching aids and learning media will increase learning motivation and can make it easier for students to understand abstract chemical concepts (Juwairiah, 2013). Learning motivation plays a crucial role in the chemistry learning process, given the complexity and abstract nature of many chemistry concepts. When students are motivated, they tend to show a higher level of engagement in learning activities, strive to understand the material in depth, and are less likely to give up easily when faced with difficulties. A study by Yu (2018) in the journals Chemistry Education Research and Practice shows that intrinsic motivation, in particular, is positively correlated with better academic achievement in science subjects, including chemistry. This indicates that an internal drive to learn and curiosity about chemical phenomena can be a key driver of success.

Efforts that can be made to provide macroscopic level experience in chemical equilibrium learning are by developing learning media in the form of sulfuric acid manufacturing teaching aids with the contact process method. By learning using contact process teaching aids, it is hoped that it can increase students' motivation to learn.

METHOD

This study used a mixed-method research design with product development using R&D methods (Research and Development) with the ADDIE model development method; Analysis, Design, Development, Implementation, Evaluation (Branch, 2009). Furthermore, at the implementation stage, research was carried out with quasi experimental method. This implementation was carried out to apply sulfuric acid, making teaching aids with a contact process to increase learning motivation. The independent variable in this study is the contact process props in the manufacture of sulfuric acid, while the dependent variable is learning motivation.

The development of the teaching aids was carried out in the laboratory at one of the senior high schools in Tangerang, Banten, from September 2024 – June 2025. The implementation was carried out in the same school with a sample of 40 students in classes XI.2 and XI.3 each. Testing the validation of the teaching aids by media, material, and language experts using a questionnaire with a Likert scale, the validation results obtained a feasibility presentation of 91% or very feasible. The learning motivation measurement instrument uses a questionnaire with a Likert scale designed to measure the dimensions of intrinsic motivation, career motivation, self-determination, self-efficacy, and value motivation (Glynn et al., 2011). Learning motivation instruments were given during pretests and posttests, both in the control class and in the experimental class.

RESULTS AND DISCUSSION

This research aims to develop a contact process teaching medium in the manufacture of sulfuric acid. Contact process props are props that can visualize how pressure and volume affect in order to production of sulfuric acid products. This prop can represent a simple description of how the process of making sulfuric acid is at the industrial level, with the concept of chemical equilibrium (Ramezani, 2019).

This study uses the ADDIE model (Branch, 2009; Mesra, 2023), which was chosen for its suitability for the development of these props. Clear steps and each stage allow for revision and evaluation, making it easy to create a practical device. If the design proves to be inadequate, it can be revised and evaluated immediately (Mesra, 2023). The stages of this research can be explained in the discussion in order of ADDIE as follows:

Analysis

At this stage, the need for teaching media in schools is determined. This analysis was carried out by making a questionnaire. The questionnaire sheets were made using Google Forms and distributed in the WhatsApp group of teachers in the Indonesian Chemical Science Teachers Association (PPSKI) of Banten province. The results of the initial analysis stated that teachers did not have props that could visualize the concept of chemical equilibrium shifts influenced by changes in pressure and volume, so that the concept was poorly understood by students. Learning about this concept that does not involve macro aspects makes student motivation decrease. Based on the results of the study, it shows that 100% of teachers have never used contact process teaching aids, teachers also have a positive attitude towards the need for sulfuric acid manufacturing teaching aids with contact processes.

Design

This stage includes the design of the contact process teaching aids. The process of designing the teaching aids follows the principles that occur in the contact process. There are four principles in the contact process, namely the production of SO_2 gas, the catalytic oxidation of SO_2 into SO_3, the absorption of SO_3 into oleum, and the dilution of oleum into sulfuric acid. Of the four principles, three principles are used in the manufacture of these teaching aids; the principle that does not exist in this teaching aid is the absorption of SO_3 into oleum. At the stage of catalytic oscillation, SO_2 to SO_3 here becomes a characteristic of the contact process. At this stage, a design is made so that the pressure is enlarged by reducing the volume of the copper pipe from one large line to three smaller lines. The design of the props can be seen in Figure 1.

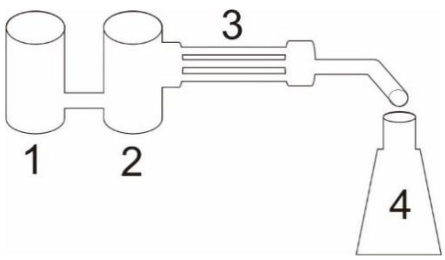

Image caption:

1. Reactor 1, the place where O_2 gas is formed
2. Reactor 2, SO_2 formation site
3. SO_2 oxidation site with the catalyst and
4. The pressure is enlarged.
5. Place of absorption of SO_3 into sulfuric acid

Figure 1. Contact Process Teaching Aids Design

Development

Development is carried out by preparing tools and materials and then assembling them into a contact process teaching aid. The results of making contact process teaching aids can be seen in Figure 2.

Figure 2. Contact Process Teaching AIDS

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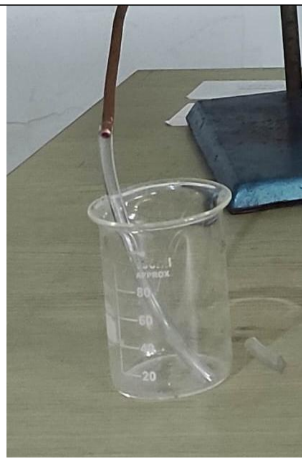
Table 1. Contact Process Props Description

Purpose	Tool Part Pictures
Oxygen gas generation (Reactor 1) - The flask separates the hydrogen peroxide so that it can drip into the reactor. - Potassium permanganate storage syringe so that it can be fed into the reactor when needed - Three-neck flasks, where the reaction of H_2O_2 with $KMnO_4$ forms O_2 gas. - Hose to deliver oxygen to reactor 2. - Rubber plugs, statipes, bosheds, clamps and washers.	
Formation of SO_2 gas (Reactor 2) - A combustion spoon with a rubber stopper to place the sulfur to be reacted with O_2 gas. - The three-point neck flask reacts with Sulfur gas which will produce SO_2 gas. - Rubber plugs, statipes, bosheads and clamps	
Where SO_3 gas is formed (balance shift pipe) - Copper pipe with a diameter of 5/8 inch with the center inserted 3 1/4 inch copper pipes, on this small pipe is placed V_2O_5 - Stove, for heating 1/4-inch copper pipes. - Plastic hose for connecting sulfur trioxide gas with water reservoir.	
Formation of sulfuric acid (absorpsi SO_3) Erlenmeyer/chemical cup to be filled with water, the water will meet with sulfur trioxide gas to form sulfuric acid.	

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The developed props are then tested by material, language, and media experts. The results of the expert validation can be shown in Table 2.

Table 2. Expert Validation Results

Aspects	%	Category
Contents/materials	93,3%	Highly feasible
Physical design	93,3%	Highly feasible
Functionality and interaction	86,6%	Highly feasible
Educational and support	92,0%	Highly feasible

Implementation

Contact process teaching aids products are implemented in teaching at one of the senior high schools in Tangerang, Banten. Teaching aids were tested on learning chemical equilibrium material in experimental classes, and were given pretests and posttests for learning motivation. For the control class, pretests and posttests were given motivation to learn but with learning without teaching aids. Data processing using SPSS 26.0 about Normality Test Data, Homogeneity Test Data, and Independent T Test Data can be seen in Figure 3, Figure 4, and Figure 5.

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk	
	Kelas	Statistic	df	Sig.	Statistic	df
Hasil	Pretes kelas kontrol	,103	40	,200*	,983	40
	Postes kelas kontrol	,093	40	,200*	,962	40
	Pretes kelas eksperimen	,061	40	,200*	,975	40
	Postes kelas eksperimen	,089	40	,200*	,960	40

Figure 3. Normality Test Data

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Nilai	Based on Mean	2,506	1	78	,117
	Based on Median	2,503	1	78	,118
	Based on Median and with adjusted df	2,503	1	73,983	,118
	Based on trimmed mean	2,506	1	78	,117

Figure 4. Homogeneity Test Data

Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence ... Lower
Nilai	Equal variances assumed	,012	-6,575	2,560	-11,672
	Equal variances not assumed	,012	-6,575	2,560	-11,677

Figure 5. Independent T Test Data

Evaluation

The evaluation at the design stage is how to obtain materials that can be assembled with precision in order to obtain a tight circuit so as to minimize leaking gases, and the selection of materials for the balance shifting parts so that they are heat resistant but easy to form. The use of potassium permanganate and hydrogen peroxide concentrations ultimately obtained the right concentration in order to obtain oxygen gas with sufficient pressure to induce gas flow.

Contact process aids show a significant positive impact on students' learning motivation. For example, when students observe direct application and color changes while producing sulfuric acid, they tend to be more engaged and eager to understand the concept of chemical equilibrium. This is supported by research that the use of kinesthetic visual learning media significantly increases students' interest in learning (Permana et al., 2019).

The results of the development of contact process teaching aids show significant potential in increasing students' learning motivation in chemical equilibrium materials, especially related to the reactions $2SO_2(g)+O_2(g)\rightleftharpoons 2SO_3(g)$ in the manufacture of sulfuric acid. These props, with their visualization of changes in pressure and volume, allow students to directly observe equilibrium shifts according to the Le Chatelier Principle. The acquisition of observational data shows that the use of these interactive teaching aids is able to attract students' attention more effectively than conventional learning methods, in line with the findings of the study by Han et al. (2020), which highlights the effectiveness of visualization and interactivity in science learning. This increase in motivation is crucial, given the complexity of chemical equilibrium material that is often considered abstract by students.

Furthermore, the positive impact of these teaching aids can also be seen from the students' responses, who stated that the material became easier to understand and relevant to industrial applications. Active involvement of students in manipulating simulation parameters and observing the results in a positive way real-time, facilitates a deeper conceptual understanding, not just memorization. This is consistent with the view of experiential learning that emphasizes the direct involvement of learners to build their knowledge, as outlined by Smith & Jones (2018), which highlights the importance of hands-on activities in chemistry learning. Thus, these teaching aids not only increase motivation but also have the potential to increase students' learning outcomes in the basic competencies of chemical equilibrium.

CONCLUSION

In this study, a contact process prop was produced in the manufacture of sulfuric acid that can visualize shifts in chemical equilibrium affected by pressure and volume. The contact process props have four main parts, namely (1) reactor 1 which functions to make oxygen gas; (2) reactor 2 which functions to make sulfur dioxide gas; (3) an equilibrium shift pipe that functions to shift the equilibrium reaction to form sulfur trioxide gas; (4) absorption as a place of absorption of sulfur trioxide gas into water to produce sulfuric acid. Development uses the ADDIE model and involves material, language, and media experts for product validation. The validation process resulted in the fact that the contact process teaching media is very feasible to be used in learning chemical equilibrium material. From independent t-tests on postes values in experimental classes and control classes, obtained a sig of 0.012, then it can be concluded that H0 is rejected and H1 is accepted or the hypothesis is accepted, which means that there is a significant positive influence of the use of contact process teaching media in increasing students' learning motivation to learn chemistry of chemical equilibrium materials, by the study in Journal of Chemical Education Innovation (Susantin & Widjajanti, 2020) shows that the use of teaching aids in learning can increase students' confidence, as well as encourage active participation in class discussions. Thus, the props not only facilitate conceptual understanding but also effectively foster students' motivation and self-confidence in learning chemistry.

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