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An analysis of high school students' academic achievement and anxiety over graphical chemistry problems about the rate of reaction: The case of Sivas province

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Abstract

The study deals with the evaluation of the achievement of high school students concerning such topics as "reaction rate, reaction order, factors affecting reaction" which are included in the unit of "Reaction Rate and Chemical Equilibrium", a part of chemistry program. To this, three measurement tools used as data collection tools; the "Achievement Test on Reaction Rate" (RRAT), the "Graphical Test on Reaction Rate (RRGT) and the "Anxiety Scale on the Use of Graphics" (ASUG) in chemistry problems. The participants of the study were 129 eleventh graders attending four Anatolian high schools in the province of Sivas. The study was carried out on one group. The findings obtained showed that the participants had higher mean scores in RRAT in contrast to those in RRGT. It was further found that the anxiety of the participants in regarding to the problems with graphics is higher. It was also determined that there is a statistically significant, negative and weal correlation between the student achievement in RRGT and the anxiety levels in regarding to the problems with graphics.

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Keywords: Reaction rate, achievement test on the reaction rate, graphics test on the reaction rate, anxiety scale for the use of graphics

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1. Introduction

> *"A candle can remain without any reaction in air for a long time, but if it is burned with match it reacts. In a closed room, air and gas can be together without any reaction. However, if someone with a burning thing enters into the room, they both react and a violent explosion occurs. An iron bar slowly oxidizes in the air. All these reactions occur with oxygen. However, the rate of each varies significantly".*

Any people who can carefully observe the events recognize that some chemical reactions last for a short time, but the others last for a long time. It has been common among people to search for increase or decrease the rate of chemical reactions. The motivation for it is that the rate of reaction should be increased to have more productive, practical and economically advantageous. However, sometime the rate of reaction should be decreased for the similar reasons. For instance, the rate of food spoilage is made slow through putting them into fridge or through adding some preservatives. The indicators of the chemical reaction include heat exchange, color change, conductivity, gas outlet, deposition, pressure and volume change (MEB, No date).

There are many concepts in science that are not isolated and specified for one specific discipline. One of these concepts is the concept of rate, which has a broad use in many areas in science and mathematics. The term "rate" is often used to describe the change in a quantity that occurs per unit of time. Both in physics and in chemistry the meaning of rate is similar but the use and the terminology of this concept is different for each domain. For instance, in chemistry, the rate of a reaction can be defined as the change in concentration of a particular reactant or product per unit of time. On the other hand, in physics, the term "velocity" is used for displacement in a certain time, which also refers to the "rate" concept. One of the objectives of the Turkish secondary science (biology, chemistry and physics) curriculum is to establish links between physics, chemistry and other science fields in terms of key science concepts (MEB, 1998; 2007; Cited in Bektaşlı & Çakmakçı, 2011).

Rate of reaction as a highly structured topic is a central part of chemistry curriculum (Cachapuz & Maskill, 1987) and is an abstract chemical topic, which is also important in learning other fundamental chemical concepts such as chemical equilibrium. Therefore, comprehension of concepts with respect to rate of reaction and factors affecting it has a key role in learning of chemistry (Cachapuz & Maskill, 1987; Ragsdale, Vanderhooft & Zipp, 1998). Since understanding concepts related to reaction rate is crucial in learning other chemical concepts, appropriate teaching strategies should be designed by considering the results of their search about rate of reaction in the literature. Although extensive research related to chemical equilibrium has been carried out, research about students' understanding of rate of reaction concepts is limited (Justi, 2002; Cited in Kaya, 2011). Students have misconceptions, thus learning difficulties, in the subject of reaction rate (deVos & Verdonk, 1986; Justi, 2002). Students are required to conceptualize descriptive, particulate, and mathematical modeling regarding chemical kinetics and the interrelations between them in order to improve their understanding of reaction rate concepts (Çakmakçı, Donnelly & Leach, 2005). In addition, rate of reaction concepts is an essential prerequisite for some chemistry concepts, especially chemical equilibrium. In educational research, although there has been substantial research on students' understanding of chemical equilibrium concepts, there is limited research related to students' understanding of rate of reaction concepts. (Gorodetsky & Gussarksy, 1986; Van Driel, 2002; Çakmakçı, 2005; Çalık, Kolomuc & Karagölge, 2010; Cited in Kaya & Geban, 2012).

There are very little data available on how understanding of chemical kinetics progresses as students move through the curriculum. It is intended that this study will provide empirical evidence about students' understanding of chemical kinetics. Since students experience difficulties in understanding in chemical kinetics both at school (De Vos & Verdonk, 1986; Justi, 2002) and university level (Lynch, 1997), further research is required in order to give insights into the ways in which students conceptualize chemical kinetics at school and university level (Çakmakçı, Donnelly & Lynch, 2005).

Research on students' understanding of rate of reaction documented following conceptual difficulties; in ability to define the rate of reaction (e.g. defining reaction rate as reaction time), difficulties in explaining how reaction rate changes as there action progresses (Çakmakçı, Leach & Donnely, 2006; Çalık, Kolomoç & Karagölge, 2010), misunderstandings of the relationships between temperature change and the rate of reaction (Çalık, Kolomuç & Karagölge, 2010; Justi, 2002; Quilez-Pardo & Solaz-Portoles, 1995; Van Driel, 2002), misunderstandings of the relationships between concentration change and the rate of reaction (Cachapuz & Maskill, 1987; Çakmakçı, Leach &

Donnely, 2006; Sözbilir, Pınarbaşı & Canpolat, 2010), misundertsandings of the effect of a catalyst on the rate of reaction and on the mechanism of their action (Çakmakçı, 2009; Hackling & Garnett, 1985; Taştan, Yalçınkaya & Boz, 2010), and having conceptual difficulties in interpreting empirical data and graphical representation (Cited in Çakmakçı, Leach & Donnely, 2006).

Anxiety is a feeling of fear and worry. In case anxiety starts to affect and individual's life quality, this could be considered as anxiety disorder (Uçar, 2004). Research on there a sons for anxiety mainly focuses on the state of feeling that experience during uncertain and uncontrollable situations. It is also individuals considered as a factor reinforcing anxiety when individuals lack some knowledge during knowledge processing process and considers this situation the sign a potential disaster. Students experience anxiety in various less on due to various reasons during their education years. These anxieties might affect their learning positively or negatively. Students tend to have anxieties through the utilization of graphs in teaching the relations between concepts in Chemistry. Chemistry is a field of science analyzing all substances found in nature. The laws are expressed through a mathematical language in chemistry. Mathematics is a tool frequently made use of in expressing the laws, solving problems and expressing problems. Graphs are quite commonly utilized in chemistry in preceding these functions. In evaluating the relationship between concepts, in expressing the directions and sizes of these relationships, in organizing and summarizing data, graphs are effectively utilized tools. Graphs make it easier for us to see the relationship amongst the large datasets. They are also useful in displaying the relationships that are difficult to express in numbers. For solving the arithmetical and algebraic problems, graphs are functional tools (Beichner, 1994; Ersoy, 2004; McKenzie & Padilla, 1986; Padilla, McKenzie & Shaw, 1986). The literature was observed to contain various studies on using, understanding and interpreting graphs. Students do not only need to have the three skills in order to interpret, draw and organize graphs but also need to overcome these challenges. The lack of performing these skills or failing to overcome these challenges may cause students to develop anxieties towards using graphs. Similarly, students' existing anxieties towards using graphs may prevent the emerging of these skills or rein force the emerging of the challenges (Cited in Seçken & Zan, 2013).

The study aims at measuring the basic knowledge and skills about the reaction rate of 129 high school students attending the eleventh grade of four different Anatolian High Schools in Sivas. In addition, the performance of the participants in regarding to the problems with or without graphics was analyzed and their anxiety level about the problems with graphics was determined. Based on these aims, the study attempts to answer the following research questions:

1) Is there any statistically significant difference between student's achievement scores in RRA test and those in RRG test?

2) What is the level of student anxiety in regarding to the chemistry problems with graphics about "the rate of reaction"?

3) Is there any statistically significant correlation between students' scores on the "RRGT" and their anxiety level in regarding to the problems with graphics?

2. Method

2.1. Participants

The participants of the study were 129 eleventh graders attending four Anatolian high schools in the province of Sivas.

2.2. Data collection tools

2.2.1. Achievement test on reaction rate (RRAT)

The RRAT, designed to evaluate the knowledge of students about the rate of reaction, is made up of 25 multiple-choice items. More specifically, the test measures the knowledge and skills about "measure of the reaction rate, collision theory, activation theory, reaction heat, reaction mechanism and the formulas and degrees of rate, and the factors affecting reaction rate". RRAT involves the chemical problems, which do not include any graphics and which attempt to evaluate the knowledge and comprehension about the rate of reaction. It was developed by the authors and was used in a pilot study with the same level 95 students. The analyses showed that its cronbach α reliability coefficient is 0,78.

2.2.2. Graphical test on reaction rate (RRGT)

The RRGT was also developed by the authors and involves those chemical problems on the rate of reaction with graphical representation. Its original version was made up of 15 multiple-choice items. These items attempt to evaluate the students' skills in regarding to practice and analysis. It was used in a pilot study with the same level 95 students other than the participants of the study. The results of validity and reliability showed that four items should be eliminated from the test, leading to the one with eleven items. The cronbach alpha reliability coefficient was found to be 0,697.

2.2.3. Anxiety scale on the use of graphics in chemistry courses (ASUG)

This scale developed by Seçken ve Zan (2013) was used to measure the anxiety level in regard to deal with the chemistry problems with graphics. It was used in a pilot study with the same level 95 students other than the participants of the study. The factor analysis showed that it has one dimension and its cronbach alpha reliability coefficient was found to be 0,935.

3. Findings

In regarding to the first research question, is there any statistically significant difference between student's achievement scores in RRA test and those in RRG test, t-test was used. The findings obtained are given in Table 1.

		Paired Differences							
					95 % Confidence Interval of the Difference				
		Mean	Std. Deviation	Std.Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	RRAT-RRGT	4,618	3,00635	,26469	4,09447	5,14196	17,447	128	,000

Table 1. Results of t-test to compare student's achievement scores in RRA test and those in RRG test.

RAs can be seen in Table 1, there is a statistically significant correlation between student's achievement scores in RRA test and those in RRG test ($p<0.05$). The direction of this correlation in favour of the scores in the RRA. In other words, the mean scores of the students in RRAT are higher than those in RRGT.

In regarding to the second research question, What is the level of student anxiety in regard to the problems with graphics about "the rate of reaction" the answers of the participants to the ASUG were analysed in terms of percentage and frequency. The results are given in Table 2.

Table 2. Percentages and frequencies of the answers to the anxiety scale on the use of graphics in chemistry problems

ITEM NO		Frequency	Percent
1) I have difficulty in interpreting the lines on a graphic.	1	11	8,5
	2	39	30,2
	3	34	26,4
	4	30	23,3
	5	15	11,6
2) I could not interpret the increases or decreases in the curves included in the graphs	1	22	17,1
	2	55	42,6
	3	27	20,9
	4	18	14,0
	5	7	5,4
3) I wish there was a way to achieve in chemistry without interpreting questions with graphs.	1	15	11,6
	2	29	22,5
	3	24	18,6
	4	38	29,5
	5	23	17,8
4) Before an important test, during a test or when studying for a test I think that some of my friends have less difficulties than I do	1	33	25,6
	2	39	30,2
	3	22	17,1
	4	17	13,2
	5	18	14,0
5) I think that graphical questions are a way to make sense the theoretical knowledge.	1	30	23,3
	2	37	28,7
	3	23	17,8
	4	20	15,5
	5	19	14,7
6) I feel anxious before the exams that questions with graphs may come up.	1	13	10,1
	2	35	27,1
	3	30	23,3
	4	31	24,0
	5	20	15,5
7) Chemistry topics with too many graphs do not attract me.	1	19	14,7
	2	33	25,6
	3	20	15,5
	4	34	26,4
	5	23	17,8
8) My anxiety towards failing to interpret questions with graphs affects my achievement in exams.	1	23	17,8
	2	44	34,1
	3	20	15,5
	4	27	20,9
	5	15	11,6
9) I can't sleep because of the thought that I will have to respond to questions with	1	65	50,4

	graphs.	2	30	23,3
		3	14	10,9
		4	7	5,4
		5	13	10,1
10)	When solving a chemistry problem with graphs or interpreting it, I feel like I am making mistakes.	1	11	8,5
		2	26	20,2
		3	37	28,7
		4	35	27,1
		5	20	15,5
11)	When I face a question with graphs, I experience a fail or right at the beginning.	1	34	26,4
		2	37	28,7
		3	24	18,6
		4	23	17,8
		5	11	8,5
12)	If I manage to interpret questions with graphs, my self-esteem will improve.	1	13	10,1
		2	31	24,0
		3	21	16,3
		4	41	31,8
		5	23	17,8
13)	I cannot be sure of my decisions in interpreting graphic questions.	1	10	7,8
		2	25	19,4
		3	31	24,0
		4	39	30,2
		5	24	18,6
14)	When talking about graphic questions, I think of difficult questions to explain.	1	19	14,7
		2	40	31,0
		3	31	24,0
		4	21	16,3
		5	18	14,0
15)	I have difficulty in understanding when my teachers interpret graphs.	1	31	24,0
		2	45	34,9
		3	19	14,7
		4	24	18,6
		5	10	7,8

As seen in Table 2, some of the student answers indicate higher levels of anxiety over the chemical problems with graphics. For instance, 39.5% of the participants stated that they agreed or totally agreed with the sixth item, namely, “I feel anxious before the exams that questions with graphs may come up. “Similarly, the rate of the students who agreed or completely agreed with the seventh item, “Chemistry topics with too many graphs do not attract me.” was found to be 44.2%. The rate of the students who agreed or completely agreed with the tenth item, “When solving a chemistry problem with graphs or interpreting it, I feel like I am making mistakes”, is 42.6%. With regard to the twelfth item, “If I manage to interpret questions with graphs, my self-esteem will improve”, the rate of the students who agreed or completely agreed with it was found to be 49.6%. The rate of the students who agreed or completely agreed with the thirteenth item, “I cannot be sure of my decisions in interpreting graphic questions”, was again higher, specifically 48.8%. In all instances, it is observed that the self-esteem of the participants in answering graphical problems is lower. However, the findings also indicate that when someone explains such problems, the participants do not experience any difficulty in dealing with the graphical problems.

In regarding to the last research question, namely "Is there any statistically significant correlation between students' scores on the "graphical test of reaction rate" and their anxiety level in regard to the problems with graphics?" correlation analysis was employed to reveal the direction and magnitude of the potential correlation. The results of the correlation analysis are given in Table 3.

Table 3. Results of the correlation analysis over the correlation between the RRGT achievement and anxiety scores

		RRGT	**ASUG**
RRGT	Pearson Correlation	1	-,419(**)
	Sig. (2-tailed)		,000
	N	129	129

** Correlation is significant at the 0.01 level (2-tailed).

As can be seen in Table 3, the results of the correlation analysis indicates that there is a statistically significant negative but a weak correlation between the students' RRGT achievement scores and their level of anxiety.

4. Conclusions

The study aims at measuring the basic knowledge and skills about the reaction rate of 129 high school students attending the eleventh grade of four different Anatolian High Schools in Sivas. In addition, the performance of the participants in regarding to the problems with or without graphics was analyzed and their anxiety level about the problems with graphics was determined.

The findings concerning the first research question showed that the mean achievement scores of the participants from the RRAT, which included 25 multiple choices and non-graphical items, are higher than those from the RRGT, which included 15 multiple choice and graphical items. This finding also supported the findings concerning the second research question, which dealt with the anxiety levels of the participants about graphical chemistry problems. The answers of the participants to the ASUG indicated that their level of anxiety in this regard is higher. Most of them reported that they do not have any interest in graphical themes such as under the unit of the rate of reaction and chemical equilibrium and that they have anxiety in drawing or interpreting graphics in the exams due to making mistakes. Therefore, it is natural that the participants have higher scores in the RRAT, which does not include graphical problems. In the study, it is also found that there is a significant but weak correlation between the mean achievement score in the RRGT and their level of anxiety over graphical problems. It means that their achievement in the RRG test becomes higher and their level of anxiety somewhat decreases. It is the goal of all educational programs and activities.

Any international or national study was not found the findings of which support the current findings. Some research on teaching and learning of chemical equilibrium have focused on students' conceptions related to chemical equilibrium (Wheeler & Kass, 1978; Hewson & Hewson, 1984; Hackling & Garnett, 1985; Quilez-Pardo & Solaz-Portoles, 1995; Van Driel, 2002), some have focused on students' frameworks in chemical equilibrium (Gussarksy & Gorodetsky, 1990; Maskill & Cachapuz, 1989), some have dealt with students' usage of Le Chatelier's principle (Banerjee, 1995), and some have investigated this subject from quantitative aspects (Hackling & Garnett, 1985; Huddle & Pillay, 1996).

Studies concerning the rate of reaction and chemical equilibrium in Turkey are mostly dealt with the students' understanding, views, comprehension or misconceptions (Çakmakçı, Donnelly & Leach, 2005; Çakmakçı Leach & Donnelly, 2006; Çalık, Kolomuç & Karagölge, 2010; Taştan, Yalçınkaya & Boz, 2010; Kaya, 2011; Kaya & Geban, 2012).

5. Suggestions

Based on the findings, the following suggestions are developed:

1. The data with the same measurement tools can be collected from the students attending other high school types.
2. Interventions to decrease anxiety could be carried out in regarding to those topics about which students have higher levels of anxiety.
3. Activities to improve student achievement about the rate of reaction can be done.
4. Misconceptions about the rate of reaction can be revealed and eliminated or reduced.

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