EFFECT OF ANALOGY APPROACH ON THE CONCEPTS OF RATES OF CHEMICAL REACTIONS ON STUDENTS' ACHIEVEMENT AND ATTITUDE

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ABSTRACT

The aim of this study was to investigate the effect of analogical instruction as compared to the lecture approach on concepts of rates of chemical reactions on grade 11 students' achievement and attitude. A quasi-experimental posttest only control group design setting was utilized, to compare the effectiveness of two teaching methods, with 72 students in the fall semesters of two consecutive academic years. Two existing classrooms students, taught by the same teacher at a government school (Yehibret Fire Preparatory School) in Wolliso Zone, Oromiya region in Ethiopia, were categorized as a control group (n=35) in 2017/18 and an experimental group (n=37) in 2018/19 academic years. In control group (CG), students were taught in lecture/ usual way of teaching chemistry while the experimental group (EG) students were received the treatment based on the six steps in 'Teaching With Analogy' (TWA) model with 'Focus–Action-Reflection' (FAR) guide and during the analogical instruction fourteen analogies were used. An equal amount of instruction was given over a period of five weeks (two hours per week, total 10 hours) for both groups and the concepts of rate of reaction involving definition of reaction rate, effects of nature of reactants, surface area, concentration, temperature and catalyst on the rate of reaction have been studied. In both groups, rate of reaction concepts test (RRCT) consisted of 20 two-tier multiple choice questions administered as a post-test after each instruction. A semi-structured interview was also conducted to six EG and six CG students (who selected using stratified sampling technique) to have detail information on their conceptual understanding of rates of reactions, however, six EG students were also interviewed to assess the effect of the analogy approach on students' attitude towards the concepts of rates of reactions. Only the experimental group students were performed the students' generated analogy worksheet. The statistical package for social sciences (SPSS) version 20 software was used to analyze the quantitative data of the study. The independent samples t-test analysis of the post-tests scores of both groups and students' interviews showed that the analogy-based learning was effective means in enhancing students' achievement and attitude towards the concepts of rate of reaction. Therefore, it can be said that high school chemistry teachers can often use analogical instruction to improve students' conceptual understanding and attitude towards the concepts of rates of reactions. *[African Journal of Chemical Education—AJCE 10(2), July 2020]*

INTRODUCTION

The main aim of science education is to help students to develop meaningful understanding of science concepts and to use these concepts for intended purposes [1]. The unit of "Chemical Kinetics" covers lots of fundamental chemistry concepts. The topics in the unit are the rate of reaction, activation energy, factors affecting the rate of reaction, collision theory, catalysts, enthalpy, and reaction mechanism, just a few to mention. These concepts are of utmost importance in order to understand the relations between chemical change and energy, the types of chemical reactions, and the chemical change processes [2]. It is also important for students of chemistry to understand chemical phenomena of everyday life and explain them from a chemical point of view as they happen. According to Tastan, Yakinkaya and Boz [3] comprehending the concept of reaction rate well may provide students with understanding chemical equilibrium easier. Ahiakwo and Isiguzo [4] also revealed that it behaves on the chemical educators to query the poor performance of the secondary students considering the fact that they are to pass into the higher institutions to study chemistry and have to come across chemical kinetics.

Despite chemical kinetics play an important role in learning next relating chemistry topics like chemical equilibrium but students in many countries (both secondary and undergraduate students) tended to accommodate alternative conceptions [5]. According to Horton [6] explanation, students encounter new information that contradicts their alternative conceptions it may be difficult for them accept the new information because it seems wrong. Once misconceptions are integrated into a students' cognitive structure, they become an obstacle in his/ her learning. Thus, the student has difficulty in connecting new information into his/ her cognitive structure including inappropriate knowledge. Therefore, during science instruction, considering students' misconceptions has a key role for promoting conceptual change in students [7]. Donnelly and

Leach [8] found in their study that high school or university students had various misconceptions of chemical reaction rate. Fahmi and Irhasyuarna [9] were studied about the misconceptions of rates of reaction on high school level, finally they concluded that misconceptions experienced by learners are caused by preconception or early concept of learners, learners associative thinking, humanistic thinking, reasoning incomplete/ wrong, intuition is wrong, the stage of cognitive development of learners and learners' knowledge. Evidence of students' misconceptions and understanding of chemical reaction rate exists in literature [2, 4, 7, 9].

Chemical reaction rate, or chemical kinetics, has been found to be one of the most difficult chemistry topics because it involves mathematical calculation and there are many factors influencing the reaction rate as stated by Justi, 2003 cited in Supasorn and Promarak [10]. Students face with difficulties, because of the abstract nature of the chemical kinetics and also they have some misconceptions about the rate of reaction concepts [11]. Several researches have conducted on the effects of several instructional tools to improve students' misconceptions on different chemical concepts. For example, 5E-learning model [12], conceptual change oriented instruction developed to improve students' achievement in chemical reaction rate [7] and the role of analogies in chemistry teaching [13]. Supasorn and Promarak [10] implemented the 5E inquiry incorporated with analogy learning approach to enhance conceptual understanding of chemical reaction rate for grade 11 students.

Many research works suggested that learning science is enhanced and the understanding level is improved when students are engaged in analogy learning activities that used to developing an understanding of abstract phenomena from concrete reference [14]. Rviolo and Garritz [15] reported about the use of analogies to teach chemical equilibrium. Pekmez [16] also reported that using of analogies to prevent misconceptions about chemical equilibrium. [17] has shown the use of analogy to help students understand reaction orders. As Deborah [18] revealed that analogical-based learning is an applicable strategy in senior secondary school chemistry students. The study of Dilber and Duzgun [19] has shown that when analogical instruction is used in asystematic manner, students' understandings of concepts and elimination of misconceptions are more enhancing than traditional instruction. The teaching with analogies allows students to actively participate in the learning process [20]. Many studies also revealed that analogies have a positive effect on changing students' interest/ attitude towards chemistry concepts [14, 21]. For example, in the study of Genc [14] the aim was to determine the effect of the analogy-based teaching on students' achievement and students' views/ attitude about analogies. According to the results of the study, students stated that learning with analogies has positive contributions in their achievement and attitude.

However, as Dilber and Duzgun [19] revealed that despite their advantages and usefulness, analogies can cause incorrect or impaired learning depending on the analog-target relationship. For example, the development of systematic understanding is difficult if the analog is unfamiliar to the learner. Analogies have been called "two-edged sword" because the appropriate knowledge they generate is often accompanied by alternative conceptions [22]. Orgill and Bodner [13] reported that effectively used analogies can help students understand difficult chemistry concepts, often with surprising results. The Teaching-With-Analogies (TWA) model developed by Glynn [23] whose implication is that teacher should try to select analogs that share many similar features with the target concept. The Focus-Action-Reflection (FAR) guide which has three stages for the systematic presentation of analogies was proposed by [24]. This model was proposed to maximize the benefits and minimize the problems encountered in analogy instruction as stated by Venville, 2008 cited in Supasorn and Promarak [10].

Pekmez [16] has conducted on using analogies to prevent misconceptions about chemical equilibrium. The result showed that teaching with analogies caused a significantly better acquisition of the concept than the traditional instruction. Finally, Pekmez [16] concluded that using analogies to teach chemistry may positively influence students' motivation to study chemistry and suggested that similar studies should be continued, and analogy activities should be developed for chemistry lessons. Gafoor and Shilna [25] in their research also suggested that for explaining abstract chemical concepts, teachers can use analogies as teaching tools. Ugur with friends [26] also suggested that science teachers can often use analogical instruction in their classroom to enhance students' understanding and eliminate misconceptions.

In addition to review of literatures, from researchers' teaching experiences and the current situation observed in the grade 11 Students at Yehibret Fire Preparatory School (Yh/F/P/S) in Wolliso Zone, some students' have difficulties/ misconceptions of the concepts of the rates of reactions. For example, some students assumed that "surface area increases means size increases and so the rate of reaction increases", and "only the rate of forward reaction increases but not the reverse" in a chemical equilibrium and most of the teachers used traditional way of teaching method to overcome such problems. However, traditional way of teaching sciences may have significant effect on students' misconceptions; it is insufficient in remedying students' misconceptions that are persistent and highly resistant to change [27]. As Opera [28] revealed that in such method the learner does not cooperate or discuss with other learners unless she or he is permitted to do so. The teacher delivers the curriculum, asks questions to which she or he knows the answers. Thus, this type of method of teaching (traditional teaching method) allows students to contribute their ideas rarely. The teacher evaluates the students' ability to participate in the lesson through learners' responses to give right answers as given by the teacher. However, this method has some strong sides. According to Yan and Subramaniam [29] it is clear that conventional teaching has not managed to address the alternative conceptions on the reaction kinetics. Although a number of researchers have been provided empirical evidences of using active and practical oriented teaching overcome such students' problems, the current situation in Ethiopian science classrooms are still dominated with teacher-centered (lecture approach). Therefore, this study has been investigated the effect of analogy approach on the concept of rate of chemical reactions on grade 11 students' achievement and attitude when compared to traditional designed chemistry instruction at Yehibret Fire Preparatory School (Yh/F/P/S) in Wolliso zone, Oromiya region in Ethiopia.

METHODOLOGY

Research design

In this study, a quasi-experimental posttest only control group design setting was utilized, to compare the effect of two different teaching methods (analogy and lecture approaches) with 72 students in the fall semesters of two consecutive academic years. Two existing classrooms students were used for this study who taught by the same teacher at a government school (Yehibret Fire preparatory school) in Wolliso zone, Oromiya region in Ethiopia. In control group (CG), students were taught in lecture/ usual way of teaching chemistry while the experimental group (EG) students were received the treatment based on the six steps in 'Teaching With Analogy' (TWA) model with 'Focus–Action-Reflection' (FAR) guide.

Sample

The participants for this study were 72 (about 17 years aged) grade 11 students who all are attending in a government school (Yh/F/P/S) at Tulu Bolo woreda, Oromiya region in Ethiopia. A convenience sampling technique was used to take these students as participants of this study; [3] stated that convenience sampling technique allows using existing groups to select the participants. Accordingly, with prior permission of the school principals two existing classrooms of the same teacher in the same school taken as a control group (n=35) in 2017/18 and an experimental group (n=37) in 2018/19 academic years. Since these students already assigned in two classrooms by the school administration based on their Ethiopian students leaving high school examination (matric) scores. Thus, both groups' students considered as having very similar knowledge levels. Moreover, the students in both groups have been living in the research area; have similar cultural, socio-economical and educational backgrounds. Before the intervention, the students also informed that the study aimed at helping their understanding of particularly the concepts of rates of reactions involving definition of reaction rate, effects of nature of reactants, surface area, concentration, temperature and catalyst on the rates of chemical reactions.

Instruments

In this work, the two data collecting instruments were rate of reaction concept test and semi-structured interviews.

Rate of reaction concept test (RRCT)

In this study the major data gathering tool was a conceptual test of rate of reaction. The test covers the different concepts of rate of a chemical reaction (see Table 1). The purpose of the rate of reaction concept test (RRCT) was particularly to measure the CG and EG students' understanding of different concepts related to chemical reactions rates. The RRCT consisted of 20 two-tier multiple choice questions. Some of the questions in the reaction rate concept test, RRCT, are taken from Ethiopian University Entrance Examinations (EUEE) questions and chemistry education literatures [4, 10]. In addition to these, because according to the current Ethiopian curriculum, the introduction of concepts of rates of reactions begin in grade 9 and 11 levels so that the test was also prepared by considering the instructional objectives of the chemical kinetics unit presented in these grade textbooks, and using already identified misconceptions (see examples in Table 9) in literatures [2, 7, 9]**.** Therefore, the distractors in the choice part of the test included the students' common misconceptions of the rates of chemical reactions. The development of this data gathering tool was based on Treagust [30] methods. To examine content validity and appropriateness, the items were evaluated by a chemistry educator and two experienced high school teachers. Prior to the administration of the test, RRCT was also conducted to 52 grade 12th Yh/F/P/S students, who exposed the rate of reaction concepts in previous year, as a pilot test.

Table 1. Specification of rate of reaction concept test

Content area	Items Number	Number of Items
Rate of reaction and calculation	1, 4, 5, 9, 14	5
Nature of reactant and rate	3, 16	2
Surface area and rate	2, 8	2
Concentration and rate	7, 15	2
Temperature and rate	6, 11,	2
Catalyst and rate	13, 17, 18	3
Reaction rate theory and energy	10, 12,19, 20	4
	Total number of items	20

Subsequently, the reliability coefficient of the RRCT was computed by Cronbach's alpha in SPSS 20 estimates of internal consistency, was found to be 0.94. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale [31]. The final version of RRCT was composed of two-tier multiple choice questions. The first tier of each item on the test was a multiple choice content question (content based questions). The second tier of each item contains possible reasons of the answer given to the first tier item (reason based questions). Examples of the conceptual test items are shown in Figure 1. Each two-tier item were rated as 5 points (2.5 points for each tiered item), so if a student who answered all of the questions correctly, can score 100. For the full list of RRCT used for this study, see Appendix A.

Question 1:`Consider the following reaction:

$N_2 (g) + 3H_2 (g) \longrightarrow 2NH_3 (g)$

1.1. The rate of formation of NH_3 is 9.0×10^{-4}mol/s, the rate of consumption of N_2 is ____

A. 4.5×10^{-4}mol/s B. 9.0×10^{-4}mol/s C. 1.4×10^{-3}mol/s

1.2. Please show your calculation method ___________________________

Question 2: Consider the rate of a chemical reaction using the same masses of marble and powdered $CaCO_3$ with similar amount of hydrochloric acid.

$CaCO_3(s) + 2HCl (aq) \longrightarrow CaCl_2 (aq)+ H_2O(l) + CO_2(g)$.

2.1. Which chemical reaction will faster? ______

A. The reaction between marble $CaCO_3$ and hydrochloric acid.

B. The reaction between powdered $CaCO_3$ and hydrochloric acid.

2.2. Why? Because_____

A. Substances with big particle size move slower than those with small particle size, their reaction rate decreases.

B. The powdered $CaCO_3$ has a greater surface area, thus rate of reaction increases.

C. If thesurface is small then the reaction will be faster, and if a large surface area, the reaction will be slower.

D. As the size of a solid reactant decrease the surface area decrease, thus rate of reaction increases.

Figure 1 Examples of two-tier multiple choice (RRCT) question

Semi-structured interviews

The interview served as an additional or supportive data collecting tool for the study. The interview was consisted of two parts and conducted with 12 students. The purpose of the first part of the interview was to gather detail information of the effect of analogy approach on students' conceptual understanding of the rates of reactions and/ or to assess the long-term effects of each instruction. Based on Pekmez [16] explanation a stratified sample technique was used to select the interview participants from both control and experimental group students. Therefore, first, in the current study students were categorized according to their achievements in the post-test (RRCT) as high achievers, average achiever and low achievers. Then two students from each of these groups were randomly selected for the interview in each group. The first part of interview was consisted of eight questions and conducted with six EG and six CG students individually by the researcher and assistant teacher. Note that the selected control group students were participated only in this part of the interview. The second part of the interview contained two main questions and conducted with only six EG students who are already had been involved in the first part. The purpose of this part of the interview was to examine the effect of analogical instruction on students' attitude/ interest towards the concepts of rates of chemical reactions. The gap time between application of RRCT and interviews for each group students was four weeks. Each interview lasted about 8-12 minutes. All the interviews were tape recorded and then converted to text for data analysis. The responses obtained from the students were classified and participants were coded, to organize similar ideas one side, experimental group students as E1-E6 and control group as C1-C6 then their responses or views presented in findings section. For the full list of the Semi-structured interviews used for this study, see Appendix B.

Procedures

This study was carried out about five weeks during in fall semester of 2017/18-2018/19 school years. The treatment tools consisted of seven learning plans for five weeks, 60 minutes' contact time (two hours per week), totally 10 hours of learning activities. During a five-week period, each group received an equal amount of instructional time and was provided with the same materials, the topics of the lesson were the same for both groups based on the current Ethiopian grade 11th chemistry curriculum, the difference were only in the way they were taught. In the study two different instructional methods were used. The control group student was taught with lecture/ usual method of teaching chemistry whereas the experimental group was taught with analogies. Both groups were taught by the same teacher/ researcher, in the same school but in different academic years.

a) *Analogical approach*

In the experimental group**,** analogies were used. The main purpose of the analogies in this study was to explain different concepts of the rates of chemical reactions. The method of teaching was more relied on the steps in the TWA model of Glynn [23] in order to use the analogical approach effectively and systematically. At the instruction time, examples of analogies were showed for each target concept directly to students which encouraging them to elaborate their understanding and to maximize their participations. Table 2 shows the contents taught and the total teaching time with analogical activities that were used for experimental group students. Therefore, in this study, at the instruction time, six steps of TWA model of were used. For example, to teach the concept of the effect of surface area the steps used were:

1. Introduce the target concept, effect of surface area of solid reactants, to students,
2. Remind students of what they know of the analog, drying of meat in air,

3. Identify relevant features of the surface area of reactants and the large and small size of meat,
4. Connect (map) the similar features of the surface area of reactants and the different size of meats,
5. Indicate where the analogy between the surface area of reactants and the size of meat breaks down and
6. Draw conclusions for the effect of surface area of solid reactants on rate of a reaction.

During the instruction, the teacher/ researcher asked some questions to activate students' prior conceptions. Some questions were: What is the rate of a chemical reaction? Do all reactions proceed with the same reaction rate? Give some examples which are slow or fast reaction. How does surface area of a reactant affect the rate of a reaction? and so on. Then after the discussions on these questions with each other and with the teacher, students noticed their misconceptions and saw the scientifically correct explanation.

Table 2: Major topics with analogy learning activities

Learning plans (hours)	Analogy activities (Examples)
1. Rate of reaction and calculation (3)	- Running a cross country with different speeds but equal distance.
2. Effect of nature of reactants and rate of reaction (1)	- Riding a horse and a donkey with limited distance.
3. Effect of surface area of reactants and rate of reaction (1)	- Cooking of the same solid food in different sizes.
4. Effect of concentration rate of reaction (1)	- Ploughing with two oxen and more oxen to plant a crop.
5. Effect of temperature and rate of reaction (1)	- Baking bread with high and low temperatures.
6. Effect of catalyst rate of reaction (1)	- Riding a bicycle in lower and higher up hill.
7. Collision theory and energy (2)	- Walking on a mountain and normal street.

The FAR guide proposed by [24] which used to make easy the TWA model was also applied to teach each concept of reaction rate in the instruction of the experimental group. Subsequently, through questions the participants were assisted to make relation by identifying similarities and differences between the given analogue and the target (see Table 3). With the discussion between students, the teacher/ researcher explained the similarities and differences between the given analogies and target concepts to the whole class, thus students who found wrong relation between the analog and target concepts were able to correct their previous work.

Table 3: Example of the three phases the FAR guide model about the effect of surface area of the solid reactants in a chemical reaction.

Focus Phase	Pre-Lesson Planning
Concept	- How a surface area of solid reactant affect the chemical reaction rate is difficult to understand.
Students	- Already understand that surface area of reactant occurs faster than the normal reaction but do not understand the way of how surface area affects the rate of the reaction.
Experience	-Drying small and large size meat in air at normal temperature
Action phase	**In-Lesson Action**
Similarities (Likes)	-Speed of drying – Rate of reaction -Drying time – reaction time -Different sized of meats – surface area of reactants - Raw meat – reaction reactant - Dried meat – reaction product and drying temp – reaction temp
Differences (unlike)	-Drying meat is physical process – reactions are chemical process
Reflection phase	**Post-Lesson Reflection**
Conclusions	- Drying small and large size meat in air at normal temperature (Clear analogy)
Improvements	- More explanation about the effect surface area on solid reactants (additional analogy).

Before the instruction, the teacher/ researcher informed students what does analogical instruction mean and how it could be used during the instruction followed by the above TWA model steps with FAR guide. Moreover, in order to be sure that the students did not form misconceptions the teacher/ researcher was verified by asking focused questions about features that are not shared between the analog and the target concept. Effective analogies can clarify thinking, help students to overcome misconceptions, and give students ways to visualize abstract concepts [32].

To enhance students' understanding of the correct scientific conception the teacher/ researcher gave priority to the analogies. Table 4 shows an example of analogical instruction. Note that a total of fourteen analogies were used, seven analogies were taken from the chemistry education research [10]. The rest were developed by the researcher by considering the students' daily life activities. According to Sarantopoulos and Tsaparlis [21] the analogies should meet all requirements for an effective analogy. Most importantly, the analogue domain has to be familiar to the students. Therefore, all analogies were modified to meet the Ethiopian social context and the grade 11th chemistry curriculum. See examples of analogies used for this study in Appendix C.

Table 4: Example of analogical instruction

No.	Learning plan (hr)	Analogy	Analogue	Target	Conclusion
1	Effect of surface area of reactants	Drying small and large size meat in air at normal temperature.	Large and small size meat	Small and large surface area	
			Row and dried meats	Reactant and product	
			Drying time	Reaction time	

Similarities:

- ✓ Speed of drying – rate of reaction
- ✓ Drying time – reaction time

- ✓ Different sized of meats – surface area of reactants
- ✓ Wet meat– reaction reactant
- ✓ Dried meat – reaction product and
- ✓ drying temp – reaction temp

Differences:

- ✓ Drying meat is physical process –reactions may physical or chemical process

b) *Lecture/ usual teaching method of chemistry*

In the control group, lecture/ usual method of teaching chemistry was applied, after prepared daily lesson plan for each lesson, the researcher was lecturing in the traditional way of teaching chemistry that means was presenting the new concept with the students just by listening, paying attention, taking notes and doing class activities individually. The students told to study the text book individually before each lesson. Most of the time of the instruction was kept by the teacher's explanation and questions. Occasionally the researcher asked questions to explore whether the concepts were understood by the students and also sometimes students were allowed to ask questions and the teacher/ researcher made appropriate explanation for the asked questions but the researcher made explanations without considering analogies and students' misconceptions. The students were also asked different questions about the different concepts of rate of reaction individually using a worksheet to enhance their understanding of reaction rate. While the students were doing the worksheet exercises, the teacher/ researcher went around the class and helped them when needed.

Right after the implementation, both group students spent an hour to complete the same post conceptual test, RRCT. In order to minimize the possibility of cheating the researcher was determined each student to have a single seat (18-20 students in each exam room) and used one invigilator for each examination room and the researcher was act as a supervisor. Moreover, in order to get detail information about their understanding concepts of the rate of reaction and to determine the effect of the new method on students' attitude towards the target concepts, participants were conducted semi-structured interviews.

Data Analysis

The data of the study were collected through the major data gathering tool, RRCT and supportive tool semi-structured interviews. The descriptive statistical analysis of the posttest mean scores in RRCT of the EG and CG students were computed in Statistical Package for Social Sciences (SPSS 20) software on the basis of the responses of respondents to each item. The inferential statistical analysis of the mean score of both groups score in RRCT was compared using independent samples t-test and discussed quantitatively. The data from students' sem-structured interviews were transcribed and discussed qualitatively on the basis of common themes. Following this, analysis and interpretation of the data was provided. Finally, based on the findings obtained in this study conclusions and recommendations were given.

Note that in this study, participant students were categorized based on their responses in RRCT into four different groups in order to determine scientifically acceptable and unacceptable explanations [9, 16]:

- Scientifically Correct (SC): The scientifically completed response with correct explanation is a part of this category.

- Partially Correct (PC): Scientifically complete responses and incorrect explanations or scientifically incorrect response and correct explanations match this category and this group student considered as having misconceptions.
- Incorrect Response (IC): This level involves completely unacceptable scientific responses or explanations this group student considered as having misconceptions.
- No Response (NR): Students who do not choose any response and make any explanations are put in this category.

RESULTS AND DISCUSSIONS

The posttest (RRCT) scores were analyzed in independent samples t-test in order to identify the effect of the treatment on students' understanding of the rate of reaction concepts. The significant level of 0.05 was considered in comparing groups. As indicated in Table 5 below, the result showed that there was statistically significant difference between the mean total posttest scores obtained in the EG and CG students in terms of understanding of rate of reaction concepts ($t\ (62.361) = -3.712$, $p < 0.05$). The mean results on the post-test score of the experimental group ($\overline{X}$ (EG) =37.6216 (SD 7.6842)) was higher than that of the control group ($\overline{X}$ (CG) = 29.5714 (SD 10.427)).

The analysis showed that students in the experimental group who were taught with the analogical instruction achieved better than students in the control group who were taught the topics with the lecture/ usual teaching method. From the results it can be said that analogical instruction was an effective means for enhancing students' conceptual understanding of the rates of chemical reactions than the lecture/ usual teaching method. Analogies may help students to achieve conceptual understanding, rather than algorithmic understanding [33].

Table 5: Independent samples t-test summary of posttest (RRCT)

	Groups	N	$\bar{X}$	SD	t	P
Post-test	Control	35	29.57	10.43	-3.71	0.000
	Experimental	37	37.62	7.68		

Previous studies also support the finding of this study related to the effect of analogy-based instruction on students' achievement [16, 19, 34-35]. For example, Samara [35] studied the effectiveness of analogy instructional strategy and the result he obtained showed that teaching with analogies is an effective method in raising students' achievement.

Comparison of the Post Test Scores of CG and EG in RRCT

In order to determine the effect analogical instruction on students' conceptual understanding of rate of a chemical reaction, students' scores in the same concept of different items of the posttest (RRCT) along with their success in percentage are also analyzed and discussed as follows:

As shown in Table 6, the percentage scores of experimental group was higher than that of the control group (EG=60.58% and CG=34. 48%). The experimental group students also obtained higher posttest percentage correct answer for diagnostic test in each target concept of the rate of chemical reaction as compared with the traditionally instructed group. For example, the highest percentage scored by the analogy-based instructed students was 73%, for the concept of the effect of nature of reactants on the rate of a chemical reaction. The result may be obtained because the EG students were taught the effect of nature of reactants on rate of a reaction concept using analogy of boiling tomatoes and potatoes at the same temperature, which may perfectly explained the underlying principle such that tomatoes are cooked faster because of its nature which is similar with the concept that some reactants react faster and others may react in slow rate due to their nature, for example, generally, reactions involving ionic species tend to proceed faster than decomposition reactions and also gaseous substances react faster than substances in other states of matter. So it can be said analogical instruction may help these students to see abstract concepts through analogies which usually happen in their life activities.

Table 6: Comparison of the post-test success of EG and CG on reaction rate concepts

	Topics (Number of Items)	Posttest score					
		Control Group			Experimental Group		
		Mean	SD	%	Mean	SD	%
1	Rate of reaction and calculation (5)	0.34	1.00	29.72	0.70	1.02	69.22
2	Nature of reactants (2)	0.51	0.69	48.55	0.79	0.56	73.00
3	Surface area and rate (2)	0.43	0.58	28.60	0.61	0.68	58.10
4	Concentration and rate (2)	0.34	0.63	30.00	0.56	0.71	56.80
5	Temperature and rate (2)	0.56	0.71	55.70	0.69	0.66	68.95
6	Catalyst and rate (3)	0.27	0.73	23.80	0.54	0.87	54.07
7	Reaction rate theory and energy (4)	0.31	0.84	25.00	0.45	0.99	43.90
	Total (20)	2.76	1.98	34.48	4.34	2.12	60.58

The experimental group students also scored higher points (69.22%), for the items of definition and calculation of the rate of a chemical reaction whereas the control group students was 29.72%. The result indicated that there was a higher difference (39.5%) in the two groups' conceptual understandings. Similar result was reported in Ahiakwo and Isiguzo [4] study that traditionally taught students' performance in basic kinetic calculation was poor. In the current study experimental group students scored in the definition and calculation concept questions better than the traditionally instructed students. This is possible that the rate of reaction is comprehended enough by EG students as these students were taught by considering misconceptions preliminarily using rate of reaction concept questions to activate their pre-existing conceptions followed by discussions with the teacher/ researcher. During the analogical instruction, the analogy used for the definition of the rate of a chemical reaction, was peeling banana fruits at different speeds, but equal time, which may sufficiently agree with the target concept, the definition and calculation of rate of reaction. This finding is also supported by Supasorn and Promarak [10] study**.** It was shown that that definition and calculation of rate of reaction was understood easily by students because of the analogy that the instructor used in similar topics.

On the other hand, the lower difference was observed between the percentage sores of EG and CG (13.25%) on the topic of effect of temperature. This means more than half of both group students gave correct answer (CG=55.70% and EG=68.95%). This finding showed that both teaching methods helped to understand this topic effectively. However, the experimental group students scored slightly higher than the control group. This possibly because the experimental group students taught the concept with analogy, cooking rice with low and high temperatures, to indicate that the rice cooked in slower rate at lower temperature which may perfectly connected with the target concept that decreasing in temperature cause decreases in frequency of collisions, thus rate of reaction decreases too. In general, the results indicated that the analogical instruction was effective means to enhance the students' conceptual understanding of rate of a chemical reaction.

The proportions of students' correct responses to each question in the posttest

The posttest (RRCT) were also examined in order to determine the effect of the analogically instruction on students' conceptual understandings of the rate of a chemical reaction and to test if misconceptions were reduced due to analogies.

Table 7: Categories of EG and CG students based on their score in RRCT

Item No.	Control Group Posttest Categories %			Experimental Group Posttest Categories %		
	SC	PC	IR	SC	PC	IR
1	28.6	28.6	40.0	75.7	8.1	16.2
2	48.6	42.9	8.6	70.3	16.2	13.5
3	60.0	31.4	8.6	94.6	5.4	-
4	31.4	34.3	31.4	78.4	16.2	2.7
5	40.0	20.0	40.0	70.3	10.8	13.5
6	54.3	37.1	8.6	73.0	21.6	-
7	17.1	48.6	34.3	59.5	32.4	8.1
8	8.6	54.3	37.1	45.9	29.7	24.3
9	40.0	48.6	11.4	67.6	27.0	5.4
10	22.9	34.3	42.9	43.2	18.9	37.8
11	57.1	22.9	20.0	64.9	5.4	29.7
12	31.4	48.6	20.0	32.4	51.4	16.2
13	11.4	20.0	68.6	54.1	13.5	32.4
14	8.6	20.0	57.1	54.1	29.7	13.5
15	42.9	28.6	28.6	54.1	29.7	16.2
16	37.1	28.6	34.3	51.4	32.4	13.5
17	31.4	45.7	22.9	48.6	35.1	16.2
18	28.6	28.6	42.9	59.5	21.6	18.9
19	5.7	5.7	88.6	54.1	21.6	24.3
20	40.0	34.3	22.9	45.9	32.4	21.6
Total	32.28	33.15	33.44	59.88	22.95	16.2

As demonstrated in Table 7 above, in control group students who were taught the rate of chemical reaction in traditional way of teaching chemistry, the percentage in scientifically correct (SC), partially correct (PC) and incorrect response (IR) categories of the post conceptual test were 32.28%, 33.15% and 33.44% respectively. They were mostly in the partially correct plus incorrect response categories (66.59%). The result showed that most of the control group students had misconceptions about reaction rate concepts. Contrary to this the experimental group student who were taught in analogical approach, the percentage of students in the same categories were 59.88%, 22.95% and 16.2% respectively. More than 50% of the EG student was in scientifically correct category. The results indicated that more experimental group students replied the concepts of rate of reaction questions correctly than that of the control group students. This may be possible because analogy-based learning activates their pre-existing knowledge and help to connect with the scientifically accepted concept.

According to Table 7 above, for instance, Question 8 was one of poorly scored (8.6%) item by traditional taught students; both groups were requested to investigate the conceptual understanding of the effect of surface area of reactants on the rate of a chemical reaction. Almost half (45.9%) of students who taught in analogical approach replied correctly this question. The result illustrated that there was an observable difference between the CG and EG students' responses. This large difference may happen because the CG students may get confusion in a relation between size and surface area. Opera [28] revealed that lecture method of teaching allows students to contribute their ideas rarely. The experimental group students could score more because they taught the concept with analogy such as, drying small and large size meat in air at normal temperature, to indicate that small sized meat dried faster than larger one which may perfectly connect with the target concept that as the size of solid substance decreases the surface area increases, thus rate of a chemical reaction increases.

Question 13, which was asked to compare and explain a catalyst and reaction intermediate from a given reaction, more than half (54.1%) of experimental group students gave correct answers whereas 11.4% of traditional taught students replied correctly. The result showed that the concept of catalyst and reaction intermediate were understood better by analogically taught group than traditionally instructed group. This may because for example, the experimental group students were taught with analogy, riding a bicycle in lower and higher uphill to indicate riding is faster in lower uphill which perfectly associated with the effect of the catalyst that catalyzed reaction under goes faster with lower activation energy.

Moreover, questions 12 and 20, both were aimed to evaluate students' understanding of reaction theory and energy using graphs which are representing of exothermic and endothermic processes but in different styles. Both group students scored below 50% for these two different but the same concept questions. The students may know the meaning of exothermic and endothermic processes but they could not understand the concepts from the graph. This indicates that they were not capable of using their knowledge on different conditions. This may be because the poor instruction of drawing class in lower level causes too difficult the students understanding of information in a given graph**.** This result is consistent with the study of graphical problems of the rate of reaction [36-37]. For example, Secken and Seyhan [36] were studied about the performance of the participants in regarding to the problems with or without graphics. The result indicated some of the students' were in higher levels of anxiety over the chemical problems with graphics. Then they concluded that students have anxiety in drawing or interpreting graphics in the exams due to making mistakes. The causes of students' anxiety include redundancy of the curriculum, low awareness of career opportunities, the teachers and their teaching materials and lack of teaching aids/ laboratories [38].

In general, in the current study, the results indicated that the analogy-based instruction was more effective than the lecture/ usual teaching method of chemistry in enhancing students' conceptual understanding and reducing misconceptions of the rate of chemical reaction. This finding confirms the previous studies that revealed the power of analogical learning on the understanding and reducing misconceptions of science concepts [1, 13, 19, 21, 26]. For example, when analogical instruction is used, it is highly probable that these lead to a significantly improved the understanding of scientific conception and elimination of alternative conceptions [26].

Students' Interview

Does using analogy approach has effect on the students' conceptual understanding of rate of reaction and knowledge retention? What is the effect of analogical instruction on students' attitude towards concepts of rates of reactions? In order to answer these questions of the study, qualitative analysis was also performed on students' interview responses. Therefore, the purpose of this part of the interview was to gather detail information of the effect of analogy approach on students' conceptual understanding of the rates of reactions and/ or to assess the long-term effects of each instruction, and to examine the effect of analogical instruction on students' attitude/ interest towards the concepts of rates of chemical reactions. A two component of semi-structured interview was conducted:

Students' conceptual understanding

The purpose of this part of the interview was to gather detail information of the effect of analogy approach on students' conceptual understanding of the rates of reactions and/ or to assess the long-term effects of each instruction. To achieve this aim, six EG and six CG students were selected for conducting the interviews.

In order to ensure that the concepts of the rate of chemical reaction have lasted long time, the interview was conducted after a month of the end of class for each group student. In this part of the interview each selected EG and CG student was asked eight semi-structured interview questions. This part of the interview consisted of questions selected from the RRCT. Some of the selected CG and EG students' responses for the first part of the interview are analyzed and discussed as follows:

For the interview question 3, students were asked to explain the effect of a change in a surface area of a solid reactant on the rate of a chemical reaction. When the students' responses examined, most of the experimental and control group students explained the concept correctly. However, most of the control group students could not explain the reasons in detail or explained partially. For instance, a student coded as C2 stated that “As surface area of solid reactants increase, the rate of reaction also increases” and also a student coded as C3 explained as “a chemical reaction rate is increasing because surface area of reactants increase” whereas students in experimental group coded as E1 and E2 explained the effect of surface area on the rate of a reaction with its reason, For instance, a student coded as E1 was giving scientifically correct explanation using analogy “… when powder and marble $CaCO_3$ reacts with HCl acid, the powdered form of $CaCO_3$ reacts faster than the marble, because size and surface area inversely related”. The above students’ explanation showed that the experimental group students’ conceptual understanding and knowledge retention of rates of reactions were better than that of traditionally instructed students. This is possible because the EG students taught with analogies like, cooking small and large size potatoes, which perfectly associated with the effect of surface area on the rate of reaction concept whereas the CG students failed to remember the concepts may be because they were exposed to the conventional instruction which do not allow them to be active during the learning process. An analogy can allow new material to be more easily assimilated with the students’ prior knowledge and can help make science concepts meaningful to students [33].

In interview question 5, students asked to compare and contrast the effect of change in concentration and pressure of reactants on the rate of reaction. It was determined that most experimental group students were given scientifically correct explanations based on the ideal gas theory. This may because analogies motivate learners to participate in active construction of meaning and assist to construct their own knowledge [13]. For example, students coded as E1, E2 and E5 explained the relationship based on an equation, $PV=nRT \Rightarrow P\alpha \frac{n}{v}$, to show the direct relationship between pressure and concentration. For example, a student coded as E2 explained that “according to the ideal gas theory, as pressure increases, the concentration also increases, thus the rate of reaction increases but pressure only has effect on gaseous reactions”. Most of CG students were given partially correct answers for the same question. For example, a student coded as C2 stated that “…pressures affect only the gaseous reactants while changes in concentration affect all states of matter”. Students coded as C5 and C6 could not remember or gave scientifically wrong explanations. For example, a student coded as C6 explained as “…as concentration increases, pressure become decreases, when pressure decreases rate of reaction increases”. The students’ responses showed that the CG students may misunderstand the relationships between the effect of change in concentration and pressure of reactants on the rate of reaction.

In interview question 8, the students were requested to explain the main requirements of all successful collisions?” It was determined that most of the experimental group students (E1, E3, E5, and E6) explained based on collision theory. For instance, a student coded as E1 stated that “…the particle must be colliding in proper orientation with sufficient energy and must have energy greater or equal to the activation energy.” The control group students also tried to explain the requirements but partially, it was decided that most of this group students could not express the concept clearly and completely. For example, a student coded as C5 said nothing about the theory and a student coded as C1 explained partially as “… must collide in proper orientation and sufficient energy.” In general, based on this part of the students’ interview responses, it was determined that most of the CG students were failed to remember and could not give scientifically correct explanations for most interview questions as compared with the experimental group students. This may possibly because the control group was taught the concepts of rate of reaction in traditionally teaching way of chemistry in which there is little cooperation and interaction between the teacher and pupils in the learning process so they might not grasp the concepts fully [39]. The EG students' responses showed that they retain more of the rate of reaction concepts for long period of time. This may possible because the experimental group students taught with analogies which provide favorable conditions to understand difficult concepts easily. Previous study of Orgill and Bodner [32] revealed that effective analogies do help students to understand, visualized and recall what they have learnt in class.

This may not be surprising that the EG students who taught with analogies achieved better than the traditionally instructed students. This may possible because, in this study, the steps involving in TWA model helping the students for mapping the similarities of the target /unfamiliar/ concepts with the analogue /familiar/ concepts (daily activities) and for indicating where the analogy breaks down. When students study new concepts, meaningful learning proceeds when they find and visualize connections between a newly taught context and what they already know [22]**.** Analogies can help students relate new information to prior knowledge, to integrate information for one subject area into another and to relate classroom information to everyday experiences [20].

Students' attitude towards the concepts of rates of reactions

The purpose of this part of the interview was to examine the effect of analogical instruction on students' attitude/ interest towards the concepts of rates of chemical reactions. This part of the interview consisted of two main interview questions: Q1. What is your attitude towards the analogy-based learning approach on the concepts of rate of reaction? Please explain. Q2. What do you think about you gained from the lessons conducted using analogical approach? Please explain. Only selected students who were taught the concepts of rate of reaction with analogy were conducted this interview. Some students' responses for this part of the interview are analyzed and discussed as follows:

In this interview, when the students asked whether they like or not the analogical instruction, it was decided that all students have positive attitudes towards the analogy-based learning. For example, when a student coded as E1 was asked to explain whether the analogical instruction was helped him for understanding the rate of reaction concepts or not. The student explained as "… before I learnt with analogies, I thought that size increases mean surface area also increases but now because of analogies I have understood that when size of solid reactants decrease their surface area increase, thus rate of a reaction increases". Other students coded as E4 and E3 were also asked to explain whether they like or not the analogical instruction. The student (E4) explanation was "I like it, because when I learnt this chapter with analogy, I have understood more of the concepts". The student coded as E3 also explained as "I like it, because analogies helped me to learn and understand the topics easily" and this student gave also his analogical example as "if you want to cook meat *wet* quickly, the size should decreases because if size decreases, surface area increases then it cooks fast, and analogies help to make difficult concepts easy". The EG students' views of the analogical instruction showed that they are benefited from the analogies and due to the analogical instruction, their interest/ attitude towards the concepts of rate reaction improved. Analogies are often fun for the students, turning the lessons into interesting and never boring sessions [21].

While the students requested to explain whether they want to learn other concepts with analogy or not, it was determined that almost all students like the analogical approach and feeling to learn other subjects with analogies. For example, a student coded as E2 viewed as "I want also to learn other subjects with analogies". For the interview question "what did you gain from analogy-based instruction?" please explain. All students gave positive opinions, for example a student coded as E6 said I gained a lot and used her "…in process of cooking potatoes, if I cut it to small pieces and using high temperature it will cook faster" analogy, to express the effect of surface area and temperature on rate of a reaction. She was also explained the question requested to explain how analogical instruction enhanced her interest and she said "…because analogy allows for comparing the concepts with our daily activities it helps to do not forget what I have learnt so it was interesting". In general, the students' views showed during both parts of the interviews, the analogical instruction helps them to make sense the difficult concepts and retain more knowledge, and develop interest towards rate of reaction concepts. Thiele and Treagust [33] revealed that analogies are used in three major ways: to provide visualization of abstract concepts, to compare similarities of the students' real world with the new concepts, and to provide a motivational function.

The views of EG students of the current study confirm the study of Genc [14]. It was aimed to determine the effect of the analogy-based teaching on students' achievement and students' views about analogies. The subjected students' responses showed that learning with analogies has positive contributions in both their achievement and attitude. However, several researches revealed that if students taught a single chemistry topic with short period of time using analogies may has a positive influence on their motivation to study chemistry, it may difficult to say that students' attitude towards chemistry is changed completely [16, 26]. Generally, in the current study, the students' views in the interview indicted that all students who conducted the interview has positive interest/ attitude towards the rate of reaction concepts due to the influence of the analogy-based learning. Therefore, it can be said that analogical instruction has impact on students' interest/ attitude towards the concepts of the rate of reaction.

The current study revealed that although analogical instruction caused better understanding of the rate of reaction concepts and was more effective in reducing students' difficulty or misconceptions. The experimental group students still have few difficulties as observed in the statistical analyses and the conducted interviews. There are evidences supporting this result that misconceptions are robust and resistant to change [7, 19, 37].

In general, it can be said that there are several reasons behind the effectiveness of analogical instruction in this study. The analogy-based learning was effective means of teaching concepts of rates of reactions when compared with the traditional way of instruction. This may because the analogical instruction was designed by considering students' difficulties related to the rate of reaction concepts. With analogical instruction students were able to compare their pre-existing concepts and scientific knowledge through analogies [16]. During the start of each analogical instruction the experimental group students were asked some related questions in order to activate their previous knowledge. After discussing these questions, correct scientific knowledge was given by analogies. According to Samara [35] analogies can help students relate new information to prior knowledge, to integrate information for one subject area into another, and to relate classroom information to everyday experiences. In control group the students were not participate actively, the researcher explained concepts without considering analogies and students' misconceptions, spend most time by explanations and occasionally allowed them to ask questions in the mean time of the instruction, and the researcher gave explanation for their questions and the interaction between students and the researcher/ teacher was little, teacher-centered approach. Yan and Subramaniam [29] revealed that it is clear that conventional teaching has not managed to address the alternative conceptions on the reaction kinetics.

The steps in Glynn's [23] teaching with analogy (TWA) model were helped to use analogies effectively and systematically. The students in experimental group had a chance of involvement actively during the analogical instruction. Teaching with analogies (TWA) allows students to actively participate in the learning process [35]. The learning plan in the current study, developed by the researcher based on TWA model with FAR guide, was served as a teacher guide to control the analogical instruction as a result enabled the teacher/ researcher to teach the students with confidence. Harrison and Treagust [22] argued that analogy is a powerful way to think, construct ideas and test new knowledge. However, they warned that when TWA not presented effectively and in systematic way, there are possible misconceptions associated with each analogy**.** The teaching with analogies model shows how to use an analogy systematically and helps to explain fundamental concepts in a meaningful way [21]. Generally, the steps in TWA model with FAR guide and the learning plan are played the main role for the effectiveness of the analogical instruction in the current study as well**.**

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In this study, the effect of analogy approach on the concepts of rates of chemical reactions on students' achievement and attitude has been studied in comparison with the lecture/ usual teaching method of chemistry. Based on the results of the study the following conclusions have been drawn:

1. The analogically instructed students' conceptual understanding was better than the students taught in lecture method. The analogical instruction was effective way in enhancing of

students' conceptual understanding of rate of chemical reaction and for helping students correct their misconceptions.

2. The experimental group students' conceptual understanding and knowledge retention of the rates of reactions were better than that of control group students. The analogical instruction was also effective means to retain knowledge of concepts of rate of reaction for long period of time.
3. Experimental group students' comments given in interviews showed that they have positive attitude towards the analogy-based learning. The analogy-based-learning was effective means to improve students' interest/ attitude towards the concepts of rate of reaction.

Recommendations

Based on the results of this study, the following recommendations have been made:

1. It is better that high school chemistry teachers' design analogy-based instruction as instructional strategy at the time of teaching concepts of rate of reaction to enhance students' conceptual understanding, interest/ attitude and knowledge retention, and overcome their misconceptions.
2. Researchers can replicate the study on performances of female and male students on rate of reaction concepts. This may help the researchers to find out whether or not there are significant differences between female and male students' conceptual understanding of rate of reaction.
3. Analogical instruction is more effective method in enhancing students' conceptual understanding of rate of reaction when comparing with traditionally designed chemistry instruction. However, the current study revealed that the students who were taught with analogies still have few difficulties/ misconceptions. Therefore, it is better future researches

may focus on a combination of analogical approach with another conceptual change strategy. This may help the researchers to have better result upon enhancing students' understanding of reaction rate concepts.

4. The study was limited to the concepts of rate of a chemical reaction, specifically to the effect of nature of reactants, surface area of reactants, concentration of reactants, and temperature of reactants and presence of catalysts on the rate of a chemical reaction. Therefore, researchers can replicate the study on other concepts of rate of reaction such as 'orders of reaction'.
5. Analogy can cause misunderstandings, thus applying teaching with analogies (TWA) model with FAR guide can help chemistry teachers to use analogies effectively and reduce the occurrence of misconceptions due to analogies.
6. Curriculum developers may better design analogy-based-learning approach for the rate of reaction concepts in high school chemistry syllabus.

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Appendix-A –Rate of Reaction Conceptual Test (RRCT)

DIRECTION: For the First Tier Item Choose the Best answer and in the Second Tier Item Choose the Reason or Write the Reason for Your Choice in the First Tier (Each has 1.5 points).

Question 1:`Consider the following reaction:

$$N_2\,(g) + 3H_2\,(g) \longrightarrow 2NH_3\,(g)$$

1.1. The rate of formation of NH_3 is 9.0 x 10 $^{-4}$mol/s, the rate of consumption of N_2 is ____

A. 4.5 x 10 $^{-4}$mol/s B. 9.0 x 10 $^{-4}$mol/s C. 1.4 x 10 $^{-3}$mol/s

1.2. Please show your calculation method ________________

Question 2: Consider the rate of a chemical reaction using the same masses of marble and powdered $CaCO_3$ with similar amount of hydrochloric acid.

$$CaCO_3(s) + 2HCl\,(aq) \longrightarrow CaCl_2\,(aq) + H_2O(l) + CO_2(g).$$

2.1. Which chemical reaction will faster? ______

A. The reaction between marble $CaCO_3$ and hydrochloric acid

B. The reaction between powdered $CaCO_3$ and hydrochloric acid

2.2. Why? Because_____

A. Substances with big particle size move slower than those with small particle size, their reaction rate decreases.

B. The powdered $CaCO_3$ has a greater surface area, thus rate of reaction increases.

C. If thesurface is small then the reaction will be faster, and if a large surface area, the reaction will be slower.

D. As the size of a solid reactant decrease the surface area decrease, thus rate of reaction increases.

Question 3: Consider the rate of the reaction of copper and magnesium with hydrochloric acid.

3.1. Which metal reacts faster with hydrochloric acid? ______

A.Copper (s) B.Magnesium (s)

3.2. Because ____

A. Reactions involving the breaking of stronger bonds proceed faster.

B. Generally, alkaline earth metals are more active than transition metals.

C. When the particle size of a solid reactant is decreased, its volume is decreased, and therefore rate ofreaction increases.

Question 4: Consider the reaction of magnesium ribbons and Sulphuric acid.

$$Mg\,(s) + H_2SO_4\,(aq) \longrightarrow MgSO_4\,(aq) + H_2\,(g)$$

The volume of H_2 (g) measured from the initial to 5.00 cm^3 is shown below.

Volume (cm^3) of H_2 (g)	1.00	2.00	3.00	4.00	5.00
Time (s)	4.00	6.00	9.00	14.00	20.00

4.1. What is the average rate of H_2 (g) production? _______

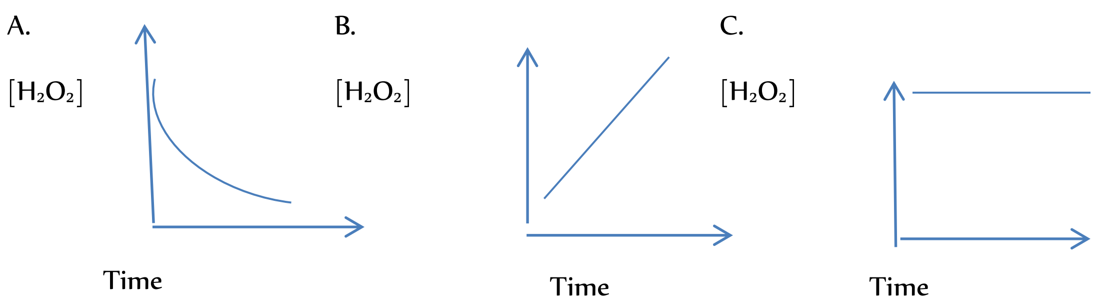
A. 0.17 cm^3/s B. 0.25 cm^3/s C. 0.50cm^3/s

4.2. Please supply your calculation method________________________________

Question 5: Consider the following reaction

$$2H_2O_2\ (l) \longrightarrow 2H_2O\ (l) + O_2\ (g)$$

5.1. Which graph shows the relationship between rate of consumption of H_2O_2 and time?___



5.2. Because _____

A. The rate of a reaction is the same at any time during the reaction.

B.The rate of a reaction decreases with passage of time as the concentration of reactants decreases.

C. The concentration of a reactant is directly proportional to the time of a reaction.

D. The reaction rate is constant because noadditional concentration.

Question 6: Assume that youstored some food in a fridge to preventspoilage.

6.1. What factor were you applying to slow the rate ofreaction? _____

A. Effect of temperature. B. Effect of concentration of a reactant.

6.2. Explain your answer? Because _____

A. Reaction rate is independent of reactants' concentration.

B. As temperature decreases the activation energy, it enables the reaction to decrease its rate.

C. Decreasing in temperature decrease in frequency ofcollision, thus rate of reaction decreases.

D. When temperature increases, rate of reaction decreases.

Question 7: Consider the following reaction :

$$Zn(s) + 2HCl\ (aq) \longrightarrow ZnCl_2\ (aq) + H_2(g)$$

7.1. When the concentration of HCl increased, the rate of the reaction_____

A. Remain the same. B. Increases. C. Decreases.

7.2. Because ________

A. When concentration of a substance increases, its kinetic energy increases, thus the rate of reaction increases.

B. Decreasing in concentration of one of the reactants increases the concentration of the otherreactant; thus, reaction rate is constant.

C. The number of effective collisions increases, thus the rate of reaction increases.

D.When concentration increases, surface area increases; thus, reaction rate increases.

Question 8: Consider the following reaction:

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

8.1. If you want to increase the rate of the overall reaction, what would you do? _____

A. Increase the surface area of the Mg wire, and dilute the concentration of the HCl.

B. Cut Mg wire into small pieces, while using the same concentration of HCl.

C. Cut Mg wire into small pieces, and increase the concentration of HCl.

D. Use the same amount of Mg wire, while increasing the concentration of HCl.

8.2. Because ______

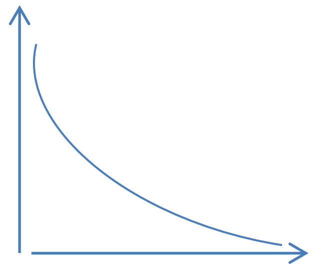
A. When the concentration of a reactant increases, its kinetic energy increases, thus the rate of the reaction increases.

B. When the surface area of a solid reactant increases, the number of collisions per second increases, thus the rate of the reaction increases.

C. When the concentration increases, the surface area increases, thus the rate of the reaction increases.

D.When particle size of reactant is decreased, its volume is decreased and therefore rate ofreaction increases.

Question 9: Consider the following chemical reaction rate Vs. time graph.



9.1. Which of the following is true? ______

A. The reaction rate increases with time. B. The reaction rate decreases with time.

9.2. This is because ______

A. Rate of reaction is theperiod of time in which reactant undergoes a reaction or products are formed in a reaction.

B. Rate of reaction is the change in concentration of a reactant or a product over a given period of time.

C. Reaction rate is the time between the beginning and finishing of a reaction.

D. Reaction rate is the number of reactions that take place per unit of time.

Question 10: When a lit match is touched to the wick of a candle, the candle ($C_{20}H_{42}$) begins to burn.

$$2C_{20}H_{42}\ (s) + 61O_2\ (g) \longrightarrow 40CO_2\ (g) + 42H_2O\ (g) + heat$$

10.1. In this reaction, the match ________

A. Increases the temperature. B. Acts as a catalyst. C. Supplies activation energy.

10.2. This is because ________

A. In exothermic reactions, heat from outside is needed and the reaction is faster.

B. Activation energy is the energy required for the particles in the reaction to collide in theappropriate direction.

C. The catalyst facilitates the collisions.

D. Activation energy required to initiate a chemical reaction.

Question 11: A student placed 3.0 g of Mg into some HCl in two different experiments. In each case, it reacted according the following equation:

$$Mg\ (s) + 2HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2\ (g)$$

In the first experiment, it took 3.2 minutes for all of the Mg to react. In the second experiment, it took 5.4 minutes for all of the Mg to react.

11.1. Which of the following could account for the change in rate of the second experiment?

A. The magnesium was powdered. B. The temperature was decreased.

11.2. Because_____

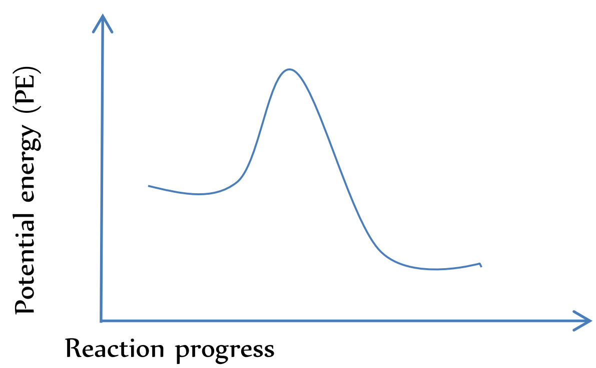
A. When temperature decreases, the frequency for collision decreases, thus the time required for the reaction increases.

B. If a surface area is large, the reaction will be slowerand the time required for the reaction decreases.

C. If thesurface is small then the reaction will be faster, and and the time required for the reaction increases.

D. A change in temperature does not affect reaction rate.

Question 12: Consider a chemical reaction system described by the diagram below:



12.1. Which of the following expressions describe the graph properly? _____

A.The forward reaction is endothermic. B. The forward reaction is exothermic.

C. The reverse reaction is exothermic.

12.2. Because ______

A. PE reactants > PE activated complex > PE products.

B. PE activated complex > PE reactants > PE products.

C. PE activated complex > PE products > PE reactants.

D. PE products > PE activated complex > PE reactants.

Question 13: Consider the following reaction mechanism:

Step 1: $NO (g) + O_3 (g) \longrightarrow NO_2 (g) + O_2 (g)$

Step 2: O (g) + NO_2 (g) $\longrightarrow$ NO (g) + O_2 (g)

13.1. The species NO is a______

A. Catalyst B. Reaction intermediate

13.2. Because _______

A. Catalyst is a substance which is formed and then consumed during a reaction.

B. The substance which participates in a reaction and gets out as the same substance is anintermediate substance.

C. A catalyst is a substance which accelerates the rate of a reaction and may be recovered unchanged at the end of the reaction.

D. Catalyst is an intermediate substance which participates in a reaction as a reactant but getsout without affecting the reaction.

Question 14: Consider the following reaction:

Zn (s) + $2HCl$ (aq) $\longrightarrow$ $ZnCl_2$ (aq) + H_2 (g)

Solid zinc was added to 1.0M HCl. In 20.0s, the temperature of the container increased at 0.5 ℃ and 25.00mL of H_2 was produced.

14.1. The rate of this reaction was _____

A. 1.0M HCl/s B. 1.25 mLH_2/s C. 0.050 mol HCl/s

14.2. Show your calculation method_______________________________________

Question 15: A student has prepared 10M, 5M, 1M and 0.5M nitric acid solutions in four test tubes and he put 2cm long magnesium ribbon in each test tube; then he observed the fastest consumption of magnesium ribbon in the test tube that contains 10M solution.

15.1. What does the fastest reaction rate indicate? ______

A. Temperature dependence of the reaction B. Concentration dependence of the reaction

C. Surface area dependence of the reaction

15.2. Because_____

A. When temperature of a substance increases, its kinetic energy decreases; thus, rate ofreaction increases.

B. While a reaction occurs, concentration of products increases in time; thus, reaction rateincreases.

C. When particle size of reactant is decreased, its volume is decreased and therefore rate ofreaction increases.

D. When concentration of a reactant increases, the number of collision between the reacting species per second increases, thus, rate of reaction increases.

Question 16: Consider that individual properties of substances or nature of reactants could affect the rate of a reaction.

16.1. Which of these reactions react rapidly at room temperature?______

A. $Pb(NO_3)_2$ (s) + $2KI$ (s) $\longrightarrow$ PbI_2 (s) + $2KNO_3$(s)

B. Pb^{2+} (aq) + $2I^-$(aq) $\longrightarrow$ PbI_2(s)

16.2. Because_______

A. In solid reaction, the ionic bonding in each compound is weak, thus rate of reaction is fast.

B. Generally, reactions involving ionic species tend to proceed faster than solids.
C. The surface area in solid reaction is greater, thus the rate of the reaction is fast.
D. Reactions between ions occur usually faster.

Question 17: Consider the following reaction.

$$2H_2O_2\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g)$$

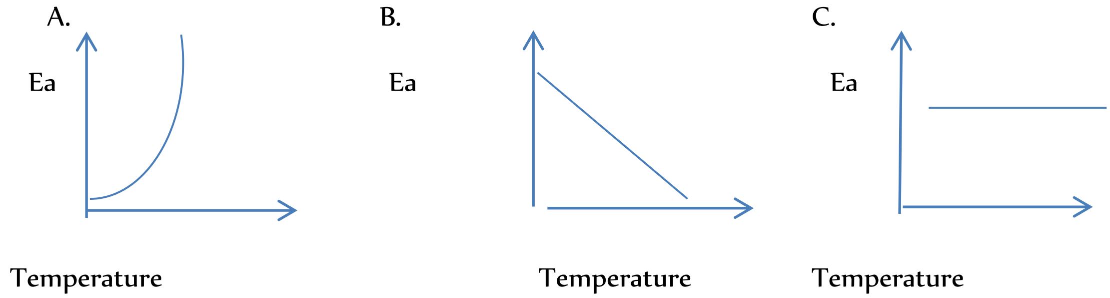
17.1. Which factor explains why the above reaction speeds up in the presences of MnO_2 (s)?
A. Nature of reactant B. Presence of catalyst C. Change in concentration
17.2. Because _____
A. When solid substance added to aqueous solution, increases the concentration, thus the rate of reaction increases.
B. Reaction involving solid tends to faster than aqueous solution.
C. A catalyst provides an alternative pathway to reaction mechanism, thus the rate of reaction increases.
D. Catalysts accelerate the reaction rate and ease of collision.
Question 18: Consider the following reaction:

$$N_2\ (g) + 3H_2\ (g) \longrightarrow 2NH_3\ (g)$$

18.1. When a catalyst is added to the reaction, which effect does the catalyst have on the reaction? ______
I. It changes the ΔH of a reaction.
II. It increases the kinetic energy of the reactants.
III. It provides a reaction mechanism with lower activation energy.
A. I and II only B.III only C. I, II and III
18. 2. Because ________
A. The catalyst facilitates the collision and affects the reaction rate is higher ΔH, thus the rate of the reaction increases.
B.When a catalyst added, its kinetic energy increases; thus, rate ofreaction increases.
C. In a reaction with mechanism, activation energy of the fast step is smaller than that of slow step.
D. When activation energyof a reaction decreases, reaction rate decreases as well.
Question 19: Consider the following reaction:

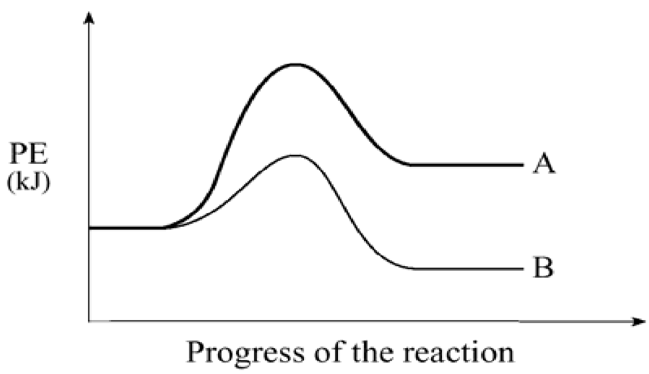
$$CH_4\ (g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2H_2O\ (g)$$

19.1. Which graph shows the relationship between activation energy (Ea) and temperature?



19.2. The reason for my answer is, because______
A. The activation energy of a reaction decreases with an increase in temperature.
B. Activation energy is the energy required for the particles in the reaction to collide in theappropriate direction.
C. The activation energy of a reaction in solution does not change with an increase in temperature.
D. Increase in temperaturemay affect the activation energy.

Question 20: Consider the following potential energy diagram that represents two different reactions.



20.1. Which of the following statements is correct? _____
A. Reaction A and B are both exothermic.
B. Reaction B is exothermic.
C. Reaction A is exothermic.

20.2. Because_____
A. The potential energy = enthalpy (ΔH).
B. The products have more potentialenergy than the reactants.
C. The activation energy (Ea) = enthalpy (ΔH).

D. Thereactants have morepotential energy than theproducts.

Appendix-B –Semi-Structured Interview

Semi-structured Interview Questions (Part A)

Purpose: aimed to gather detail information about the students' understanding of the rate of reaction concepts and to assess the effect of treatments on students' knowledge retention or long term effect of the treatments.

Q1. What is the rate of a reaction? Could you give some examples of the factors that affect the rate of a reaction?

Q2. Do the individual properties of substances (nature of reactants) affect the rate of a reaction? Please give some of these properties.

Q3. What is the effect of change in a surface area of a solid reactant on the rate of a chemical reaction? Please explain.

Q4. Does any change in concentration of reactants affect the rate of a chemical reaction? How? Please explain.

Q5. Compare and contrast the effect of change in concentration and pressure of reactants?

Q6. Does any change in temperature of reactants affect the rate of a chemical reaction? How? Please explain.

Q7. How catalysts affect the rate of a chemical reaction? Is there any difference between a catalyst and a reaction intermediate? Please explain.

Q8. According to collision theory, what are the main requirements that required for all successful collisions? Please explain.

Semi-structured Interview Questions (Part B)

Purpose: aimed in order to determine the students' attitude towards the analogy learning approaches on the concept of rate of a reaction and to evaluate what the students gained from the lessons conducted in the analogical approach.

Q1. What is your attitude towards the analogy-based learning approach on the concepts of rate of reaction? Please explain.

Do you like your teacher to use analogies more often in the class? Please explain?
Q2. What did you gain from analogy-based instruction? Please explain.

Did the analogies help you to understand the rate of reaction concepts better? Why?

Appendix-C- Some Analogies Used In This Study

Definition of rate of a chemical reaction
Biking a bicycle with different speeds, but in equal distance
Peeling banana fruits with different speeds, but equal time

Effect of nature reactants
Boiling of tomatoes and potatoes
Riding a horse and a donkey with limited distance

Effect of surface area of reactants
Cooking small and large size potatoes
Drying small and large size meat in air at normal temperature

Effect of concentration of reactants
Making a house with two and more people
Ploughing a limited land with two and four oxen

Effect Of temperature
Boiling of eggs with high and low temperature
Baking bread with low and high temperature

Effect of a catalyst
Riding a bicycle in lower and higher up hill
Walking to school with common road and short cut