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Development of a Creativity-Based Cognitive Test Design to Measure Students' Problem-Solving Abilities

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Abstract

Education is a form of business that is carried out in a planned and systematic manner that aims to provide insight, knowledge, skills, and expertise to students (Kurniawan, 2015). Education is needed as a means to shape one's character and character in order to be able to face the current developments of the times, advance the nation, and be able to compete with other nations. The success of education in an area is determined by an assessment. Assessment activities carried out by a teacher cannot be separated from the use of instruments. The instrument is a measuring tool that is used to obtain information data on a matter. The use of the right assessment instrument if used will produce accurate data and assessment conclusions. So that with the accuracy of the assessment instrument, it is an important step to assist the government in the education sector. In the 2013 curriculum the assessment includes three main components, namely the assessment of knowledge, skills and attitudes which must be met in a balanced manner. Based on the results of research and discussion of test instruments to measure problem-solving abilities based on creative thinking on basic chemical laws, it can be concluded that: 1) The design of test instruments to measure problem-solving abilities based on students' creative thinking based on aspects of Fluency, Flexibility, Originality, and Elaboration, 2) The test instrument for measuring problem-solving skills based on creative thinking on the basic chemical laws material that has been developed meets valid and reliable criteria, 3) The practicality of the higher-order thinking enrichment test instrument was measured using the student and teacher response scales. The results of the responses of students and teachers stated that the response agreed to the use of test instruments to measure problem solving abilities based on students' creative thinking. These results state that the test instrument for measuring problem-solving skills based on students' creative thinking is practically used as an assessment instrument in the learning process.

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INTRODUCTION

Education is a form of business that is carried out in a planned and systematic manner that aims to provide insight, knowledge, skills, and expertise to students (Kurniawan, 2015) . The success of education in an area is determined by an assessment. Assessment is a series of activities carried out to obtain data, analyze and interpret conclusions based on the analysis of the data that has been obtained (Agustini, Rery, & Anwar, 2020) .

The assessment carried out in learning functions to improve the learning process as well as to become a reference and guideline for taking steps in implementing the learning process further. Assessment activities carried out by a teacher cannot be separated from the use of instruments. The use of the right assessment instrument will produce accurate data and assessment conclusions.

In the 2013 curriculum the assessment includes three main components, namely the assessment of knowledge, skills and attitudes which must be met in a balanced manner. Implementation of the 2013 curriculum emphasizes development creativity and strengthening character. The 2013 curriculum is implemented with the hope of producing Indonesian people who are intelligent, productive, creative, innovative, and have noble character and character. Learning in the 2013 curriculum requires students' thinking skills.

Diverse patterns of thinking need to be developed by students, from basic thinking to higher level (complex) thinking. Students' thinking ability is an aspect that needs to be emphasized in the learning process. According to Costa (1985), there are four types of high-order thinking patterns, namely, critical thinking, creative thinking, problem solving, and decision making. By increasing students' higher-order thinking skills, it is an effort to achieve learning objectives in the 2013 curriculum (Ardiana & Sudarmin, 2015) .

One of the important high-order thinking skills that a person has to face challenges in the 21st century is problem-solving ability. Problem solving is part of the skills or intellectual skills that are assessed as important and significant learning outcomes in the educational process. The increasingly advanced era of globalization, makes the challenges and demands of life even higher. The problems that arise are also increasingly complex. Thus, we as humans must be able to survive and adapt in this era by being equipped with the ability to think, namely with good problem-solving skills.

Good problem solving skills need to be balanced with good creative thinking skills as well. The ability to think creatively is an ability to create or as a means of providing creative ideas to solve problems. In Ipek's research (2012), states that student creativity is needed so that students are able to solve problems with the various ideas and methods they have. Hasan & Rahman (2012) also stated that creativity in solving problems can increase students' awareness in problem solving.

The process of creative thinking is a process that combines logical thinking and divergent thinking. Divergent thinking is used to find ideas to solve problems, while logical thinking is used to verify these ideas into a creative solution (Sari, Ikhsan, & Saminan, 2017) . The ability to think creatively is very important for students to participate in every learning process, so that they can explore their brain abilities, so that they are able to produce solutions to a problem by his creativity.

The results of observations show that the four teachers have never made a test assessment instrument to measure students' high-level thinking skills regarding problem solving abilities and specific creative thinking skills. The forms of assessment that are often used are the types of multiple choice questions, short essays, and closed essays. The assessment instrument used is focused on measuring the achievement of learning indicators and has not paid attention to students' higher order thinking skills. Most of the questions used only measure memorization and understanding aspects. The questions used were adopted from various sources, both from internet sources and from books. Questions that match the indicators are used by the teacher as an assessment instrument.

The results of interviews with several students said that chemistry is a subject that is considered difficult and complicated. Students said that chemistry concepts are abstract in nature, such as learning a new language because chemistry has a special vocabulary. The basic law of

chemistry is one of the abstract and mathematical chemical materials. Research conducted by Fajri (2019) also states that students still often equate one law with another. In fact, the basic laws of chemistry are one of the important materials that form the basis for studying chemical calculations.

So, it is necessary to develop a creativity-based cognitive test assessment instrument to determine the level of students' problem-solving abilities in basic chemical law material. The test assessment instrument was made based on creativity. The test assessment developed was in the form of open-ended description questions adapted to learning indicators on basic chemical law materials and indicators of problem solving and indicators of creative thinking.

METHOD

The Research on test instruments is to measure students' creativity-based problem-solving abilities is a type of Research and Development research. The type of Research and Development research carried out adopts the 4-D development model. This type or 4-D research and development model was developed by Thiagarajan et al. (1974) with research stages namely, define, design, develop, and dissemination . The 4-D research model has systematic steps or stages so that it is easy to understand.

The define stage is used in initial research to collect data about existing phenomena or for needs analysis. The design phase was carried out by researchers to design test instruments to measure students' creativity-based problem solving abilities on basic chemical law material. The indicators of creative thinking skills that will be used are indicators according to Munandar (2012) and indicators of problem solving are indicators according to Polya (2004). The instrument being tested will be validated by an expert or experts. At the develop stage , small-scale and large-scale tests are carried out to test the practicality and feasibility of the product so that it is used as a target study. Publication or dissemination is carried out at the disseminate stage of the developed test assessment instrument design product.

RESULTS AND DISCUSSION

The first stage of the initial research was to make observations at several senior high schools in Semarang and Banjarnegara. Field observations are needed to obtain information about phenomena that actually occur in the world of education, especially in the scope of high school. Information obtained from field observations is regarding the process of teaching and learning, evaluation, and assessment.

The results of the analysis of field observations that have been carried out when viewed from the aspect of the curriculum, have adhered to the 2013 curriculum. The 2013 curriculum requires students to be able to think at a high level which will later become a provision to face the challenges of the 4th industrial revolution in the future. The 2013 curriculum is used with the hope that it will produce intelligent Indonesian people who are productive, creative and innovative who have complete, integrated and balanced character and noble character. Updates regarding learning in the 2013 curriculum require students' thinking skills.

Observations made in several high schools in Semarang and in Banjarnegara regarding the assessment instruments used by teachers are almost the same, namely using instruments or questions that still measure memorization and understanding of concepts/material. The questions given still range from C1 to C3 and place more emphasis on measuring student achievement. So, not yet able to know the level of high-order thinking skills of students. The type of questions used as an assessment instrument used multiple choice questions and descriptions. Teachers was said that the test instruments that were often tested had weaknesses. The weakness of the multiple choice question type is that students who do not know the answer often answer questions by

composing/shooting directly. This makes the teacher unable to know the thinking ability of his students. The description questions given were still not able to measure students' higher-order thinking abilities. Most students work on questions in an instant and simple way.

Observations regarding learning materials, especially chemistry subjects, it is known that the basic laws of chemistry are one of the most complex chemical materials. Most students sometimes still understand only basic material and are not yet deep. In fact, material on the basic laws of chemistry is needed to become the basis for the next material. So that in studying this material it is necessary to have good mastery of the material, good problem-solving skills, and good higher-order thinking skills.

Initial Analysis

The making of the question grid refers to the chemistry learning syllabus in accordance with the 2013 curriculum. The existing syllabus is analyzed so that it can determine the indicator limits and competencies to be measured. In addition an analysis of indicators of problem solving and creative thinking was also carried out. The purpose of knowing and analyzing indicators and competencies is to obtain test instruments that are suitable for students' conditions and can achieve learning objectives. This is in line with Nurhadi, I., Masykuri, M., & Widiyatmoko, A. (2019) that said Creating a critical thinking test tool that emphasizes creativity and applies to chemical problem-solving at the high school level would be a suitable approach to enhance the problem-solving abilities of students consequently, Indicators that must be achieved in accordance with the ability to solve problems and think creatively.

The problem-solving indicators used are understanding the problem, devising a plan (planning for completion), carrying out the plan (implementing the plan), looking back (checking the process and results). While there are 4 indicators of creative thinking, namely Fluency (thinking fluently), Flexibility (thinking flexibly), Originality (originality of thinking), and Elaboration (thinking in detail/decomposition). Meanwhile, the indicators that must be achieved in basic chemical law material are in accordance with basic competence 3.11 according to the syllabus in the 2013 curriculum.

Question Ability Test

The test questions to measure problem solving and creative thinking skills that are developed are limited to description questions. The test questions consist of 12 questions on basic chemical laws. The preparation of questions is based on indicators of learning achievement and the questions that have been designed. It arranged based on learning indicators that refer to the 2013 curriculum syllabus, indicators of problem solving and creative thinking.

Haryani, S., & Santoso, B. (2019) suggests that the development of an assessment instrument for science process skills, there is a need for creativity aspects in measuring students' problem-solving abilities, thus the instruments developed to measure students' problem-solving abilities and creative thinking are as follows.

Question number 1

> Wood ash is ash produced from burning wood. Most people usually dispose of the ashes from burning wood by watering them or throwing them away directly. In fact, wood ash is very beneficial for soil fertility because of its nutrients which contain calcium, potassium, magnesium, carbonate, and many more. One day in an open space, Bayu conducted an experiment to burn 40 grams of wood with oxygen until it was all burnt. He wanted to produce ash to be used as fertilizer for crops. The amount of oxygen used by Bayu is 0.025 liters. In his experiment produces carbon dioxide gas, water vapor, and ash. Based on this information, what is the estimated mass of the ash formed? Include your reasons!

Question number 1 refers to the fluency aspect (fluent thinking), with indicators of creative thinking sparking answers by solving problems or questions smoothly. The indicators of questions that can be achieved in question number 1 are being able to apply and examine problems with Lavoisier's law. Question number 1 is included in the category of questions C5. To answer question number 1 students can write down what is known and what is asked, then students are able to write down chemical reactions and calculate the mass before chemistry occurs, then students are able to analyse factors that can affect the mass of chemical reactions that occur and determine the mass after a chemical reaction.

As suggest by Setyowati, E., Kadarohman, A., & Sunarno, W. (2019) in the article that arguing in measuring critical thinking skills in chemistry education should encompass more than just recognizing correct answers. Instead, it should also include the evaluation of students' reasoning, problem-solving, and decision-making abilities. As a result, indicators triggering answers by solving problems or questions smoothly can be shown by the ability to answer or solve questions in the correct sequence and workmanship.

Question number 2

Anton is doing an experiment to make table salt in the laboratory. There are 3 different compositions in each experiment. In the first experiment, Anton reacted 1 gram of Na and 1.5 grams of Cl_2 to produce 2.5 grams of NaCl. In the second experiment, Anton made 5 grams of NaCl with a mass of 2 grams of Na. In the third experiment, Anton made NaCl with a composition of 3 grams of Na and 4.5 grams of Cl_2 . Based on available information:

Make a table of experimental data for the reaction of Na and Cl_2 according to Anton's experiment!

What is the correct mass of Cl_2 in experiment 2 and the mass of NaCl in experiment 3 to complete Anton's experimental data?

In your opinion, what are the basic chemical laws that were applied to the experiment? Include the reason!

Question number 2 refers to the aspect of originality (originality of thinking) with indicators of creative thinking the ability to create new and unique expressions namely showing the originality of his thinking in making tables of experimental data that are adjusted to the information on the questions and determining the basic laws of chemistry that are appropriate in his opinion. This depends on the creativity of students in producing their expressions. The indicator of the problem that can be achieved in question number 2 is being able to make a table of experimental data and complete the blank data (by applying Proust's and Lavoisier's laws) and interpreting any basic chemical laws used. In question number 2 there are 3 question items. If students can complete the five item questions sequentially with the right answers, it can be said that students meet the indicators. Question number 2 is included in the category of questions C5.

Question number 3

A student is doing some experiments in the laboratory to react between nitrogen and oxygen. The experiments carried out produced reactions and formed various types of compounds. These compounds are compounds N_2O, NO_2 , N_2O_3 , and N_2O_4 , with the mass composition as follows:

No	Senyawa	Massa N	Massa O
1	N_2O	28 gram	16 gram
2	NO_2	14 gram	16 gram
3	N_2O_3	28 gram	48 gram
4	N_2O_4	28 gram	64 gram

If the student wants to make 4 compounds (N_2O, NO_2, N_2O_3 , and N_2O_4) with a fixed

mass of nitrogen, what is the ratio of the mass of oxygen for each compound?

Question number 3 refers to the elaboration aspect (detailed thinking/decomposition) with indicators being able to add or detail details of an object or idea, so that it becomes more developed. The indicator of the problem that can be achieved in question number 3 is being able to compare the masses of elements if one of the other elements is considered constant by applying the law of multiple comparisons/Dalton's law. Question number 3 is included in the category of questions C5. To answer question number 3 students must be able to equate the mass of nitrogen in this case equate the mass of nitrogen in the second experiment with other experiments (for example by making the mass of nitrogen to be 7) then students determine the mass of oxygen and then determine the ratio.

Question number 4

A child in the laboratory makes compounds with materials consisting of the elements carbon (C) and oxygen (O). After the elements C and O are reacted through a combustion reaction, they produce CO compounds and CO_2 compounds . If the mass of C in compound CO is 25% and in compound CO_2 is 20%, do the resulting two compounds obey Dalton's law? Explain why!

Question number 4 refers to the elaboration aspect (detailed thinking/decomposition) with indicators being able to add or detail details of an object or idea, so that it becomes more developed. The indicator of the problem that can be achieved in question number 4 is being able to prove whether the two compounds produced comply with Dalton's law. Question number 4 is included in the category of questions C5. To answer question number 4 students must be able to determine the mass of oxygen (O) if the mass of carbon (C) is kept constant (eg 50%) and then determine whether the mass ratio of oxygen fulfills Dalton's law.

Question number 5

Butane gas (C_4H_{10}) is a gas used as fuel in lighters, a mixture of LPG gas, and is even sold in bottles for portable gas that climbers usually carry when camping. If a climber has butane gas in a bottle that will be used for cooking, oxygen is needed so that the combustion reaction can occur which produces carbon dioxide and water vapor. Because, without the presence of oxygen gas can not occur combustion reactions. If the climber has 1.2 liters of butane gas, how much oxygen gas is needed for the butane gas to react completely?

Question number 5 refers to the aspect of flexibility ((thinking flexibly) with an indicator of skill in the way of approach or way of thinking. The indicator of the question that can be achieved in question number 5 is being able to determine the volume of oxygen gas needed for complete combustion of butane gas (Gay Lussac's Law) . Question number 5 is included in question C5. To answer question number 5 students must be able to write down the chemical reaction that occurs and determine the volume of oxygen needed for complete combustion to occur with the formula.

Question number 6

In the chemical industry, there are 2 types of cylinders filled with different gases. The tubes are tube X and tube Y. Tube X has a volume of 6 liters filled with N_2 gas having a temperature of 25°C and a pressure of 76 cmHg. In this tube there are 3 x 10 22 molecules of gas N_2. If cylinder Y, which has a volume of 8 liters, is filled with SO_3 gas , how many SO_3 gas molecules will cylinder Y have the same temperature and pressure as cylinder X?

Question number 6 refers to the aspect of Originality (originality of thinking) with an indicator of ability to combine parts or elements. The indicator of the problem that can be achieved in question number 6 is being able to determine the number of molecules of one gas if the number of molecules of the other gas is known by applying Avogadro's law/hypothesis. Question number 6 is

included in question C5. To answer question number 6 students must understand Avogadro's hypothesis and be skilled in determining the number of SO3 molecules.

Question number 7

> Today, Rani got an assignment from the teacher to identify compounds in the laboratory. The compound is a 200 ml hydrocarbon gas whose molecular formula is unknown. Identification of the C_xH_y compound was carried out by the combustion process using O_2 gas . This reaction produces 400 ml of CO2 gas and 300 ml of water vapour. Based on the information available, what is the molecular formula of the hydrocarbon gas?

Question number 7 is included in the aspect of fluency (thinking fluently) with indicators of triggering answers by solving problems or questions smoothly. The problem indicator that can be achieved in question number 7 is being able to formulate/compile the right molecular formula with the existing gas volume data. In this matter students are expected to be able to apply Avogadro's law/hypothesis. Question number 7 is included in problem C6. To answer question number 7 students must write down the equivalent reaction equation then calculate the number of C atoms and the number of H atoms by equating the number of atoms on the left side and the right side.

Question number 8

> Mr. Doni is renovating the terrace of his house. In its completion requires quite a lot of building materials, including: bricks, sand, cement, ceramics, and nails. Because it was already the dry season, Mr. Doni put all the materials outside the house without fear of getting wet from the rain. However, over time there is one material that has rusted. Iron-based nails (Fe) as much as 500 grams placed in an open container experience rust. Rusting is an event that occurs because a substance reacts with oxygen. Based on this description:
>
> Why do Pak Doni's nails rust?
>
> What is the approximate mass of the rusty nail? Explain!

Question number 8 is included in the aspect of flexibility (flexible thinking) with indicators of being able to see problems from different perspectives. The indicator of the problem that can be achieved in question number 8 is being able to explain the rusting reaction that occurs and determine the approximate mass of the rusted iron. (Lavoisier's law). In this question, students are expected to understand the concept of Lavoisier's law. In question number 8 there are 2 question items. If students can solve the two items of questions in a sequence with the right answers, it can be said that students meet the indicators. Question number 8 is included in question C5.

Question number 9

> The plants in Pak Andi's garden look greener, fresher, and grow faster than the plants in Pak Beni's garden. In fact, they watered and fertilized with the same amount and intensity. After being investigated, it turns out that there are differences in the use of plant fertilizers. Pak Andi uses urea fertilizer $[CO(NH_2)_2]$ while Pak Beni uses ZA $(NH_4)_2SO_4$ fertilizer. Actually both fertilizers are equally good for plant growth. However, the higher nitrogen content in urea fertilizer resulted in better plant growth in Pak Andi's garden. Based on this information, make proof that urea fertilizer is more efficient than ZA fertilizer! (Ar C=12, H=1, O=16, N=14, S=32)

Question number 9 is included in the aspect of fluency (thinking fluently) with indicators of triggering answers by solving problems or questions smoothly. The indicator of the problem that can be achieved in question number 9 is being able to prove that the nitrogen content of urea fertilizer is higher than that of ZA fertilizer. Students are expected to be able to apply the application of Proust's law. Question number 9 is included in question C5. To answer question number 9 students must understand Proust's law to determine the nitrogen content in the two fertilizers and then compare them.

Question number 10

Look at the following picture.

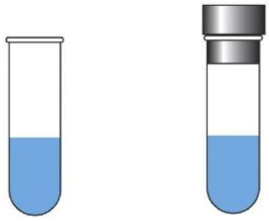

Figure 1 **Figure 2**

Figures 1 and 2 are test tubes which contain acetic acid (CH_3COOH) and baking soda ($NaHCO_3$) to react to produce sodium acetate (CH_3COONa), carbon dioxide (CO_2), and water (H_2O). The initial masses of acetic acid and baking soda reacted are the same for each test tube. The difference is, the test tube picture 1 is not covered, while the test tube picture 2 is covered. After the reaction took place and it was weighed, it turned out that the mass of the reaction product in test tube 1 was less than the mass of the reaction product in test tube 2. In your opinion, why could this happen?

Question number 10 is included in the aspect of flexibility (flexibility of thinking) with indicators of being able to see problems from different perspectives. The indicator of the problem that can be achieved in question number 10 is being able to explain why the reaction product in the open tube has less mass than the reaction product in the closed tube. In this question, students are expected to understand the concept of Lavoisier's law. Question number 10 is included in question C5. To answer question number 10 students must understand the concept of Lavoiser's law and be able to analyze open space to be able to influence the mass of a substance after the reaction occurs.

Question number 11

Water (H_2O) is a liquid consisting of the elements hydrogen and oxygen. Water is one of the sources of life for living things on earth. Scientists say that the water that is on earth was originally formed in asteroids. If an asteroid is illustrated as a container containing 27 grams of water, the water is formed from 3 grams of hydrogen and 24 grams of oxygen. If there are 3 grams of hydrogen and 16 grams of oxygen in another asteroid, how many grams of water can form?

Question number 11 is included in the aspect of originality (originality of thinking) with an indicator of the ability to produce new and unique expressions. The problem indicator that can be achieved in question number 11 is being able to calculate the amount of water that is formed if hydrogen and oxygen are provided in a certain composition. Question number 11 is included in question C4.

Question number 12

One of the compounds used to make plant fertilizers is magnesium oxide which consists of magnesium and oxygen. The composition of magnesium and oxygen required to make magnesium oxide is 3:2. An analyst at a plant fertilizer factory said that the composition of magnesium oxide needed is still less than 100 grams to produce good quality fertilizer. If 50 grams of magnesium is still available in the laboratory and oxygen is still abundant, is it possible to make an additional 100 grams of magnesium oxide? Explain!

Question number 12 is included in the Elaboration aspect (thinking in detail/decomposition) with the indicator of adding or detailing the details of an object or idea, so that it becomes more developed. The problem indicator that can be achieved in question number 12 is being able to determine whether a compound can be made with the amount of material available. Question number 12 is included in question C5.

In all of question, the problem solving ability can be demonstrated by writing down what is known and what is being asked (understanding the problem), completing or answering questions

(devising a plan and carrying out the plan), re-examining the work steps and the resulting answers whether they are in accordance with the questions (looking back).

CONCLUSION

Based on the results of research and discussion of test instruments to measure problem-solving abilities based on creative thinking on basic chemical laws, it can be concluded that:

Design of test instruments to measure problem-solving abilities based on students' creative thinking based on aspects of Fluency, Flexibility, Originality, and Elaboration (detailed thinking/decomposition). The form of the test instrument developed is an essay test. The material taken is focused on basic chemical laws. The test instrument is made by analyzing aspects and indicators, then making a grid first. The test instrument for measuring problem-solving skills based on creative thinking should have good content validity before being used to measure it.

The test instrument for measuring problem-solving skills based on creative thinking on the reaction rate material that has been developed meets valid and reliable criteria. Valid it as from a test instrument to measure problem-solving skills based on creative thinking on basic chemical laws declared valid by instrument experts and declared very valid by experts on problem solving skills based on creative thinking and chemists. The reliability of the test instrument for measuring problem-solving skills based on creative thinking on basic chemical law material was declared reliable with a reliability value of 0.720 at the small-scale trial stage and 0.745 at the large-scale trial stage.

The practicality of the higher-order thinking enrichment test instrument was measured using the student and teacher response scales. The results of the responses of students and teachers stated that the response agreed to the use of test instruments to measure problem solving abilities based on students' creative thinking. These results state that the test instrument for measuring problem-solving skills based on students' creative thinking is practically used as an assessment instrument in the learning process.

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