Structured Clock Reaction Demonstration Implementation on Assessing Student's Understanding of Atomic Structure, Chemistry Bond, Thermochemistry, and Acid and Base Concepts

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Introduction

Chemistry education paradigm in Indonesia has shifted from behaviorism into constructivism. This shift has some effect to all of the aspects inside. According to the last paradigm, knowledge has to be constructed by students themselves.

Knowledge construction is started with a phenomena or object observation based on their prior knowledge. Student gives a meaning to whatever phenomena they found. Construction process will run continuously, so cognitive structure will develop and become more detail. Concept is a proposition set that has a function to give a meaning on particular topic (Nakhleh, 1992). Concept consists of interrelated simple declarative statement (proposition) represent student knowledge construction.

Concept learning is a process happens naturally on all human age level. This process includes discovery the similarities of the objects on the world, category creating based on the similarity, and category abstraction. But it does not mean that it can happen automatically and easily. Even sometime, teacher efforts on helping this process make it more difficult (Eggen & Kauchak, 1979).

Abraham *et. al.* (1992) divided student undestanding of concept into six degree as shown on the table here.

Degree of understanding	Scoring criteria
No response	Blank I don't know I don't understand
No understanding	Repeats question Irrelevant or unclear response
Specific misconception	Responses that include illogical or incorrect Information
Partial understanding with specific misconception	Responses that show understanding of the concept but also make statements which demonstrate a misunderstanding
Partial understanding	Responses that include at least one of the components of the validated response,'but not all the components
Sound understanding	Responses that include all components of the validated response

Many studies has taken a focus on misconceptions. The constructivist views that on constructing the knowledge, student does not always make it succesfully. There can be a misconception that will lead to some difficulties on learning process. For that case, student's understanding of chemistry concept must be

identified with an assessment that can cover student understanding wider. Identification result can be used to improve teaching and learning process on chemistry.

There are many studies on student understanding of chemistry concept identification. Among of them are multiple choices with reason test and interview. But, paper and pencil based test give students chanche on cheating or guessing the right answer. To identify student understanding of chemisty concept, it is necessary to develop a method that has chemistry characteristics. It always relate to matter and its change, and energy. Beside that, this method has to have sensitivity on student cognitive structure regulation and restructurisation.

Demonstration assessment becomes a choice. Demonstration has been implemented in chemistry classroom to attract student attention, and it can nurture student understanding effectively. Teacher can show phenomena illustration happened in their day life to stimulate student mind, nurture the curiosity and aptitude toward chemistry. Demonstration gives student chance to observe the change on reaction, analyze data, make a conclusion to propose some hypothesis (Miller, 1993), and make a relationship between macroscopic, microscopic, and symbolic world (Deese *et. al.*, 2000).

Demonstration clock reaction is the reaction that give simple understood sign in initial reaction before product concentration get it significant (Shakhashiri, 1984; Billingham & Needham, 1992). Structured clock reaction demonstration (SCRD) is modified from this definition.

Purposes

This study aims to know:

1. Profile of student understanding of concept explored by structured clock reaction demontration (SCRD).
2. Student misconception patterns identified by SCRD.

Experiment

This is a descriptive study with the following steps.

a. Identifying and analising the demonstration that will be implemented to assess student understanding of chemistry concept. The following is the demontration and concept related to be implemented on this study.

Tabel 1. Demonstration and the concept identified

No	Demonstration title	Concept
1	Chemistry of Respiration	Indicator pH range
2	Magic Glass	Acid-bases neutralization
3	Solution chemistry	Buffer solution
4	Dramatic Show	Acid-base reaction
5	Magic Balloon	Atomic structure
6	Smoke Ring	Chemical bonding

7	Floating Ball	Chemical bonding
8	Magic Money	Miscibility
9	Wood Ice	Thermochemistry

b. Make demonstration worksheet and assessment guide. Score range of every understanding degree on each demonstration are different. It fits to number of requirements and explanation. Score range shown here.

Tabel 2. Score range on understanding level for every

No	Category	Score range								
		Demo 1	Demo 2	Demo 3	Demo 4	Demo 5	Demo 6	Demo 7	Demo 8	Demo 9
1.	NR	0	0	0	0	0	0	0	0	0
2.	NU	1 – 2	1 – 8	1 – 4	1 – 8	1-4	1-6	1-4	1-5	1-6
3.	SM	3 – 6	9 – 14	5 – 10	9 – 12	5-13	7-13	5-10	6-9	7 -12
4.	UM	7 – 13	15-22	11- 20	13 -21	14-18	14-18	11-16	10-14	13-17
5.	PU	14 –17	23 –26	21 –24	22 –25	19-24	19-24	17-24	15-24	18-24
6.	SU	18	27	25	30	25	25	25	25	25

where

NR : No response
NU : No understanding
SM : Specific misconception
UM : Partial understanding with specific misconception
PU : Partial understanding
SU : Sound understanding
Demo1 : Chemistry of Respiration
Demo2 : Magic Glass
Demo3 : Solution chemistry
Demo4 : Dramatic Show
Demo5 : Magic Balloon
Demo6 : Smoke Ring
Demo7 : Floating Ball
Demo8 : Magic Money
Demo9 : Wood Ice

c. Make two student worksheets.
   1) First worksheet, this worksheet is filled after they observe on the first stage demonstration but before they know the result of the last stage.
   2) Second worksheet, this worksheet is filled after they know the result and they have to explain the similarities and diffeerences between their prediction and demonstration result.

d. Do demonstration to assess student understanding. Structured demonstration was divided into two stage. First, observation stage. This stage led student attention to the concept will be assessed. They make an observasion note, integrate their observation to the theory they get in the class. It will be used to make a prediction on the next stage. Demonstration was done with the following steps:
   1) Give students direction and worksheets.

2) Introduce all equipments used on the demonstration.
3) Do SCRD for observation stage.
4) Give student time to make a note on their observation.
5) Do the beggining of the main assessment demonstration
6) Ask a question as writen on the worksheet and demonstration guide.
7) Give student time to write down the answer of question and make a prediction what going to happen, on worksheet (max 5 minutes)
8) Collect students answer sheet.
9) Continue the main demonstration to show the fact.
10) Give students time to explain if their prediction fit to the fact or their explanation of the fact, compare with their prediction.
11) Collect their explanation.
12) Prepare the next demonstration

e. Score student answer and clasify them into degree of understanding.
f. Analyze students answer to find some misconception

Result

Here are the result, after we analysed all of students answers carefully.

No	Demonstration	Concept	%					
			NR	NU	SM	UM	PU	SU
1	Chemistry of Respiration	Indicator pH range	0	0	14,29	85,71	0	0
2	Magic Glass	Acid-bases neutralization	0	0	21,05	68,42	7,89	2,63
3	Solution chemistry	Buffer solution	0	0	11,76	70,59	17,65	0
4	Dramatic Show	Acid-base reaction	0	5,56	83,33	11,11	0	0
5	Magic Balloon	Atomic structure	0	2,78	77,78	19,44	0	0
6	Smoke Ring	Chemical bonding	0	66,67	30,55	2,78	0	0
7	Floating Ball	Chemical bonding	0	0	64,71	29,41	0	5,88
8	Magic Money	Miscibility	0	47,06	23,53	29,41	0	0
9	Wood Ice	Thermochemistry	0	17,64	41,18	41,18	0	0

Students worksheets were analysed further to explore student misconceptions term. Here the list of student misconceptions.

Tabel 3. Misconceptions type explored with *Clock Reaction*

Demonstration	Misconception
Chemistry of Respiration	Students do not know how to write the reaction: $2NaOH + CO_2 \rightarrow Na_2O + HCOO$
Magic Glass	1. The solution of sodium hydroxide become unoriginal after

	aquadest addition 2. Mixing of weak acid and strong base makes neutral salt. 3. Weak acid will be up when it is reacted to strong base 4. Mixture of sodium hydroxide solution and acetic acid on the same concentration will makes neutral salt
Chemistry of Solution	1. Acid-base indicator change solution pH 2. Buffer solution is a solution that has pH = 7 (neutral)
Dramatic Show	1. Carbon dioxide gases neutralize phenolphtalein so sodium hydroxide solution becomes colourless. 2. The formula of sodium bicarbonate is $Na(HCO)_3$ 3. Chloride acid Asam klorida ditambah indikator metil orange menghasilkan gas karbon dioksida 4. The reaction between chloride acid solution and sodium bicarbonate causes precipitation
Magic Balloon	• Electromagnetic force makes paper pieces attracted to balloon • Electron transfer from hair into balloon makes balloon has positive charges • Atom consists of negative and positive ions
Smoke Ring	• Cold water is lighter than hot water
Floating Ball	• Water and oil cannot mix up because they are non polar • Water and oil cannot mix up because there are no bonding electron pairs
Magic Money	• Water cannot be burnt out because it does not contain O_2 • Methanol can be burnt out because it contains O_2 • Water and methanol can be mixed up easily because they have same concentration
Wood Ice	• Endothermic reaction can be signalled from heat emitted from system to its surround • All reaction that produce gas is exothermic reaction

1. Student understanding of concept profile explored with structured clock reaction demonstration

On attracting student attention to the new concept, sometime teachers use single demonstration only. Teacher gives some comment or explanation, then, to enforce concept to understand. It cannot work on assessment, because a demonstration can be viewed from different ways and we do not give students explanation. Student can think different concept we mean, and it will make them confuse when they face the question we serve. May be, they can answer what they think, but it will give us a wide range concept to analyze.

To get our focus, we done the demonstration as assessment in structured manner. That means that we had a structured answer sheet to help student focus what they need to answer the question to come and a set of demonstration contain observation and main demonstration. We did demonstration(s) on the observation stage to help student get the data they need. We had student to write certain data on the answer sheet. It does not mean they cannot take other data, they still have a chance to take a note as demonstration goes on.

The demonstration of Chemistry of Respiration is aimed to identify students understanding of indicator pH range concept. On the observation stage, student had to observe the colour of indicators differences on acid, base, and neutral condition and write down the data on their answer sheet. On the

main demonstration, they have to make a prediction about what will happen if we blow a base (sodium hydroxide) solution with indicator added. It looks like so simple to be understood, but the result shows that there are 14.29% of student on SM and 85.71% of students on UM level.

Chemistry of solution was used to explore student understanding of buffer solution concept. Student was faced to the colour changes of indicator in aquadest on acid and base addition. Then, they asked to predict what will happen to the colour of indicator in buffer solution when acid and base solution is added. The result showed that there are 11.76% of student on SM and 70.59% on UM level.

Magic Glass Demonstration is aimed to explore student understanding of acid base neutralization reaction. On observation stage student had to observe phenolphthalein colour on base, neutral, and acid solution. Then, they told that there were a solution contains sodium hydroxide and indicator in one glass and acetic acid solution on the other glass. The acid had concentration higher then base. Student had to predict the colour change when the solution contains sodium hydroxide and indicator is added to acetic acid on the same volume. The result showed that student understanding of this concept is more varieties. There are 21.05% of student on SM, 68.42% on UM, 7.89% on PU, and 2.63% on SU.

Dramatic show was aimed to explore student understanding of acid and base concept. Student faced the reaction between hydrochloride acid and sodium bicarbonate solution on observation stage. They asked to observe the colour changes of indicator on this reaction. Then, on the main demonstration, they had to predict what will happen when carbon dioxide gas flown into the sodium hydroxide solution. The result shows that number of student had misconception on this concept is highest, namely 83.33% of student.

Magic balloon explores student understanding of atomic structure concept, especially on electron transfer. Student observe the interaction between balloon that inhibited on hair with paper. After that, student predicted what happen if the balloon interaction with coin money and little stick for tooth in the plastic bottle.

Almost all student get wrong prediction. There are 77.78% students that keep their preconception that magnetism is the only force to make attraction happened. Meanwhile, there are 19.44% students able to use right concept to make explanation after they know the result of the demonstration. The rest of them cannot give the clear answer, evenly after they know the result of the end demonstration.

Smoke ring demonstration explore student understanding of molecule motion concept. On the observation stage they observe hot red water spread out quickly into cold water. Then, student have to predict what will be happened when green cold water is dropped into cold water. We hoped that student can compare the spread rate between red hot water and green cold water. More than 50% of students seem to get difficulty on the concept of this demonstration. Almost of them predict that cold water will float on hot water. They failed to understand that cold water is heavier than hot water. It shows that they mixed up cold water and ice properties.

Floating ball demonstration explore student understanding of chemical bonding concept, especially on polar and non polar bonding. On the main demonstration student have to make two

predictions. First, students have to predict what will be happened when green water is dropped into a glass contains water and fried oil. Then they have to predict what will be happened when the green water ball is pushed into the water layer. In fact, this demonstration comes from student daily life but they still do not know what the concepts inside. There are only 5.88% of students who understand this concept.

Magic money demonstration gives magic sensation. First, student faces to the differences between water and methanol properties when they are burnt. Then they have to predict what will be happened when a money (paper) soaked into water-methanol mixture is burnt. Almost all students take a wrong prediction and explanation and there is only 29.41% of students can change their concept after the demonstration up.

The last demonstration is wood ice. This demonstration explore student understanding of thermochemistry concept. Student faced a common demonstration on thermochemistry concept. $Ba(OH)_2.8H_2O$ and NH_4SCN powder was mixed up. They had known before that this reaction will give a drastically temperature decrease. This demonstration is modified, we put the beaker glass on the wet wood plate before we mix the powder. Many student get misconceptions, even there are 17.64% of students was classified into no understanding level.

This founding is interesting, because it seems that they had learnt all of the concepts on the classroom. This condition shows that there are still so many misconception experienced by student. They cannot apply their concept to a 'real' world like demonstration. We used to say that our student had understood because they can do the final exam or get a good mark. We cannot imagine that our student make a wrong construction about chemistry.

2. Terms of Student Misconceptions Explored with SCRD

We analyzed student statements written on their answer sheet to find any sentences that had possibility to lead to misconception. We began with student answer sheet that had been categorized into misconception level. From this It will take time to present all of student misconception sentences. We classified them into three groups of concept components, namely definition, attribution, and application.

The statement of "buffer solution is a solution that has pH = 7", is an example of misconception on definition level we found. This statement shows confusion happened on buffer solution characteristic. They knew that adding acid makes water become acid solution, and base makes base solution. Yet, buffer solution can maintain pH value on acid and base addition. They make correlation between these two principles, make them took a wrong conclusion that buffer solution has pH = 7. This statement did not came on the first worksheet, before they know the result but also on the last worksheet where they have to explain the fact with their understanding. This statement shows that they did not understand the idea to representation concept, even though they have had the data from the observation.

The statement of "sodium hydroxide becomes unoriginal after water addition' is another example of misconception on definition level. This sentence shows that student mix up solution and dilution term. The student experienced the difficulty when being pointed in the use of chemical terms that had different from

everyday life. Student seemed to assume that all chemical in the laboratory is in the pure condition. This brought a consequence to that statement to explain the phenomena they faced in the main demonstration.

Student does not understand the concept of stoichiometry of solution and neutralization reaction. They do not consider the quantity of acid and base. Their answers show inconsistency on problem solving. Some students said that the mixture of sodium hydroxide and acetic acid on the same concentration will become a neutral salt (solution).

Misconception type on definition level also comes when students find similar term. For example, on the sentence of "Electromagnetic force makes paper pieces attracted to balloon ". This sentence, clearly, shows confusion experienced by student on electromagnetic and attraction force happened between two charges (electrostatic force). Student had known before, that magnetism can make two things attract each other. This 'knowledge' gives students prior knowledge that all attraction force is magnetism. This understanding becomes resist in their mind so when they find attraction case between two things they will say that it is magnetism. Unfortunately, they know that the charge (electron) take role on the demonstration, so they mixed up the concept magnetism and electromagnetism. They thought that electromagnetism is attraction between two charges. None of them did mention electrostatic term.

The sentence "the electron transfer from hairs into balloon makes balloon has positive charge", shows that student has not understood yet the term electron and charge definitions. Student has mentioned on electron transfer, it means that if there is no misconception happened here, they have to conclude that balloon will have positive charge. Another example of misconception on definition level is "Atom consists of negative and positive ions". Student assumed that electron is negative ion and proton is positive ion.

A misconception on application level can be seen on the following statement. "red cabbage indicator will change pH value", "methyl orange indicator will change pH value", "carbon dioxide gas will neutralize phenolphthalein indicator so that sodium hydroxide solution becomes colourless", and "hydrochloride acid will produce carbon dioxide when it reacts with methyl orange indicator". These sentence show that student do not understand acid-base concept.

It also show that, in fact, student has known that an indicator is a weak acid or base. But this understanding leads student to wrong decision, that indicator acid will change pH value. The statement of "hydrochloride acid will produce carbon dioxide when it reacts with methyl orange indicator" even far from concept understanding. This answer cannot explain the data they observed before. They did not understand indicator behaviour exactly.

Another misconception on application level is "the reaction of hydrochloride acid and sodium bicarbonate will produce precipitation". This statement shows that they cannot make a prediction on product of a reaction. This can be caused by the assumption that every acid base reaction produces salt. Salt, on their knowledge, is a solid and precipitate.

Mixture or miscibility concept seems to be mixed up with other concepts. Some student gave this statement: "water and oil cannot be mixed up because they do not have bonding pair electron". This statement is confusing. They did not use polarity concept to explain this case. The other students seem to mix the concept with limited reaction, it is shown on this statement: "Water and methanol can be mixed up because they have same concentration".

Conclusion

This result showed that misconceptions case is so complex. This can resist student to understand the concept. This study proves that paper and pencil based test is not enough to explore student misconception. It needs an alternative assessment like this demonstration assessment to do that. This structured demonstration help student to think scientifically, and help them to revise their concept understanding

All misconceptions above show that student may be give the right answer on theoretical test. Paper-pencil based test make them to rote the concept without understanding. If we always make the paper and pencil based test as a measurement of achievement we will find student pass the exam without understand the concept, and of course the science process included. On doing SCRD test, student has to know the concept conclude on the demonstration, combine their theory understanding and data from the observation, and predict the future happen. This test is an instrument of assessment that has chemistry characteristic. This test give student chance to do self assessment

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