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A COMPARISON OF CHEMISTRY TEACHERS' AND GRADE 11 STUDENTS' ALTERNATIVE CONCEPTIONS OF 'RATE OF REACTION'

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Abstract. *The purpose of this study is to compare alternative conceptions of chemistry teachers and Grade 11 students on the subject of 'rate of reaction'. This study was conducted with a total of seventy chemistry teachers and seventy two grade 11 students. To collect data, a 'rate of reaction' concept test comprising 9 lead and 10 sub-questions (in total 19 items) were employed. Also, a structured interview session was conducted with 10 chemistry teachers and 13 grade 11 students. Since the chemistry teachers and grade 11 students possessed similar alternative conceptions, it can be deduced that the chemistry teachers seem to have been principal source at transmitting their alternative conceptions to the grade 11 students. It is recommended that, a common database or website should be created to afford the current chemistry teachers to easily access to improved teaching materials and/or instruments in chemistry education.*

Key words: *alternative conception, chemistry teacher, grade 11 students, rate of reaction.*

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Introduction

Constructivist learning theory suggests that students' learning is active rather than that they be passive recipients of learning (e.g. Fensham, 1992). It also claims that students (or people), construct their own knowledge in their minds as a result of interaction with the environment (e.g. Brooks & Brooks, 1999). From this perspective, if the students construct chemical facts or concepts or phenomena in their mind by help of their pre-existing knowledge, then grasping scientific understanding has a great importance for further learning. However, related literature indicates that the students' pre-existing knowledge or pre-conceptions are different from scientifically accepted ones (e.g. Nakhleh, 1992; Nicoll, 2001). These studies have reported that they may result from exposure to several factors, i.e. teacher, TV, friends, social environment etc. (Hand & Treagust, 1991; Nakhleh, 1992). In fact, these factors seem to be outcomes of social aspect of constructivism.

The topic 'rate of reaction' involves in several concepts like rate of reaction, collision theory, reaction mechanism, factors affecting rate of reaction, the effect of the catalyst on the reaction rate, enthalpy and activation energy. For this reason, all these concepts are necessary for the understanding of the topic 'rate of reaction' and generally included in the teaching/learning of the topic. Since these concepts are interrelated with other subsequent chemistry concepts, 'rate of reaction' is a cornerstone for chemistry arguments. Phrased differently, if alternative conceptions emerge in the subject of 'rate of reaction', it will affect other interrelated chemistry subjects. Because of the importance of 'rate of reaction', a few studies have been conducted within three perspectives: (i) determining students' alternative conceptions (Cakmakci, 2005; Nakipoğlu, Benlikaya & Kalın, 2002; Taştan, Yalçınkaya & Boz, 2010), and (ii) conducting conceptual change approaches to overcome their alternative conceptions (Akkaya, 2003; Balcı, 2006; Bozkoyun,

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2004; Çalik, Kolomuç & Karagölge, 2010; Tezcan & Yılmaz, 2003; Van Driel, 2002), and (iii) comparing students' ideas of the concept 'rate' at different contexts (Bektaşlı & Çakmakcı, 2011). Within these studies, Taştan *et al.* (2010) determined pre-service chemistry teachers' ideas about reaction mechanism, while Cakmakci (2005) carried out a cross-sectional study of the understanding of chemical kinetics among Turkish secondary and undergraduate students. Meanwhile, to accomplish conceptual change, different methods have been used: laboratory activities (Akkaya, 2003), conceptual change texts (Bozkoyun, 2004), group discussions, hands-on activities (Van Driel, 2002), package programs for computer-aided instruction (Tezcan & Yılmaz 2003) and conceptual change pedagogy including animations and worksheets (Çalik *et al.*, 2010). Moreover, Bektaşlı and Çakmakcı (2011) investigated consistency of grade 11 students' ideas of the concept 'rate', i.e. velocity of an object in physics and rate of reaction in chemistry. However, none of the foregoing studies has concentrated on comparing the chemistry teachers' alternative conceptions of 'rate of reaction' with grade 11 students' conceptions to directly reject or accept whether the teachers are the principal source for the alternative conceptions. Indeed, although Cakmakci (2005), Nakipoğlu *et al.* (2002) and Taştan *et al.* (2010) reported that student teachers as well as students at different stages have difficulty conceptualizing the 'rate of reaction' concepts or hold some alternative conceptions, there is an important omission about a comparison between chemistry teachers and their students. Some studies such as Çalık and Ayas (2005), Ebenezer and Gaskell (1995), Ginns and Watters (1995), Goodwin (1995), Taber and Tan (2011) and Valanides (2000) hypothesized that students' alternative conceptions may be derived from their teachers. Therein, such a speculative hypothesis needs to be investigated in order to provide new evidence regarding sources of alternative conceptions.

Context of the Study

Secondary education, is of four years duration, and free in public schools in an aim to facilitate students to capture the following features: (1) general culture knowledge (2) scientific literacy (3) participating in the economic, social and cultural development of the country and (4) preparing the students for institutions of higher education (Çalik, 2010). At grade 9 students are introduced to general courses such as chemistry, physics, mathematics, biology, Modern Turkish History and Principles of Atatürk and English language. Later they are divided into three main disciplines depending on their interests/talents: (1) social science, (2) science and (3) equal weight (social science and science) (Çalik, 2010). Students who select the science stream attend a grade 11 chemistry course which includes: Chemical Reactions and Energy, Rate of Reaction and Chemical Equilibrium, Solubility Equilibrium, Electrochemistry and Radioactivity. The students in the social science and equal weight (social science and science) programmes do not take any chemistry topic and/or course.

For the undergraduate chemistry education program, up until 1998 the department of chemistry education ran a four-year undergraduate program with the aim of preparing chemistry teachers for secondary schools. After 1998, project *'Reconstruction of Faculty of Education'* changed it into a five-year undergraduate program. Thereby, chemistry subject matter courses are taught by the members of Science and Literature Faculty while pedagogical content courses (i.e. Special Teaching Method (Chemistry Teaching) I-II, Measurement and Assessment, Instructional Technology and Material Development) are taught by the Faculty of Education. By 2010, chemistry students wishing to become chemistry teachers after graduating from Department of Chemistry must have attended a three semester pedagogical course (called graduate program without thesis). However, the Higher Education Council decided to alter these teacher education programmes and gave an opportunity for the students from Department of Chemistry to take teaching certification by completing short-term weekend pedagogical courses similar to earlier courses such as *'Reconstruction of Faculty of Education'*. Due to decreasing number of undergraduate students at Department of Chemistry, the Higher Education Council, with demands of these departments, attempted to make them appeal by creating alternative employment opportunities, i.e. chemistry teacher. In brief, a two-headed chemistry education has appeared again. Also, the Department of Chemistry Education has been continuing to run a five-year undergraduate program. Chemistry student teachers must attend General Chemistry II, Analytical Chemistry II, Physical Chemistry II and Biochemistry related to 'rate of reaction' concepts.

The Purpose

The purpose of this study is to compare the chemistry teachers' alternative conceptions of 'rate of reaction' with those of grade 11 students.

Methodology of Research

Because the current study intended to determine the nature and degree of existing cases i.e. alternative conceptions of the chemistry teachers and grade 11 students, its general charecteristic fits with descriptive research design (i.e. Kurnaz & Calik, 2009). The descriptive research design provides an answer to such questions as "*What is happening?", "How is happening?* "and *"Why is happening?"*

Sample

Since the first author participated in several in-service education programmes on "Introduction of Newly Released Chemistry Curriculum", he handed 'Rate of Reaction' Concept Test out about 300 chemistry teachers. However, only 70 chemistry teachers filled in the instrument and handed it in the first author. To achieve sample variation for the grade 11 students, each teacher was asked to find at least three students at different levels (average, above average and under average) from his/her own class. Unfortunately, a few teachers followed this procedure and then delivered the instruments to the authors. In brief, the research covers seventy chemistry teachers (whose experiences ranged from 10 to 25 years) and seventy-two grade 11 students (aged 16–18 years) in Turkey. The researchers chose grade 11 students as the study sample, because the topic 'rate of reaction' is formally introduced at this grade.

The sample was selected using convenience sampling method because the first author tried to directly reach all participants at in-service education programmes. Turkey consists of seven geographical regions with totally 81 cities. In context of the present study, the chemistry teachers were from 28 different cities at seven geographical regions while the students came from 9 different cities in three different geographical regions (Black Sea, Marmara and Eastern Anatolia Regions). The students had very similar socio-economic and educational backgrounds. That is, all students possessed average socio-economic condition. All teachers under investigation were master chemistry teachers that deployed to train the chemistry teachers in their own cities. In other words, after in-service professional development on innovative technologies or curricula, it was expected that these chemistry teachers would actively play a significiant role to help teachers at the same city understand innovations and developments (e.g. Çalik & Ayas, 2008).

Data Collection

Çalik et al. (2010) adapted A 'Rate of Reaction' Concept Test (9 lead and 10 sub-questions - in total 19 items - see the following link at http://ktu.academia.edu/MUAMMERCALIK/Teaching/39398/Rate_of_Reaction_Concept_Test) from Cakmakci's (2005) study, and translated it into Turkish. Further, they pilot-tested it with 32 grade 11 students, apart from the main study, to measure the reliability of the Rate of Reaction Concept Test. Also, a group of experts, three chemistry educators and three chemistry teachers, confirmed construct and face validity of the instrument. Cronbach's alpha reliability of the instrument translated version was found 0.94. This means that the instrument's reliability was higher than the acceptable reliability value suggested by Hair, Black, Babin, Anderson and Tatham (2006).

To triangulate data, the first author called the teachers and grade 11 students for conducting a phone or 'face to face' interview protocols. Even though most of the teachers were reluctant to take part in such an interview session, the authors convinced some of them to participate in interview session and to find three students at different levels (average, above average and under average) from their own classes. To sum up, 10 chemistry teachers (aged 32-55 years—6 males and 6 females) and 13 grade 11 students (aged 16-17 years—7 females and 6 males) participated in structured interview sessions (either 'face to

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face' or phone interview). Each session took about 10-15 minutes. The interviewee chemistry teachers depicted that nine out of them did not attend any course of alternative conceptions in chemistry and of conceptual change in in-service education. Three of them noted that they were aware of these alternative conceptions and conceptual change strategies because of some common undergraduate courses in pre-service education. The interview questions are presented in Appendix A.

Data Analysis

In analyzing survey data, the authors followed the criteria suggested by Abraham, Williamson and Westbrook (1994) to label grade 11 student and the chemistry teacher responses: ***Sound Understanding (SU)*** for responses that included all components of the validated answers, ***Partial Understanding (PU)*** for responses that included at least one of the components of a validated response, but not all the components, ***Partial Understanding with Specific Alternative Conception (PUSAC)*** for responses that showed understanding of the concept, but also made statements which demonstrated a misunderstanding, ***Specific Alternative Conceptions (SAC)*** for responses that included illogical or incorrect information only, and ***No Understanding (NU)*** for responses that consisted of the repeating question; irrelevant or unclear response; or no response. Before classifying the grade 11 student and the chemistry teacher responses, the authors met with six chemistry teachers to debate the criteria, and all agreed on the appropriate answers for the questions. Then, the researchers scored draft data responses separately and negotiated the categorization. There was a high agreement (about 90%) for most items in categorizing the data. All disagreements were resolved by negotiation. Furthermore, they re-examined and recalculated principal items and their sub-questions in regard to an alternative conception thematic schema created by Çalik *et al.* (2010). A sample categorizing procedure for Item 2 is presented as follows:

Table 1. A sample categorizing procedure for Item 1.

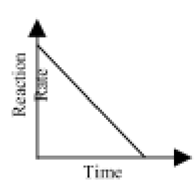
Sound Understanding	An increase in the temperature increases the kinetic energy of particles, which causes more collisions between particles per unit of time. Thereby, collision probability amongst the hot water pipe, oxygen and water increases to pass threshold (activation) energy. For this reason, the outside of the hot water pipe was more rusty than the outside of the cold water pipe. To sum up, increasing temperature usually increases the rate of a reaction whether the reaction is exothermic or endothermic.
Partial Understanding	Because temperature increases rate of reaction, the outside of the hot water pipe was more rusty than the outside of the cold water pipe
Partial Understanding with Specific Alternative Conception	Temperature affects rate of reaction because heat acts as a catalyst and causes to rust outside of the hot water pipe more
Specific Alternative Conceptions	The fact that hot water melts the water pipe made of iron more boosts its rusty environment

In analyzing interview protocols, firstly each session was classified in regard to similarities and differences (Merriam, 1988; Yin, 1994). Later, themes and codes emerged were presented in tables using simple frequency technique.

Results of Research

As seen in Table 2, percentages of the chemistry teachers' responses labeled under SU were between 31% (Item 3d) and 100% (Item 7b) while those for grade 11 students were between 1% (Item 7a) and 77% (Item 7b). Percentages of the students' and chemistry teachers' responses to each item are presented in Table 2.

Table 2. Percentages of the chemistry teachers' and the grade 11 students' responses to each item.

Item No.		SU	PU	PUSAC	SAC	NU	Expected Sound Understanding response (Adapted from Cakmakci (2005))
1a	*S*	8	36	11	6	39	Reaction rate can be defined as the change in concentration of a particular reactant or product per unit of time. The rate of a reaction is commonly employed in three different forms: the average rate of reaction, the instantaneous rate of reaction, and the initial rate of reaction.
	T	71	-	14	15	-	
1b	*S*	8	36	33	16	7	The higher the concentration of molecules, the greater the number of collisions in unit time and hence the faster the reaction. As reactants are consumed, their concentrations drop, collisions occur less frequently, and reaction rate decreases. However, this is not the case for zero order reactions in which reaction rate is independent of the concentrations of reactants, and accordingly reaction rate is constant during the reaction.
	T	73	-	20	7	-	
2	*S*	8	38	22	13	19	An increase in the temperature increases the kinetic energy of particles, which causes more collisions between particles per unit of time. Thereby, collision probability amongst the hot water pipe, oxygen and water increases to pass threshold (activation) energy. For this reason, the outside of the hot water pipe was more rusty than the outside of the cold water pipe. To sum up, increasing temperature usually increases the rate of a reaction whether the reaction is exothermic or endothermic.
	T	60	19	10	11	-	
3a	*S*	13	38	29	10	10	The reaction rate is the slope of the concentration versus time graph. As the slope of the graph is constant, it can be concluded that this reaction is a zero order reaction with respect to NO.
	T	71	-	10	19	-	
3b	*S*	17	26	29	11	17	The reaction rate is not affected by the changes in the concentration of NO. Because, the reaction is a zero order reaction and its rate only depends on the rate constant.
	T	55	26	7	-	12	
3c	*S*	16	26	13	5	40	Increasing the temperature of a reaction mixture increases the kinetic energy of particles, which causes more collisions between particles per unit of time. Increasing temperature usually increases the rate of a reaction whether the reaction is exothermic or endothermic. Reaction rates increase with temperature because a higher temperature means a greater proportion of reactant molecules have enough energy to overcome the activation energy barrier per unit of time. A small increase in temperature may produce a large increase in the rate of a reaction, since there is a large increase in the proportion of molecules which possess the activation energy. For example, a small input of energy is usually required to initiate some reactions such as fuels and explosives which are exceedingly exothermic reactions.
	T	59	20	21	-	-	
3d	*S*	17	38	26	-	19	The surface of a solid catalyst is important to the reaction rate. The reaction occurs on the surface of the solid catalyst, therefore rate increases with increasing the amount of solid catalyst.
	T	31	26	27	16	-	
4a	*S*	-	5	63	8	24	
	T	55	13	13	-	19	
4b	*S*	4	31	36	10	19	The reaction rate (Rxn) would decrease, because the higher the concentration of molecules, the greater the number of collisions in unit time and hence the faster the reaction. As reactants are consumed, their concentrations drop, collisions occur less frequently, and the reaction rate decreases.
	T	57	-	24	-	19	

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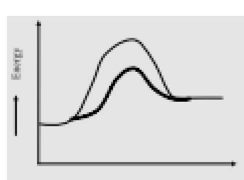
Item No.		SU	PU	PUSAC	SAC	NU	Expected Sound Understanding response (Adapted from Cakmakci (2005)
5a	*S*	10	27	19	5	39	This reaction probably proceeds via formation of J, followed by consumption of J and formation of the final product, Q: X→ J (fast) J→ Q (slow) From this proposed mechanism, the second step, the formation of Q step, is the rate-determining step.
	T	57	-	20	-	23	
5b		16	28	12	12	32	The second step is the slowest, because according to the graph consumption of [X] in unit time and formation of [J] in unit time is faster. J is an intermediate product. The rate of production of J is greater than the rate of its consumption. The slowest reaction determines the reaction rate; in that case the second step is the rate-determining step.
		50	-	20	-	30	
6		16	7	28	12	37	Rates of reactions cannot be compared by using information provided in the probe. In other words, some variables, i.e. activation energy, concentration, rate constant (k) should be given.
		34	-	30	13	23	
7a		1	8	64	10	17	The powdered MgO has a greater surface area. Increasing surface area increases interaction between reactant molecules. Thus, powdered MgO reacts faster with HCl.
		97	-	3	-	-	
7b		77	-	8	7	8	I would tell these students that one of the factors affecting reaction rate is to grind solid substances. Therefore powdered MgO reacts with hydrochloric acid faster.
		100	-	-	-	-	
8a		77	-	5	3	15	Activation energy is the energy barrier that reactant particles must have to overcome for a reaction. Further, the activation energy is the minimum energy amount to form an activated complex in a reaction.
		86	7	-	-	7	
8b		35	10	5	18	32	The first reaction occurs faster than the second reaction does, because the energy barrier for the first one is lower. Therefore, the reaction with the lower activation energy occurs faster.
		86	5	-	-	9	
9a		47	13	7	5	28	1. A catalyst increases the rate of a reaction by providing an alternative path having lower activation energy. A catalyst lowers activation energy of a reaction, as a result the reaction proceeds faster. 2. A catalyst decreases the activation energy of a reaction with an alternative path possessing lower activation energy. A catalyst increases the rate of a reaction by lowering activation energy of the reaction. 3. A catalyst does not affect or does not change the yield of products. The catalyst will not affect the yield, because it is not used up during the reaction. 4. A catalyst changes the mechanisms of a reaction. The catalyst reacts with one or more of the reactants. Thus, the catalysed reaction occurs in more than one step
		66	17	11	-	6	
9b		10	36	31	13	10	
		87	-	-	4	9	
9c		5	28	20	4	43	A catalyst decreases the activation energy of the reaction by providing an alternative path with lower activation energy.
		86	-	-	-	14	

T: Chemistry Teacher, S: Grade 11 Student

Since our main aim was to draw out the chemistry teachers' and the grade 11 students' alternative conceptions of 'rate of reaction', their alternative conceptions and their percentages are displayed in Table 3.

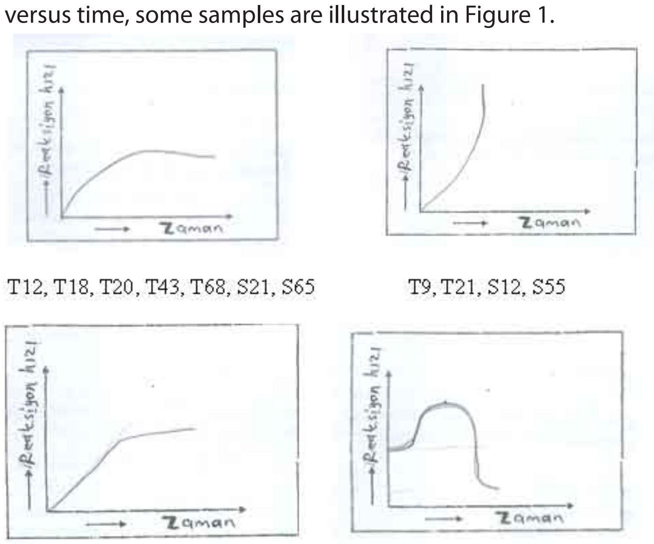
Table 3. Percentages of the chemistry teachers' and the grade 11 students' alternative conceptions of 'Rate of Reaction'.

Categories of alternative conceptions	Response criteria	Chemistry teachers	Grade 11 students
Inability to define the 'rate of reaction'	PUSAC	18	28
	SAC	12	15
Misunderstanding/misapplying of the relationship between temperature and the 'rate of reaction'	PUSAC	10	29
	SAC	11	10
Misunderstanding/misapplying of the relationship between concentration and the 'rate of reaction'	PUSAC	17	33
	SAC	9	6
Lack of understanding of reaction mechanism or which step, if the reaction consists of more than one step, determines the 'rate of reaction'	PUSAC	21	21
	SAC	21	25
Lack of understanding of how enthalpy influences the 'rate of reaction'	PUSAC	30	64
	SAC	13	10
Lack of understanding of the effect of 'surface area' on the 'rate of reaction'	PUSAC	2	7
	SAC	-	5
Misinterpretation of effect of a catalyst on the 'rate of reaction'	PUSAC	11	31
	SAC	-	13

** Since the test included sub-questions, students' alternative conceptions were recalculated and also decimals were rounded.*

As seen in Table 3, percentages of the responses categorized under PUSAC were between 2% and 30% for the chemistry teachers, whilst those for grade 11 students were between 7% and 64%. Likewise, percentages for the responses classified at SAC ranged from zero to 21% whereas those for grade 11 students fell between 5% and 25%.

Since some of the items required the chemistry teachers and grade 11 students to draw graphics of rate of reaction versus time, some samples are illustrated in Figure 1.



T5, T60, S10, S61 T2, T3, T6, T11, T14, T26, S16, S33

Figure 1: Some sample graphics for rate of reaction versus time (T: Chemistry Teacher, S: Grade 11 Student; 'Reaksiyon hızı' means 'Rate of reaction'; 'Zaman' means 'time').

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Some sample diagrams for uncatalysed and catalysed drawn by the sample under investigation are presented in Figure 2.

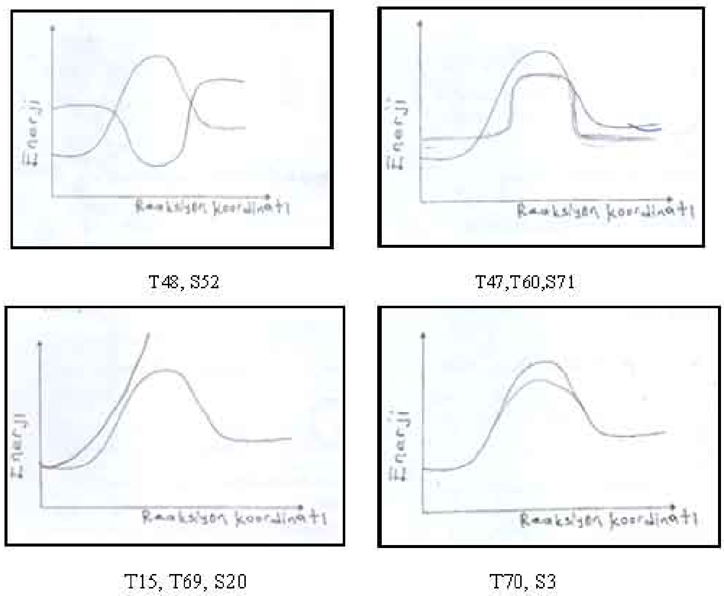

Figure 2: Energy diagram for a reaction in the absence and presence of a catalyst (T: Chemistry Teacher, S: Grade 11 student; 'Enerji' means 'Energy' and 'Reaksiyon koordinatı' means 'Reaction Coordinate').

As seen in Table 4, frequencies of possible sources concerning alternative conceptions varied in regard to given category. However, majority of the interviewees' responses to first question fell into three principal codes, i.e. textbook, teacher and student. Few chemistry teachers and grade 11 students mentioned about several other codes, e.g. topic order in curriculum (T1), peer (S1) and society (T1).

Table 4. Frequencies of the chemistry teachers' and the grade 11 students' views of possible sources concerning relevant alternative conceptions.

Categories of alternative conceptions	Possible sources	Teacher Code	f	Student Code	f
Inability to define the 'rate of reaction'	Textbook	T1, T6, T10, T12	4	S1, S5, S7, S10-S13	7
	Teacher	T2, T6, T10, T11	4	S9	1
	Student	T3-T5, T7, T8	5	S2-S4, S6, S8	5
Misunderstanding/misapplying of the relationship between temperature and the 'rate of reaction'	Textbook	T6, T10	2	S5, S7, S8, S13	4
	Teacher	T1-T3, T9, T10, T11	6	S11-S12	2
	Student	T4, T5, T7, T8, T12	5	S1-S4, S6, S9, S10	7
Misunderstanding/misapplying of the relationship between concentration and the 'rate of reaction'	Textbook	T1, T6, T10-T12	5	S9, S11-S13	4
	Teacher	T2, T3, T5, T6, T10	5	S1, S5, S7, S10	4
	Student	T4, T7-T9	4	S2-S4, S6, S8	5
	Topic order in curriculum	T1	1	--	--

Lack of understanding of reaction mechanism or which step, if the reaction consists of more than one step, determines the 'rate of reaction'	Textbook	T1, T5, T6, T10-T12	6	S8, S10	2
	Teacher	T1-T3, T9, T10	5	S9, S11-13	4
	Student	T4, T7, T8	3	S1-S7	7
Lack of understanding of how enthalpy influences the 'rate of reaction'	Textbook	T6, T10-T12	4	--	--
	Teacher	T2, T3, T6, T10, T11	5	--	--
	Student	T1, T4, T7-T9	5	S1-S13	13
Lack of understanding of the effect of 'surface area' on the 'rate of reaction'	Textbook	T6, T10	2	S4-S7, S9, S10	6
	Teacher	T1-T3, T6, T9, T10-T12	8	S8, S11-S13	4
	Student	T4, T5, T7, T8	4	S1-S3	3
Misinterpretation of effect of a catalyst on the 'rate of reaction'	Textbook	T6, T10-T12	4	S13	1
	Teacher	T2, T6, T9-T11	5	S7, S10	2
	Student	T3-T5, T7, T8	5	S2-S6, S8, S9, S11, S12	9
	Peer	--	--	S1	1
	Society	T1	1	--	--

T: Chemistry Teacher, S: Grade 11 Student

As can be seen in Table 5, nearly half of the chemistry teachers depicted they had encountered with the alternative conceptions during their teaching carriers. Further, they employed several dealing procedure for alternative conceptions, i.e. making the issue concrete and/or linking with daily life (T1, T4, T7-T10), repeating/revising the topic (T3, T5, T9, T11-T12). Only two grade 11 students (S1 and S11) addressed that they had encountered with these alternative conceptions and solved them by help of textbook and teacher. Also, most of the grade 11 students thought they had not encountered with the alternative conceptions while their teachers were teaching 'rate of reaction' topic.

Table 5. Frequencies of the chemistry teachers' and grade 11 students' responses to second interview question.

Categories	Dealing procedure	Teacher/Student Code	f
I have encountered with them	Making the issue concrete and/or linking with daily life	T1, T4, T7-T10	6
	Implementing experiments in laboratory	T1	1
	Consulting to experienced teachers	T2	1
	Repeating/revising the topic	T3, T5, T9, T11-T12	5
	Animation/Simulation	T4	1
	Working out the issues by help of textbook and teacher	S1, S11	2
I have not encountered with them		T6, S2-S10, S12, S13	12

As seen in Table 6, most of the chemistry teachers emphasized various elements of learning environment, i.e. overloaded curriculum (T6), lack of concrete example (T5), inability to use laboratory (T6) while majority of the grade 11 students (S2, S3, S5, S6, S8-S10) stressed teacher's principal role in knowledge construction.

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Table 6. Frequencies of the chemistry teachers' and grade 11 students' responses to third interview question.

Categories	Reasons	Teacher Code	f	Student Code	f
Strongly agree	A lack of concrete example	T5	1	-	-
	Overloaded curriculum	T6	1	-	-
	Inability to use laboratory	T6	1	-	-
	Teacher's principal role in knowledge construction	T10	1	S2, S3, S5, S6, S8-S10	7
Agree	Limited teaching hours per week	T1	1	-	-
	More detailed topics in curriculum	T1, T12	1	-	-
	Conventional teaching methods	T1, T11, T12	1	-	-
	A lack of student pre-existing knowledge	T1, T2, T9	3	-	-
	Concentration problem in teaching / learning chemistry	T3, T7	2	-	-
	A lack of concrete example	T4	1	-	-
	Impact of chemistry teacher on student learning	-	-	S4	1
Disagree	Student's principal role in knowledge construction	-	-	S1, S11-S13	4
	No reason	T8	1	-	-

Discussion

As seen in Tables 2-3, it was drawn out that although the chemistry teachers offered some types of alternative conceptions less frequently than grade 11 students, they retained high levels of alternative conceptions commonly found among the grade 11 students. This is in a harmony with Taber and Tan (2011)'s findings. Especially, alternative conceptions of 'Inability to define the 'rate of reaction' category may result from inability to distinguish the 'rate of reaction' concept from the 'time of reaction' one (e.g. Cakmakci, 2005; Çalik *et al.*, 2010; Nakipoğlu *et al.*, 2002). Further, this may stem from the concept 'rate' at different context. That is, students generally learn the concept 'rate' as a velocity of an object in physics and rate of reaction in chemistry. This means that students may have confused the meanings of the concept 'rate' with each other. The alternative conception 'Misunderstanding/misapplying of the relationship between temperature and the 'rate of reaction' was also very common for both the chemistry teachers and grade 11 students. In this case, the chemistry teachers and the grade 11 students were unable to explain the relationship between temperature and rate of reaction nor to relate them to daily life events. This situation may stem from a lack of grade 11 students' and chemistry teachers' contextual learning. Otherwise they may have stored the concepts in a fragmented structure in their mind (e.g. Çalık & Ayas, 2005; Haidar & Abraham, 1991). In other words, the chemistry teachers and the grade 11 students have difficulties explaining the reasons behind the phenomena even though they know what the chemical phenomena are (e.g. Karslı & Çalik, 2012; Özmen, Demircioğlu & Demircioğlu, 2009; Tezcan & Yılmaz, 2003).

The category 'misunderstanding/misapplying of the relationship between concentration and the 'rate of reaction' may stem from the function of the catalyst. As seen in Table 3, an increase in the amount of the catalyst seems to have confused both the chemistry teachers' and grade 11 students' views. For the category 'Lack of understanding of how enthalpy influences the 'rate of reaction' the chemistry teachers and the grade 11 students generally evaluated how temperature changed the rate of reaction. Such deficiency may stem from inability to comprehend transformation of the reactants into products. That is, the chemistry teachers and the grade 11 students may have disregarded transformation of the reactants into products. Furthermore, they may have confused this item with previous ones. For the category 'Lack of understanding of the effect of 'surface area' on the 'rate of reaction', the majority of the chemistry teachers and grade 11 students grasped this notion scientifically. This may stem from the concept of surface area which is also covered while presenting solubility concept (e.g. Çalık, Ayas & Ebenezer, 2009).

Drawings of the chemistry teachers' and the grade 11 students are very similar to each other in terms of rate of reaction versus time (see Figure 1). This may come from their difficulties with algorithmic, conceptual and graphical understandings (i.e. Coştu, 2010). Similarly, for the category 'Lack of understanding of the reaction mechanism, or which step if the reaction consists of more than one step, determines the 'rate of reaction' a minority of the chemistry teachers and grade 11 students responded sufficiently to this question. This may come from their inability to interpret graphical knowledge (i.e. Coştu, 2010; Çalik *et al.*, 2010). As seen in Figures 1-2, graphs of rate of reaction versus time and energy diagrams seem to pose problems for the grade 11 students and the chemistry teachers. For example, some grade 11 students and chemistry teachers drew that time versus rate of reaction gradually reached at a constant vertical line. They might think that rate of reaction increases on the course of time even if Item 4a depicts that concentration of Chemical A decreases with time. Also, most of the grade 11 students and the chemistry teachers at Figure 1 drew an inverse half-U shaped developmental curve meaning rate of reaction rapidly increases and then slowly increases or decreases. Overall of these issues shows that they may have misinterpreted the given graph. In other words, they have some pitfalls integrating their graph knowledge into conceptual understanding.

For the category 'Misinterpretation of effect of a catalyst on the 'rate of reaction', even though the chemistry teachers and the grade 11 students addressed what the catalyst was through the reaction equation, they showed some deficiencies in discriminating the catalyzed reactions from the uncatalyzed ones (see Figure 2). Further, their alternative conceptions of the effect of the catalyst on the 'rate of reaction' may stem from confusion about the function of the catalyst. That is, both the chemistry teachers and the grade 11 students may have thought that the presence of the catalyst in a reaction may form various products which differ from the uncatalysted. Further, they may have lacked of comprehending the scientific idea "the catalyst does not commence and end any chemical reaction".

The interviewees' responses to the first question (see Table 4) reinforce the idea 'alternative conceptions are outputs of complex learning variables' (e.g. Çalik, Ayas & Coll, 2009; Hand & Treagust, 1991; Nakhleh, 1992). However, the interactive learning environment amongst textbook, teacher and student seems to be principal sources of the alternative conceptions. In other words, such results somewhat support our speculative hypothesis.

The chemistry teachers' responses to the second question (see Table 5), except for animation/simulation, also prove that they have lacked of proper pre-service or in-service education background concerning conceptual change strategies. Phrased differently they have had very limited awareness of conceptual change theories/strategies/models. Moreover, most of the grade 11 students thought they had not encountered with the alternative conceptions while their teachers were teaching 'rate of reaction' topic. Indeed, this reflects cultural norms for young Turkish people. That is, they may have refrained from commenting their teachers' instruction styles.

As seen in Table 6, a significant number of the grade 11 students stressed teacher's principal role in knowledge construction. This means that the grade 11 students viewed the teachers as a principal source of alternative conceptions. Other words, they see the teachers as principal source in knowledge construction. For example, S7 stated what the teachers taught was always accepted as a correct knowledge and trusted the teacher knowledge. Further, this reveals a pitfall of scientific habits of mind (i.e. mistrust of arguments from authority) (e.g. Çalik & Coll, 2012). The grade 11 students' responses highly prove our speculative hypothesis. Furthermore, the chemistry teachers' responses indicate different elements of the learning environment. As a matter of fact, they tended to blame other issues for the the possible sources of alternative conceptions. In fact, each teacher may commonly see himself/herself as a perfect qualified teacher, i.e. subject matter knowledge, pedagogical content knowledge. Such an idea may have led them to answer the questions subjectively. In brief, they may have focused on other deficiencies rather than their roles in knowledge construction.

Since one of the tenets of constructivism is that learning is an interaction between preexisting and new knowledge (e.g. Çalik, Ayas & Coll, 2010; Taylor & Coll, 1997), prior knowledge plays a significant role in further learning (see, e.g. Pines & West 1986). In other words, teacher training programs and teaching experiences for some teachers under investigation have not helped the chemistry teachers overcome their own alternative conceptions. Furthermore, this proves that their alternative conceptions are robust, and highly resistant to change through traditional teaching approaches (e.g. Çalık & Ayas, 2005; Nakhleh, 1992). In fact, even though chemistry educators emphasize contemporary trends in chemistry education in their courses, scientists are generally far away from these notions and commonly use didactic learning in their courses of subject matter knowledge (e.g. Calik, 2011). As a consequence, scientists who have been employed in teacher training programs should be informed about the current trends in chemistry education, so that much more collaborative work between scientists and science educators may emerge. Otherwise, the fact that the grade 11 students and the chemistry teachers have similar alternative conceptions shows that some of the chemistry teachers have been unconscious of the students' difficulties or alternative conceptions (e.g. Kind, 2009). If they had been aware of them, they would have possessed a chance to overcome their own alternative conceptions. On the contrary, if the teachers have similar alternative conceptions as their students, it is likely that they may not take notice of their students' alternative conceptions at all.

Conclusion and Implications for Practice

To sum up, since the chemistry teachers and grade 11 students possessed similar alternative conceptions, it can be deduced that the chemistry teachers seem to have been a principal source for transmitting their certain insidious alternative conceptions to the grade 11 students (e.g. Çalık & Ayas, 2005; Taber & Tan, 2011). The intuitive appeal of certain alternative conceptions offers that the chemistry teachers can readily be reproduced down 'generations' of learners (i.e. Taber & Tan, 2011). But this does not mean that there is only one possible source engendering alternative conceptions because the learning process is very complicated and involved for several other reasons, i.e. teaching method, textbook, procedural learning and so forth (e.g. Çalik *et al.*, 2009; Hand & Treagust, 1991; Nakhleh, 1992). Further, the chemistry teachers' reactions to the alternative conceptions point out an inability to notice conceptual change strategies.

Since *Reconstruction of Faculty of Education* in Turkey, there has been a great effort on getting the student teachers to become aware of the students' alternative conceptions and to practice how to treat them. However, such a result shows that much more are needed to result in better conceptual understanding. Moreover, a common database or website should be created to afford the current chemistry teachers to easily access to improved teaching materials and/or instruments in chemistry education. Such a database or website will give an opportunity for the chemistry teachers to implement these materials and/or instruments in their classes.

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Appendix A. The interview questions for chemistry teachers and grade 11 students

1. Please address what possible sources of the following alternative conceptions are.

Categories of alternative conceptions	Possible sources
Misunderstanding/misapplying of the relationship between concentration and the 'rate of reaction'	
Lack of understanding of reaction mechanism or which step, if the reaction consists of more than one step, determines the 'rate of reaction'	
Lack of understanding of how enthalpy influences the 'rate of reaction'	
Lack of understanding of the effect of 'surface area' on the 'rate of reaction'	
Misinterpretation of effect of a catalyst on the 'rate of reaction'	

2. Have you encountered such alternative conceptions during your teaching carrier (for teachers) or while your chemistry teachers were teaching 'Rate of Reaction' topic (for grade 11 students)? If ok, how did you deal with them?
3. At which level do you agree the idea 'the teachers transmit their alternative conceptions to the students?' Please defend your response.

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