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Stoichiometry E-Book Based on Creative Problem Solving (CPS) to Solve Conceptual Problems

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ABSTRAK

Kurangnya bahan ajar yang dapat memunculkan ide penyelesaian masalah dapat menghambat kemampuan mahasiswa dalam menyelesaikan permasalahan konseptual. Penelitian ini bertujuan untuk menghasilkan e-book berbasis Creative Problem-Solving yang valid dan layak digunakan serta dapat menumbuhkan kemampuan mahasiswa dalam menyelesaikan permasalahan konseptual. Bentuk penelitian yang digunakan adalah Research and Developmet (R&D) yang mengacu pada model pengembangan ADDIE, dimulai dari tahap analyze, design. develop, implement and evaluate. Hasil yang diperoleh menunjukkan bahwa e-book yang dikembangkan valid secara content validity dan face validity dalam aspek kesesuaian capaian pembelajaran dengan konsep atau isi materi, kebahasaaan, panduan, kemudahan penggunaan, kemenarikan tampilan, kejelasan petunjuk penggunaan, kejelasan materi, kejelasan gambar, kejelasana video, kemenarikan analogi, kejelasan contoh dan soal latihan, kejelasan langkah Creative Problem Solving serta terbukti dalam membantu mahasiswa dalam menyelesaikan permasalahan konseptual setelah diterapkannya e-book dalam pembelajaran. Berdasarkan hasil yang diperoleh dapat disimpulkan bahwa e-book yang dikembangkan layak digunakan.

ABSTRACT

A lack of teaching materials that can bring up problem-solving ideas can inhibit students' ability to solve conceptual problems. This research aims to produce an e-book based on Creative Problem Solving that is valid and feasible and can foster students' ability to solve conceptual problems. This research is Research and Development (R & R&D), which refers to the ADDIE development model, starting from the analysis, design, development, implementation, and evaluation stages. The results show that the e-book is valid in content validity and face validity in terms of conformity of learning achievement with the concept or content material, language, guidance, ease of use, appearance, clarity of instructions for use, clarity of the material, clarity of image, video clarity, analogy, clarity of examples and exercise questions, clarity of creative problem-solving steps and proved can help students in completing conceptual problems after the application of e-books in learning. Based on the results obtained, we can be concluded that the e-book developed is feasible to use.

1. INTRODUCTION

Stoichiometry is an important concept that prospective chemistry teachers must master because it is useful for learning other chemical concepts. Stoichiometry is the basis for predicting the equivalence point of a titration, determining the heat released or received in a reaction, and determining the equilibrium constant (Febriyanti et al., 2019; Hanson, 2016). Stoichiometry is a branch of chemistry that studies the quantitative relationship between reactants and products (Giunta, 2016). Stoichiometry consists of several interrelated concepts: balancing chemical reactions, mole concepts, mole ratios of reactants and reaction products, and limiting reactions (Gauchon & Méheut, 2007; Gulacar et al., 2013; Makhechane & Qhobela, 2019).

There are two types of problems given to measure understanding of stoichiometry, namely algorithmic and conceptual problems. The characteristics of algorithmic problems are that the problem-solving method is known and can be easily memorized, the information or data is presented clearly and completely, and the solution method is limited to identical problems (Stamovlasis et al., 2005). Conceptual

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problems have a characteristic, namely the way of solving the problem is a hypothesis that is compiled using related concepts and evaluated for accuracy in solving problems, the information or data presented is incomplete or needs to be converted first before being used, and the settlement method only applies to problem situations that given (Cracolice et al., 2008; Randles & Overton, 2015; Sangguro et al., 2019). From the two types of stoichiometry problems, it can be seen that mastery of the concept of stoichiometry is not only limited to the ability to explain but can solve various problems involving the application of these concepts in various situations, especially in determining the number of reactants and reaction products (Broman & Parchmann, 2014; Niaz & Montes, 2012; Sangguro et al., 2019). In other words, they understand the stoichiometric concept of chemistry teacher prospective students if they can solve conceptual problems rather than algorithmic problems.

Many studies show that prospective teacher students' stoichiometric conceptual problems are still more difficult to solve than algorithmic problems. In the mole concept, students can solve algorithmic problems with complete data or information and standard procedures but fail to solve complex problems that require reasoning in managing existing information to solve problems (Taha et al., 2014). Students also found difficulties in changing the narrative of the problem in the form of reaction equations, did not understand the procedures carried out in solving problems, and failed to use existing information or data to solve stoichiometry problems (Chandrasegaran et al., 2009; Danjuma, 2011; Gulacar et al., 2013). Students can solve the same stoichiometric problem with the example exercise but fail to solve a different problem (Kartal & Kartal, 2019).

The problem-solving ability of prospective chemistry teacher students at Tanjungpura University on the concept of stoichiometry is only limited to using the same procedure or method as the sample questions. The biggest failure occurs if the stoichiometry problem is different from the sample questions given. The data or information in solving the problem is incomplete, and they do not have the skills to design their problem-solving. After studying the concept of stoichiometry, it is known from the test results that students can only answer three of the ten test questions. The three questions answered correctly are questions that have the same procedure as the examples of exercises given learning. In other words, problem-solving skills are not just knowledge in understanding chemistry but using chemistry to solve existing problems using scientific steps (Randles & Overton, 2015). It is following the demands of the KKNI, which requires undergraduate students to apply logical, critical, systematic, and innovative thinking in the development or implementation of science and technology that pays attention to and applies humanities values in their field of expertise.

Creative problem solving (CPs) strategies can be used as a solution to develop students' skills in solving conceptual problems in stoichiometry. CPs is a process of thinking with a new or different perspective, presenting original ideas, or connecting previously unrelated ideas into a single unit to solve a problem (Triyono et al., 2017; Vernon et al., 2016; Vidal, 2010). CPs have five steps in solving problems: finding facts or data, determining problems, determining ideas, determining solutions, and accepting results (Asmawat et al., 2018; Fauziah et al., 2019; Hobri et al., 2020). The advantage of CPs is that it allows students to use ideas from new or different perspectives, connect previously unrelated ideas into a single unit, formulate maps or settlement frameworks and recheck them with commonly used settlement frameworks so that they can correct the correctness of each completion step made (Vernon et al., 2016; Vidal, 2010; Wood, 2006).

Based on the description above, it is necessary to develop a CPs-based stoichiometry e-book to foster problem-solving skills in solving conceptual problems of stoichiometry concepts. This research aims to produce an e-book of CPs-based stoichiometry that is valid and suitable for use in learning. The developed e-book can explain stoichiometric concepts through writing, pictures, and videos suitable for student learning styles, presenting examples of conceptual problems and how to solve them through the CPs stage. The final part of each discussion will be given a case or conceptual problem different from the sample questions and asks students to solve the problem by following the CPs steps independently.

2. METHODS

The method used in this research is Research and Development (R&D), which refers to the ADDIE development model, starting from the analysis, design stage, development, implementation, and evaluation (Branch, 2009). The analysis stage explores the obstacles students face in solving conceptual problems in stoichiometry. The design stage in the research is designing a CPs-based stoichiometry e-book draft starting from an analysis of learning outcomes and the limits of the stoichiometric concept to be developed. The development stage in this research is to compile a CPs-based stoichiometric e-book draft and validate the draft with two techniques, namely content validity and face validity. The implementation stage in this research is to implement the e-book draft that was developed to learn the stoichiometry concept. This study's evaluation stage evaluates the results of students' conceptual problem solving from the implement stage and then revises the CPs-based stoichiometry e-book draft. In the second year of study, the subjects in the analysis stage were ten students of the chemistry education study program FKIP Untan in the 2nd year. The basis for choosing that these students had attended lectures on the concept of stoichiometry in the first year of lectures. In the development stage, the subjects involved in content validity are experts in the fields of chemistry and chemistry education, each of which is five people with a minimum academic position of Lector and on face validity, 25 students of chemistry education at FKIP Untan 2nd year who have studied the concept of stoichiometry. The subjects involved in the implementation stage were 25 students of the chemistry education program FKIP Untan who took basic chemistry courses on stoichiometry.

At the analysis stage, the data collection tool is an interview guide that contains the weaknesses faced in solving conceptual problems in the stoichiometric concept. In the development stage, the data collection tool on content validity is a validation sheet, and on the face validity is a CPs-based stoichiometric e-book display assessment sheet. The data collection tool is an exercise test for solving stoichiometric conceptual problems in the evaluation stage. The data collected from the interviews at the analysis stage were described qualitatively regarding the obstacles or constraints experienced by students in solving conceptual problems in stoichiometry. The data obtained from the validation sheet is then analyzed to determine the amount of content validity index (VCI) using the first equation. It is declared valid if it obtains a VCI score of 0.8 for each aspect observed (Yusoff, 2019). The second equation's approval percentage determines the data collected on the display assessment sheet.

3. RESULTS AND DICCUSSION

Results

The first stage of this research is to analyze problems, especially the problems students face in studying the concept of stoichiometry. From the results of interviews with ten students of chemistry education FKIP Untan in the 2nd year of lectures, information was obtained that most of them had difficulty solving stoichiometry problems when given problems that were different from the sample questions, requiring complex completion steps outside of sample questions and difficulties in deciphering data. Incomplete in the question. They also said that in studying the concept of stoichiometry, the learning tendency is to study examples of questions given by lecturers and books and use them to work on other problems. After analyzing the problems, the next step enters the second stage, namely the design stage. At this stage, the learning outcomes that can help students learn stoichiometric concepts are determined, and the limits of the concepts to be learned from the e-book that will be developed are determined. The results at the design stage are presented in Table 1.

Table 1. the results of the analysis of learning outcomes and concept boundaries at the design stage

No	Capaian Pembelajaran	Concept limitation
1	Explain the definition of the mole as the SI unit for the number of particles	• Substance and number of particles • Determination of Avogadro's number from X-ray shooting onto pure silicon crystals. • Analogy of Avogadro's number with ordinary objects and atoms
2	Converting moles to the mass of a substance or vice versa	• The relation of Molar mass to relative atomic or molecular mass. • The relationship between moles, molar mass, and mass of a substance. • The relationship between the density of solids and liquids with the conversion of moles.
3	Converting moles to the concentration of a solution or vice versa	• Molarity relationship with moles
4	Determine the moles of a gaseous substance based on Avogadro's hypothesis or the Ideal Gas Law.	• Moles of gas under standard conditions (temperature 00C, pressure 1 atm). • Mol with ideal gas equation (nonstandard state)
5	Describe the physical characteristics of a chemical change or reaction	• Chemical reactions involving energy changes • Chemical reactions that produce gases.

No	Capaian Pembelajaran	Concept limitation
		• Chemical reactions that produce insoluble precipitates. • A chemical reaction that produces a fixed color.
6	Explain how to write chemical equations	• The meaning of the symbol for the reaction equation. • reaction coefficient
7	Balance a reaction equation.	• The "inspection" or trial and error method of balancing reactions
8	Explain the meaning of the reaction coefficient in the balanced reaction equation	• The relationship between reaction coefficients and moles of substances.
9	Predict quantitative amounts of reactants or products	• Reaction stoichiometry (exactly exhausted) • Utilization of the ratio of reaction coefficients in determining moles if one mole of substances involved in the reaction is known.
10	Predicting the quantitative amount of a reactant that acts as a barrier	• The limiting reaction is determined by the amount of reactant used up first.

After determining the learning outcomes and concept boundaries, they enter the third stage, the development stage. At this stage, a CPs-based stoichiometry concept e-book begins with compiling e-book material and conceptual problem-solving exercises with CPs steps. The material presented in the draft e-book contains a description of the material, analogies, supporting videos, and multi-representation-based images (Figure 1).

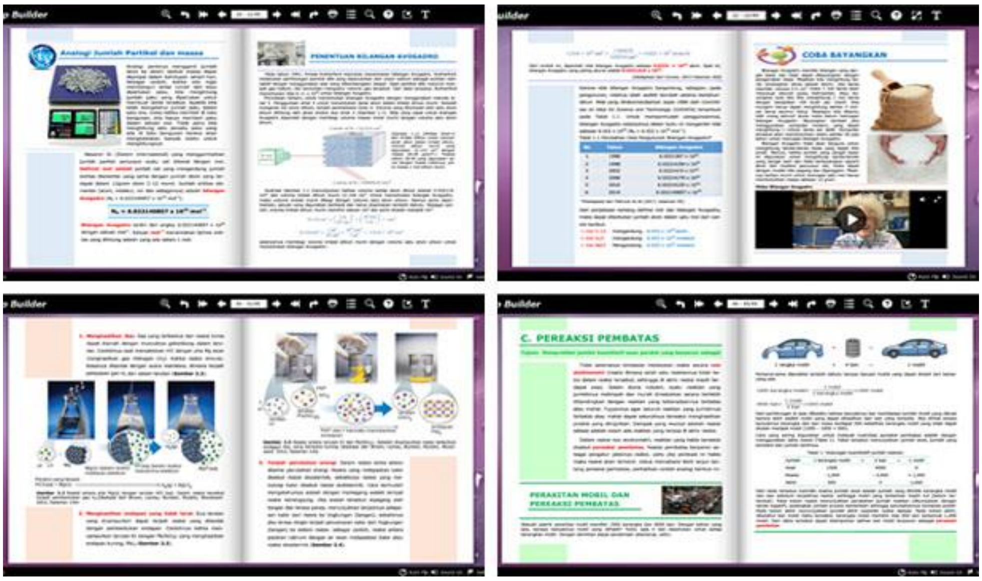

Figure 1. Sample presentation of ebook draft material

Examples of working on the problems presented in the draft e-book following the CPs steps starting from the fact or data finding stage, problem determination, idea determination, solution determination, and acceptance of results (Broman & Parchmann, 2014; Yuriev et al., 2017). The search for facts or data is described clearly, carefully, and objectively about what data is presented in the problem. Determination of the problem is described as a form of clarification in a stoichiometric problem with a clear statement of the problem to be solved. Determination of ideas focuses on selecting concepts that can be used, analyzing the completeness of the data from the problem, reconstructing incomplete data, and compiling the data used in performing stoichiometric calculations. Determination of solutions is focused on applying the ideas that have been outlined previously and correcting again whether these ideas can be applied in solving stoichiometric problems. Acceptance of the results is focused on the final decision to accept or reject the results obtained in determining the solution by considering the correctness of the concept, the accuracy of the data used, and logical and acceptable problem-solving steps. An example of the application of CPs in solving conceptual problems in the e-book draft is presented in Figure 2.

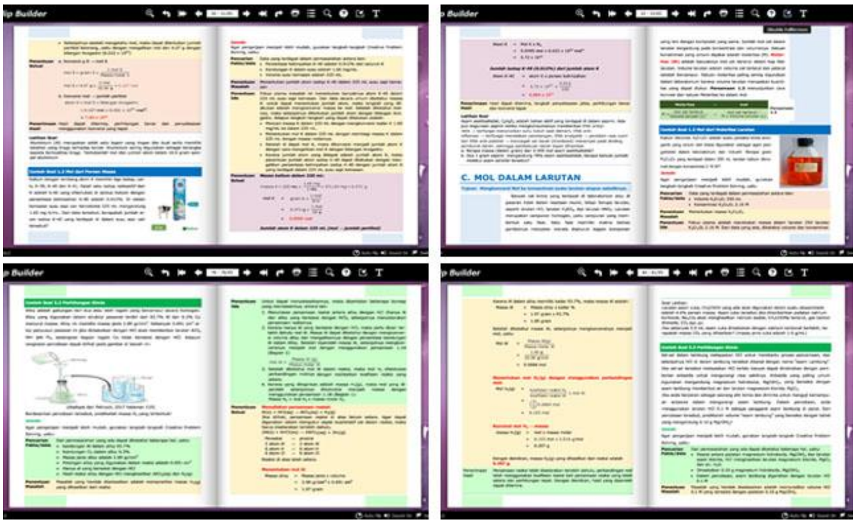

Figure 2. Examples of Application of CPs on conceptual problems

The results of the e-book draft are then validated in two forms, namely content validity and face validity. Content validity in this study is intended to minimize errors in several ways, including learning achievement, concept or content of the material, language, and guidance using CPs steps in solving conceptual problems. Furthermore, the content validity (VCI) score is determined from content validity. The results obtained from the VCI score indicate that the developed e-book draft is declared valid in all aspects assessed by ten validators. The next step is to provide a draft e-book to 20 chemistry education students at FKIP Untan to measure face validity. The purpose of doing face validity is to see the responses and views of the draft e-Book based on the experience, understanding, and study habits of potential users. Aspects measured from face validity include ease of use, the attractiveness of appearance, clarity of instructions for use, clarity of the material, clarity of images, clarity of video, the attractiveness of analogies, clarity of examples and practice questions, and clarity of clarity CPs steps. The results obtained from face validity show that the average acceptance is very high. It shows that the e-Book draft that has been developed can be accepted based on the point of view of potential users. Percentage of approval of prospective users on face validity is presented in Table 2.

Table 2. Percentage of approval of prospective users on face validity

No	Aspect	Percentage
1	CPs-based stoichiometry e-Book application is easy to use	100
2	Easy-to-understand CPs-based stoichiometry e-Book display	95
3	Instructions for using the application are very clear, making it easy to use	95
4	The description of the material or concepts contained in the e-book is easy to understand or clearly understand the meaning	90
5	The images presented in the e-book make it easier to understand the explanation	100
6	The videos presented in the e-book make it easier to understand the concept	95
7	The analogy presented in the e-book makes it easier to understand the concept	90
8	Examples and practice questions in the e-book are unique, different from the usual ones that are trained in learning	85
9	The examples and practice questions in the e-book explain problem-solving ideas, not solving procedures.	85
10	Practice questions in the same chapter in the e-book have their way of solving, cannot apply the same procedure to different questions.	90
	Average	**92,5**

After being declared valid on content validity and potential users can receive the developed e-book draft, it enters the fourth stage, namely the implement stage. At this stage, the e-book draft is applied to learn stoichiometry. Learning is carried out online in two meetings, with each time allocation for each meeting being 150 minutes. Before starting the meeting, each student was distributed a draft of the CPs-based stoichiometry e-book. At the first meeting, students explored the concept of moles and reaction equations by utilizing the e-book provided, solving conceptual problems, and collecting the results of solving these problems for the lecturer. At the second meeting, students explored the concept of chemical calculations and limiting reactions, solving conceptual problems with CPs steps, and collected the results of solving these problems for the lecturer. After completion of implementation, then enter the fifth stage, namely the evaluation stage. At this stage, an assessment of the completion of conceptual problems that students have completed is carried out at the implementation stage. The overall average result obtained from solving students' conceptual problems on the stoichiometric concept is 88.92.

Discussion

This research aims to produce a valid, CPs-based stoichiometry e-book that can be used to develop conceptual problem-solving skills using stoichiometry concepts. In this study, validation is reviewed from content validity and face validity. Content validity in this study is intended to measure the suitability of the e-book draft developed in learning achievement, presentation of concepts, language, and the CPs approach used in practice questions in terms of assessments given by experts in chemistry and chemistry education. The CPs-based stoichiometry e-book is declared valid by the validator. The learning outcomes of each material in the e-book are written clearly at the beginning of the sub-chapter with the aim that students can find out the abilities they can gain from reading the developed e-book (Lau et al., 2019: Muswita et al., 2018; Tang, 2021).

The description of the material in the e-book is presented sequentially, starting from basic concepts to complex concepts using interactive, clear, easy-to-understand language and no ambiguous words. In addition, in the e-book, videos, multi-representation-based images, and analogies aim to help and make it easier for students to understand the topic being studied. This is supported by several research results showing that videos, images, and analogies can make it easier to understand the topic being studied (Batubara & Batubara, 2020; Firman et al., 2021; Li et al., 2021). The use of videos about guidelines for using chemicals effectively increases knowledge of safety at work using chemicals (Subamia et al., 2021). Research studies show that students in chemistry classes can entertain and help them understand information related to the material being studied, especially if the analogy comes from objects or events around them (Rahayu & Sutrisno, 2019). The study of multi-representation-based images was carried out by (Ferreira & Lawrie 2019), who stated that the design and selection of images in chemistry learning by combining chemical representations in macroscopic, microscopic, and symbolic makes concept learning more in-depth and increases student participation in digging information. In addition, the examples and practice questions designed in this stoichiometry e-book are conceptual problems with the characteristics of having predictive completion steps and only apply to certain problem situations; the data provided needs to be converted first. Furthermore, in completing examples and practice questions, applying CPs steps. Selection of CPs as an aid in solving conceptual problems.

Face validity in this study is intended to see the responses of potential e-book users to minimize the gap between expert and prospective users' assessments. The importance of minimizing the gap between expert and potential user assessments because of the accuracy of the e-book, which is considered valid by experts but unacceptable to potential users (Korat et al., 2021; Muswita et al., 2018; Uygarer & Uzunboylu, 2017). Their limited understanding, knowledge, and habits can make e-books useless and not be implemented in learning (Franck et al., 2016; Zechariah et al., 2021). Prospective users give a relatively high acceptance. High acceptance of material descriptions, videos, analogies, and pictures in e-books can help students obtain more complete information than just explanations in text form (Bobek & Tversky, 2016). Acceptance of examples and practice questions in e-books that are different from usual teaching problem-solving ideas and not solving procedures and applying different settlement procedures from each example and practice question (Liao et al., 2018; Raihan et al., 2018). This shows that the e-book makes potential users with different background knowledge, skills, and learning experiences able to learn CPs in solving conceptual problems and have no difficulty applying these CPs.

The results obtained at the evaluation stage show that students can solve conceptual problems after implementing the CPs-based e-book with an average indicator score of 88.92. These results indicate that the developed e-book can help students solve conceptual problems. Students' ability to solve conceptual problems can be caused by giving examples of questions that do not discuss a procedure for using concepts but focus on determining problem-solving ideas. Giving examples of creative ways to determine problem-solving ideas can help form new perspectives for students about various ways of solving problems. Students are accustomed to coming up with their ideas for solving a problem (Surif et al., 2014). In addition, students' ability to solve conceptual problems cannot be separated from their ability to analyze the data in the problem. The ability to analyze data is the first step in solving problems by looking at the completeness of the data and converting the data so that it can be used in problem-solving. Failure to analyze data can hinder the determination of problem-solving ideas, and the tendency is to state that the problem cannot be solved or resolved (Mehadi, 2019). Several other studies have shown that CPs can help students solve a problem. Research conducted by (Heliawati et al., 2021) concluded that applying CPs in open-ended experiments can improve scientific work skills and conceptual understanding. Research conducted by (Triyono et al., 2017) concluded that the application of CPs in science learning positively influenced the development of students' creativity. Research conducted by (Dewi & Putra, 2021) concluded that the application of multimedia-assisted CPs influences science competence at the elementary school level.

4. CONCLUSION

The CPs-based stoichiometry e-book developed is valid and suitable for use in terms of the suitability of learning outcomes with the concept or content of the material, language, guidelines for using CPs steps in solving conceptual problems, ease of use, the attractiveness of appearance and analogies, clarity of instructions for use, materials, pictures, videos, examples, practice questions, and CPs steps as well as the implementation of e-books in learning can help students solve conceptual problems with satisfactory results. The CPs-based stoichiometry e-book developed is valid and suitable for use in terms of the suitability of learning outcomes with the concept or content of the material, language, guidelines for using CPs steps in solving conceptual problems, ease of use, the attractiveness of appearance and analogies, clarity of instructions for use, materials, pictures, videos, examples, practice questions, and CPs steps as well as the implementation of e-books in learning can help students solve conceptual problems with satisfactory results.

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