

PRE-SERVICE CHEMISTRY TEACHERS' KNOWLEDGE OF LEARNERS'
ALTERNATIVE CONCEPTIONS AND THEIR WAYS OF DEALING WITH
THEM

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DEALING WITH THEM**

submitted by **ŞERİFE GÜRLER** in partial fulfillment of the requirements for the degree of **Master of Science in Science Education in Mathematics and Science Education, Middle East Technical University** by,

Prof. Dr. Naci Emre Altun
Dean, **Graduate School of Natural and Applied Sciences** _____

Prof. Dr. Mine Işıksal Bostan
Head of the Department, **Mathematics and Science Education** _____

Prof. Dr. Yezdan Boz
Supervisor, **Mathematics and Science Education, METU** _____

Examining Committee Members:

Prof. Dr. Jale Çakıroğlu
Mathematics and Science Education, METU _____

Prof. Dr. Yezdan Boz
Mathematics and Science Education, METU _____

Prof. Dr. Ayla Çetin Dindar
Mathematics and Science Education, Bartın Uni. _____

Date: 29.08.2024



I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name Last name: Şerife Gürler

Signature:

ABSTRACT

PRE-SERVICE CHEMISTRY TEACHERS' KNOWLEDGE OF LEARNERS' ALTERNATIVE CONCEPTIONS AND THEIR WAYS OF DEALING WITH THEM

Gürler, Şerife

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This study aimed to examine pre-service chemistry teachers' conceptions of reaction rate concepts, their knowledge of learners' alternative conceptions and their teaching strategies to handling learners' alternative conceptions in the rate of reaction topic. Moreover, the change in pre-service chemistry teachers' knowledge of learners' alternative conceptions and how they deal with learners' alternative conceptions as they take pedagogical content knowledge courses in teacher education programs was explored. Twenty pre-service chemistry teachers at a university in Ankara were involved in this research. Group 1 was composed of seven pre-service teachers who did not take any pedagogical content knowledge courses. Group 2 involved six pre-service teachers who completed most of the pedagogical content knowledge courses. Group 3 included seven pre-service teachers who completed all pedagogical content knowledge courses. A questionnaire, involving five scenario-based questions and semi-structured interviews were used to assess pre-service chemistry teachers' conceptions, knowledge of learners' alternative conceptions and methods used to eliminate these alternative conceptions in the reaction rate topic. Analysis of data

showed that Group 3 students had the least alternative conceptions of most of the reaction rate concepts. However, they still had alternative conceptions about interpreting reaction rate-time graph. Moreover, taking pedagogical content knowledge courses enhanced pre-service teachers' ability to identify students' alternative conceptions and their selection of various teaching strategies. However, identification of students' alternative conceptions by pre-service chemistry teachers does not guarantee the use of suitable method to eliminate these alternative conceptions. This study has some implications for teacher education programs.

Keywords: Pre-service Chemistry Teachers, Alternative Conceptions, Reaction Rate, Knowledge of Learners, Knowledge of Instructional Strategy

ÖZ

KİMYA ÖĞRETMENİ ADAYLARININ ÖĞRENCİLERİN ALTERNATİF KAVRAMLARI HAKKINDAKİ BİLGİLERİ VE BUNLARLA BAŞA ÇIKMA YÖNTEMLERİ

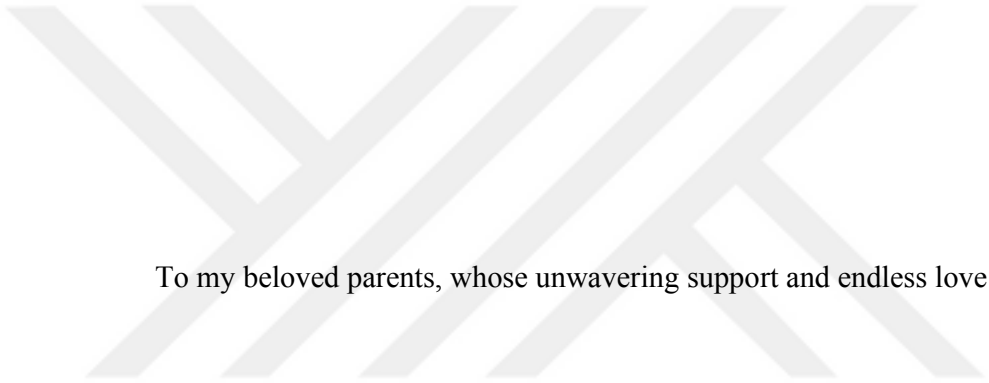
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Bu çalışma, kimya öğretmeni adaylarının reaksiyon hızı kavramlarıyla ilgili anlayışlarını, öğrencilerin alternatif kavramları hakkındaki bilgilerini ve reaksiyon hızı konusundaki öğrencilerin alternatif kavramlarıyla başa çıkma stratejilerini incelemeyi amaçlamaktadır. Ayrıca, öğretmen eğitimi programlarında pedagojik alan bilgisi dersleri aldıkça kimya öğretmeni adaylarının öğrencilerin alternatif kavramları konusundaki bilgilerindeki değişim ve bu alternatif kavramlarla nasıl başa çıktıkları araştırılmıştır. Bu araştırmaya Ankara'da bir üniversitede okuyan yirmi kimya öğretmeni adayı katılmıştır. Grup 1, herhangi bir pedagojik alan bilgisi dersi almamış yedi öğretmen adayından oluşmaktadır. Grup 2, pedagojik alan bilgisi derslerinin çoğunu tamamlamış altı öğretmen adayını içermektedir. Grup 3, tüm pedagojik alan bilgisi derslerini tamamlamış yedi öğretmen adayından oluşmaktadır. Öğretmen adaylarının reaksiyon hızı konusundaki anlamalarını, öğrencilerin bu konuda alternatif kavramları hakkındaki bilgilerini ve bu alternatif kavramları ortadan kaldırmak için kullandıkları yöntemleri değerlendirmek için beş senaryo

tabanlı soruyu içeren bir anket ve yarı yapılandırılmış görüşmeler kullanılmıştır. Verilerin analizi, grup 3'teki öğrencilerin çoğunun reaksiyon hızı kavramında en az alternatif kavrama sahip olduğunu göstermiştir. Ancak, hala reaksiyon hızı-zaman grafiğini yorumlama konusunda alternatif kavramlara sahip oldukları belirlenmiştir. Ayrıca, pedagojik alan bilgisi dersleri almak, öğretmen adaylarının öğrencilerin alternatif kavramlarını belirleme yeteneklerini ve çeşitli öğretim stratejileri seçme becerilerini geliştirmiştir. Ancak, kimya öğretmen adaylarının öğrencilerin alternatif kavramlarını belirlemesi, bu alternatif kavramları ortadan kaldırmak için uygun yöntemi kullanacaklarını garanti etmez. Bu çalışmanın öğretmen eğitimi programları için bazı önerileri bulunmaktadır.

Anahtar Kelimeler: Kimya Öğretmeni Adayları, Alternatif Kavramlar, Reaksiyon Hızı, Öğrenci Bilgisi, Öğretim Stratejisi Bilgisi



To my beloved parents, whose unwavering support and endless love

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LIST OF ABBREVIATIONS

ABBREVIATIONS

AC : Alternative Conception

P : Participant

PCK : Pedagogical Content Knowledge





CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Learners already have their integrated ideas before coming to a scientific setting. In some cases, these ideas are different from scientifically correct views. These are called alternative conceptions (AC) (also known as naive beliefs and misconceptions) (Snir et al., 2003), and these alternative conceptions contradict the actual scientific phenomena. Many researchers argue that these are rigid and arduous to destroy through teachers' instruction (Driver & Easley, 1978; Viennot, 1979) since they satisfy learners' minds and do not leave them in the lurch. Additionally, they seem crucial in science learning due to impacting learning processes, even prohibiting them. Chen et al. (2020) recommended that forgetting them before getting an actual and meaningful explanation, as a result, requires particular interest. Like other chemistry topics, students and (pre-service) teachers had several alternative conceptions about reaction rate topics (BouJaoude, 1991; Cakmakci, Donnelly & Leach, 2005; Cakmakci, 2010; Fahmi & Irhasyuarna., 2017; Garnett, Garnett & Hackling et, 1995; Tastan Kırık, Yalcinkaya & Boz, 2010; Turányi & Tóth, 2013; Voska & Heikkinen, 2000).

Without external urge, learners do not realize their understanding that they are in disequilibrium with scientific knowledge. In this process, teachers' efforts gain importance in their instructions since they are considered influential in learners' development, especially in 21st-century skills. Considering the importance of teachers in their students' learning process, studies concerning teachers' knowledge have been conducted since the 1960s. Firstly, teachers' subject matter knowledge was studied. However, Shulman (1987) stated another teacher's knowledge, which was pedagogical content knowledge (PCK). It was different from subject matter knowledge and

pedagogical knowledge, rather PCK was the amalgamation of subject matter and pedagogical knowledge necessary to teach specific topics to students (Shulman, 1987). Different PCK models took part in the related literature. One of the widely used PCK models is the Magnusson et al.'s (1999) model. It consists of five components, which are science teaching orientation, knowledge of curriculum, knowledge of learner, knowledge of assessment and knowledge of instructional strategy. Knowledge of learner refers to teachers' knowledge of students' prerequisite knowledge and their alternative conceptions as well as difficulties. On the other hand, knowledge of instructional strategy involves subject-specific and topic-specific strategies that include representations such as illustrations, models, analogies, and activities such as simulation, experiment, and investigations. Studies investigating specifically the teachers' knowledge of learners' AC are not as many as studies investigating ACs only in the literature. Additionally, findings of research studies in this focus are dispersed in the literature, again showing the need for investigation. For example, while Kokkotas, Vlachos, and Koulaidis (1998) found that pre-service teachers' knowledge of learners' AC is insufficient in chemistry subjects, Pine, Messer, and John (2001) revealed the opposite, finding that teachers in elementary school had a great job of identifying possible misconceptions. Therefore, this research aims to explore pre-service chemistry teachers' conceptions and their knowledge of learners' possible ACs in the context of the reaction rate topic.

After identifying the learners' conceptions, teachers must eliminate alternative ones, as expected. Historically, many ways have been developed for these purposes, including conceptual change model, inquiry, and cooperative learning. Subsequently, literature also supports the effectiveness of these methods in many studies (Dega, Kriek & Mogese, 2013; Peterson, Carpenter & Fennema, 1989; Sinatra, Brem & Evans, 2008; Tao & Gunstone, 1999; Tastan & Boz, 2012; Vosniadou, 2013). Despite this, studies do not emphasize teachers' approach to using one of these methods to handle learners' AC. It is worth investigating since seeing the effort of teachers to handle situations does not mean anything in practice. In other words, if teachers do not appreciate or understand how to handle AC properly, no matter what the literature says, they do not care about eliminating ACs. Therefore, the present study also aims

to understand how pre-service teachers can deal with learners' ACs. It is intended to contribute to future research and teachers' practical knowledge.

Additionally, it is essential to state that research studies that investigate both (pre-service) teachers' knowledge of AC and their approach to dealing with them are lacking in literature. However, considering these together is crucial due to the relatedness of each other. That is why the present study aims to investigate pre-service teachers' knowledge of students of AC and their ways of handling them together. Moreover, the present study aims to investigate the change in pre-service teachers' knowledge of learners' AC and their ways of coping with ACs with respect to pedagogical content knowledge courses.

In this study, the chemical reaction rate topic is chosen since it is a fundamental topic in understanding the formation of chemical reactions. Reaction rates demonstrate the velocity at which chemical transformations happen. It is important to understand the rate of chemical reaction concepts due to the importance of adjustment in reaction rate in various industrial processes, medical and environmental areas (Justi, 2002). Moreover, it is a prerequisite topic for many topics such as chemical equilibrium and thermodynamics.

Moreover, the reaction rate topic is difficult for students to comprehend since it involves abstract concepts such as collision theory, activation energy, etc. Several research studies indicated many alternative conceptions (BouJaoude, 1993; Cakmakci, 2010; Cakmakci et al., 2006; Garnett et al., 1995; Justi, 2002; Kousathana & Tsaparlis, 2002). Therefore, it is vital to reveal pre-service chemistry teachers' conceptions and their knowledge of students' alternative conceptions and instructional strategies to deal with students' alternative conceptions concerning reaction rate concepts since students' scientific understanding of this topic is crucial since reaction rate topic is a fundamental topic for comprehension of reaction processes.

1.2 Significance of the Study

This study investigates pre-service chemistry teachers' conceptions of reaction rate concepts, their knowledge of learners' AC, and their ways of dealing with them, specifically in reaction rate concepts. Literature consists of much research that investigates the alternative conceptions of reaction rate since it is considered a tricky topic (BouJaoude, 1993; Cakmakci, 2010; Cakmakci et al., 2006; Garnett et al., 1995; Kousathana & Tsaparlis, 2002). Moreover, the influence of methods to deal with this AC also occurs much in the studies which show the effectiveness of conceptual change models (Dega et al., 2013; Sinatra et al., 2008; Tao & Gunstone, 1999; Vosniadou, 2013), cooperative learning (Tastan Kırık & Boz, 2012). However, the literature does not show the same value for finding the (pre-service) teachers' knowledge of their learners' possible AC in this concept. Yet, it is crucial to research teachers' knowledge of their learners' AC. Also, many teachers are unaware of learners' alternative conceptions due to a lack of interest, especially for pre-service chemistry teachers.

In addition to evaluating teachers' knowledge of learners' AC, the present study examines how teachers deal with learners' AC in reaction rates. Literature suffers from this evaluation of knowledge since teachers generally do not prefer to handle this AC by indicating a lack of time and difficulty eliciting them (Cox, Steegen & Cock, 2016). They do not even try to diagnose AC. On the other hand, this study is significant because it examines pre-service teachers' knowledge of their learners' AC and ways to replace them by providing scenario-like questions. In this way, it is assumed to result in a good fund for future research and provide teachers with a way to cope with new methods, which the literature lacks.

Moreover, the change in pre-service chemistry teachers' knowledge of learners' AC in reaction rate and their ways of dealing with learners' AC with respect to PCK courses taken in teacher education programs are examined in the present study, which the literature lacks. It is significant because research tries to improve chemistry teachers' effectiveness by improving teacher education programs that better prepare future teachers to address students' alternative conceptions, thereby enhancing student learning.

In addition to theoretical significance, this study has practical significance as well. It shapes the design of courses and curriculum in teacher education programs and enhances the effectiveness of teacher education programs. Firstly, eliciting pre-service chemistry teachers' conceptions of reaction rate topic will provide awareness for teacher educators so that alternative conceptions can be addressed in teacher education programs. This helps the preparation of pre-service chemistry teachers with robust subject matter knowledge as future teachers, which would be effective in improving their students' learning outcomes. Secondly, understanding pre-service teachers' knowledge of learners' alternative conceptions and instructional strategies to remedy them would be helpful to reveal gaps in their knowledge about students' possible alternative conceptions and methods to eliminate. This would give information about the nature of targeted and effective training in teacher education programs that enhance pre-service teachers' ability to diagnose students' alternative conceptions as well as eliminate them.

1.3 The Purpose of the Study

The purposes of the present study are to examine pre-service chemistry teachers' conceptions of reaction rate concepts, their knowledge of learners' AC in the rate of reaction topic, and their approaches to handling learners' AC. Another purpose is to examine the change in pre-service chemistry teachers' knowledge of learners' AC in reaction rate and how they deal with learners' AC concerning PCK courses taken in teacher education programs. The following research questions guided the present study.

1.4 Research Questions

1. What are pre-service chemistry teachers' conceptions about reaction rate concepts?
2. What is pre-service chemistry teachers' knowledge about the learners' AC in reaction rate?

3. How do pre-service chemistry teachers deal with learners' AC in reaction rate?
4. How does pre-service chemistry teachers' knowledge about learners' AC change concerning PCK courses taken in teacher education programs?
5. How does pre-service chemistry teachers' ways of dealing with learners' AC changes concerning PCK courses taken in teacher education programs?

1.5 Definitions of Terms

1.5.1 Alternative Conceptions (ACs):

Alternative conceptions are conceptions that learners transport to the learning process that is seen as powerful and tough to change through instruction (Driver & Easley, 1978; Viennot, 1979). They are also called misconceptions that differ from preconceptions (Vosniadou, 2011).

1.5.2 Reaction Rate:

The reaction rate is the concept learners encounter in 11th-grade chemistry courses in Türkiye. Although there are many subsections for this topic, the curriculum in Türkiye is limited to the followings:

- collision theory,
- rate of reaction,
- reaction mechanisms,
- reaction rate formula,
- factors affecting reaction rate, including type of matter, concentration, temperature, catalyst, and surface area (Turkish Ministry of National Education, 2018).

The present study aims to investigate pre-service teachers' knowledge of AC for these sub-concepts, except the reaction mechanism.

1.5.3 Pedagogical Content Knowledge:

PCK refers to “amalgamation of content and pedagogy that is uniquely the province of teachers” (Shulman, 1987, p. 8).

1.5.4 PCK Course:

In the instruction in the course deals with at least one component of PCK according to Magnusson et al's (1999) model.





CHAPTER 2

LITERATURE REVIEW

Alternative conceptions (AC), also called misconceptions, naïve conceptions significantly impact learners' understanding of science. Despite their importance in literature, teachers' knowledge of AC and their ways of handling them is not appreciated as well. Therefore, the present study aims to investigate this knowledge in reaction rate concept. In light of these, alternative conceptions, alternative conceptions with respect to reaction rate concepts, diagnosis of ACs, teachers' knowledge and models, teachers' knowledge in studies, approaches to dealing with AC and development of pre-service teachers' pedagogical content knowledge are reviewed in the literature.

2.1 Alternative Conceptions (ACs)

Constructivism is a learning theory where learners build their own meaningful understanding and knowledge through experiencing things and revealing those experiences. As a result, they have an active role in their learning.

According to John Locke (1689), humans are born with a blank mind, *tabula rasa* (a blank slate) filled by the senses as experiences occur (as cited in Maden, 2021). However, this view is reasonably rejected today with the theory of Piaget called constructivism. To him, filling the mind is an adaptive process, so rather than taking information from outside, one should find the knowledge successful and purposeful in practice (Glaserfeld, 1995). Subsequently, learners come to class with ideas already adopted from their lives, which may not be scientifically accurate (Barnett & Morran, 2002; Pine and Masser, 2000). In other words, if knowledge or concepts are felt

successful and valuable for learners, they do not have to be reflected by scientific reality.

According to Pringle (2006), while some concepts indicate validity, most preconceptions of learners are alternative to scientific conceptions. What these AC refer to in literature is also called misconceptions and naïve conceptions. Teachers often confuse AC with lack of knowledge when learners cannot explain the facts correctly. However, lack of knowledge is different, where learners have neither scientific phenomena nor AC since they never experienced or thought about them. While they can be eliminated just by experiencing through instructions, for alternative ones to be eliminated, learners often need to forget their existing conceptions (Chen et al., 2020). That is why ACs are resistant to change (Lelliott & Rollnick, 2010; Miller & Brewer, 2009; Nazé & Fontaine, 2014; Starakis & Halkia, 2013) and hard to cope with for learners. Their existing ideas come to them already useful and purposeful; therefore, teachers first need to deal with the existing ones without thinking of the absence of preconceptions. Despite the long time spent on instructions, some ACs may stay without replacing with correct ones, which again shows their strength (Cox, Steegen & Cock, 2016).

Although the reason for the lack of knowledge is logically apparent, sources of alternative concepts are many. Learners might have alternative conceptions due to *“personal experiences including direct observation and perception, peer culture, and language, as well as in teachers’ explanations and instructional materials,”* (Wandersee et al., 1994, pp. 188), resulting in AC. The clearest example that might be shown here is that although learners are found in the same place, listen to the same teacher, monitor the same procedure, and experience the same facts, they make different deductions due to carelessness in observation and critical thinking. Therefore, they gain AC. Moreover, it is not surprising that learners' conceptions are affected by the environment since they live in a socially constructed environment that includes parents, peers, and people communicating with them. Communication is essential here since the language, whether spoken or not, may result in AC, too. For instance, the melting of sugar does not pose a problem in daily life; however, in a chemistry course,

this usage causes learners to explain solubility concepts in the wrong way. Besides communication in instruction, even teachers' inappropriate statements may bring AC into learners' minds. For example, when teachers simplify or misinterpret scientific ideas during explanations, students may form alternative understandings that seem logical based on the information given but are not scientifically valid. Additionally, analogies and metaphors, while helpful for illustrating complex concepts, can lead to misunderstandings if students extend them beyond their intended meaning. Consistent use of language and terminology by teachers is essential to avoid confusion and ensure students interpret scientific concepts correctly.

Additionally, the design of instructional materials plays a significant role. If materials emphasize memorization over understanding, students may learn superficially and develop misconceptions. Effective communication also involves actively addressing and correcting student ACs, creating a supportive learning environment where students feel encouraged to understand concepts accurately.

In summary, it is significant to state that teachers have to not only deal with the learners' already formed conceptions before instruction but also, they should form clear and precise communication, use analogies carefully, utilize consistent language and terminology, think instructional material design appropriate, and engage with student ideas proactively.

Moreover, according to Blömeke et al., (2015) ACs are domain and topic-specific, so they can change according to situations that learners are found and taught. For example, in chemistry, it is taught that during reactions, mass is conserved; however, in physics class, mass is a type of energy, so after the reaction, it should decrease. While this decrease is negligible in chemistry courses, physics teachers must explicitly explain the situation. Therefore, at this point, all science teachers should pay attention to their instructions and need to show an effort to be interdisciplinary to get rid of any possible AC. Accordingly, it is essential to investigate AC as domain and topic-specific during the research process because of their context dependency.

2.2 Alternative Conceptions with Respect to Reaction Rate Concepts

Literature is abounded with the research of many ACs that learners hold (Barnett & Morran, 2002; Henriques, 2002; Tao & Gunstone, 1999), and specific to chemistry, lots of ACs are found, too (Barke et al., 2009; Horton, 2007; Tastan Kırık & Boz, 2012). Hence, in this study, chemical reaction rate is chosen as a topic since it is a complex concept for learners and teachers to grasp (BouJaoude, 1993; Cakmakci, 2010; Cakmakci et al., 2006; Garnett, et al., 1995; Kousathana & Tsapalis, 2002). The literature states many ACs in this concept (BouJaoude, 1991; Cakmakci, Donnelly & Leach, 2005; Cakmakci, 2010; Fahmi & Irhasyuarna., 2017; Garnett, Garnett & Hackling et, 1995; Tastan Kırık, Yalcinkaya & Boz, 2010; Turányi & Tóth, 2013; Voska & Heikkinen, 2000; Nakiboğlu, Benlikaya & Karakoç, 2001; Habiddin & Page, 2022; Kolomuç & Tekin, 2011; Jusniar, Effendy & Sutrisno, 2020; Rahayu, Wiji, Widhiyanti & Mulyani, 2024; Bain & Towns, 2016).

For example, Nakiboğlu et al., (2001) studied with 61 undergraduate students to collect their misconceptions on four specific headings; reaction rate, relation of reaction rate and temperature, relation of reaction rate and concentration and factors that affect reaction rate. For this they used V-diagrams and found different misconceptions which were:

- The speed of chemical reactions is equal to the product of the concentrations of the reactants.
- Reaction rate is the time it takes for reactants to turn into products.
- The reaction rate is the amount of substance turning into products per unit time at a constant temperature and concentration.
- In a chemical reaction, the process of reactants forming products is called reaction rate.
- The effect of temperature on reaction rate is increasing if the reaction is endothermic and decreasing if it is exothermic.
- A catalyst affects the reaction rate. This is because more molecules will surpass the activation energy barrier.

Additionally, Cakmakcı et al., (2005) studied with both secondary school and undergraduate students. There were 191 samples to identify misconceptions on chemical kinetics. According to the results, the researcher categorized misconceptions into five categories. These were rate with concentration or pressure; effect of temperature on rate; surface area effect; activation energy and catalysis effect; rate equations and reaction mechanisms. In these categories many misconceptions were situated.

- “Reaction rate is the time required for a reaction to be completed” (p.93).
- “Exothermic reactions have a lower activation energy” (p.181).
- “Exothermic reactions occur faster, because they do not need energy to proceed/occur” (p.181).
- “A catalyst gives energy to a reaction, therefore it increases activation energy” (p.186).
- “A catalyst reduces the activation energy. As a result, more particles will have energy greater than the activation energy. That leads to a higher percentage of products” (p.187).
- “The reaction rate is zero at the beginning. During time, the interaction of molecules increases, and as a result, the reaction rate increases” (p. 103).
- “As long as certain factors (e.g. temperature, concentration or catalysts) were not altered, the reaction rate would remain constant or remain the same during a reaction” (p.102).
- “Molecules are more strongly bonded and are closer to in granulated MgO than those of granulated ones” (p. 163).

Moreover, Mutlu and Şeşen (2016), researched with 151 pre-service science teachers to find out their alternative conceptions in general chemistry concepts. For this, they applied for a two-tier diagnostic test. Some of alternative conceptions that they found for the chemical kinetics were:

- “The reaction rate indicates how much time a reaction takes to complete” (p.84).
- “Reaction rate is a process of conversion from reactants to products” (p.84).

- “As reactants concentration increases, the reaction duration increases” (p.84).
- “As concentration increases, the number of particles per unit volume also increases; as a result, particles’ motion area decreases, and their collision becomes difficult” (p.84).
- “Powder of a substance and equal amount of the same substance in crystals complete reaction at the same time because they engage in the same reaction” (p.84).

Similarly, Habiddin and Page (2022) conducted a research study with 335 university students. In this research, they used a four-tier instrument to find out students' misconceptions in the chemical kinetics subject. According to results, some students had below misconceptions:

- “The rate of a reaction can only be expressed in terms of concentrations of reactants” (p.188).
- “An exothermic reaction is the slowest reaction” (p.191).

Different from the previous studies, Kolomuç and Tekin (2011), conducted a study with 70 chemistry teachers. The test that they applied consisted of five open-ended questions. Moreover, identified misconceptions emphasized definition of reaction rate, change in rate during the reaction, and mechanism rather than factors more. Some of misconceptions were listed below:

- “In single-step reactions, the rate of reaction is equal to the multiplication of the reactants that take part in the chemical reaction (p.92).”
- “The rate of reaction remains stable from start to finish” (p.92)
- “The rate of reaction is the transformation of mass in a given time (p.92).”
- “The rate of reaction didn’t remain stable because there were no substances affecting the reaction (p.92).”
- “The reaction is realized, and the rate of reaction gets faster and faster (p.92).”
- “Exothermic reactions are faster because there is a need for heat so that reactions can take place (p.92).”

- “In reactions with high activation energies, the probability that molecules may collide gets less (p.92).”

In addition, there were some studies that used misconceptions in the literature to find out the effect of different methods. For example, Kırık and Boz (2012) studied the effectiveness of cooperative learning environments in chemical kinetics. While doing that, they gathered data from 110 eleventh grade students. They developed a test based on students' misconceptions in the literature. After the application of the test, they found out different alternative conceptions. Some of them were listed as:

- “The reaction rate is the amount of a substance turning into products per unit time at a constant temperature and concentration (p. 232)”.
- “Students over-generalized, suggesting that the rate of reactions always decreases as the reaction proceeds without considering the order of the reaction (p. 232)”.
- “The kinetic energy of molecules increases by decreasing the volume of the vessel (The students had difficulty understanding the effect of volume on reaction rate)” (p. 232).
- “Since the molecules of granulated MgO(s) are more strongly bonded than those of powdered MgO(s) , they hardly react compared to the powdered ones (p. 232)”.
- “The activation energy of exothermic reactions is lower than that of endothermic reactions (p. 232)”.
- “A catalyst increases reaction rate without changing the mechanism” (p. 232).

Similarly, a study conducted by Jusniar, Effendy and Sutrisno (2020) used misconceptions from the literature to see their impact on chemical equilibrium concept. For this they researched 245 eleventh graders. Some mentioned misconceptions were displayed below:

- The rate of reaction is the rate of increase in the number of reactants and the rate of decrease in the number of products with time” (p.1408).
- The rate of irreversible reaction is higher with time” (p.1408).

- Catalysts accelerate the rate of reaction and increase the activation energy” (p.1409)”
- Increasing temperature will increase activation energy (p.1409)”

Likewise, Rahayu, Wiji, Widhiyanti and Mulyani (2024) examined the related literature about students’ misconceptions regarding the factors affecting reaction rate. After the review of literature, they found out 30 misconceptions. Some of them were listed below:

- “The concentration of reactants increases, the rate of reaction will increase because the surface area of reactants increases” (Siswaningsih et al, 2024).
- “Catalyst would increase the yield of the products” (Yalcinkaya et al., 2012; Turányi & Tóth, 2013; Cakmakci, 2010).
- “Exothermic reactions are faster than endothermic reactions” (Yalcinkaya et al., 2012; Kolomuç, 2012; Sözbilir, 2010; Kelly & Akaygun, 2016).
- “Catalyst increases reaction rate by decreasing the kinetic energy of the molecules” (Yalçinkaya et al., 2012).

(Rahayu, Wiji, Widhiyanti & Mulyani, 2024, p.144)

Based on these misconceptions, Rahayu et al. (2024) developed a test. Afterwards, they applied for this test to 21 students. It was found that nearly all students had the following misconceptions:

- “The concentration of reactants increases and reactions will take longer because there will be many more particles to collide” (p.143).
- “If the rate of the same reactions is compared at different temperatures, then the reaction with the highest temperature is defined as the rate of reaction” (p.143).
- “The temperature increase in an exothermic reaction can increase the forward rate and decrease the reverse rate because the equilibrium shifts to the right” (p.143).

Moreover, Bain and Towns (2016) conducted a systematic review study to reveal students' understanding on chemical kinetics. They investigated 34 different studies from the journals and publications. They concluded many alternative conceptions mentioned below. For example:

- “Increasing the concentration of reactants increases the reaction time (Kurt and Ayas, 2012)”.
- “Exothermic reactions occur faster than endothermic reactions (Çakmakci, 2010; Sözbilir et al., 2010; Çakmakci and Aydogdu, 2011; Kolomuç and Tekin, 2011; Taştan-Kırık and Boz, 2012; and Yalçinkaya et al., 2012)”.
- “Increasing the temperature increases the activation energy” (Yalçinkaya et al., 2012).
- “A catalyst increases activation energy of the reaction. (Taştan-Kırık & Boz, 2010, and Kaya & Geban, 2012)” (p.247-248).

2.3 Diagnosing Alternative Conceptions

Many research studies indicate that learners' prior knowledge and AC are crucial to science education (Sinatra et al., 2008; Taber, 2017; Sadler et al., 2013; Hartelt et al., 2022; Chen et al., 2019) since they can inhibit meaningful learning and change the time to acquire knowledge. Unfortunately, learners themselves cannot notice that they hold misunderstandings without environmental urges since possessed conceptions seem reasonable and satisfy their minds. As a result, weighing any conceptions of learners and correspondingly shaping their instructions falls upon teachers as always (Hartelt et al., 2022; Mintzes et al., 1997; Sadler et al., 2013; Juhaevah et al., 2020; Qian et al., 2019). Although teachers generally hold the constructivist belief (Aldrich & Thomas, 2005) and are conscious of the importance of AC, they refuse to care for them by indicating many excuses such as lack of time and strain of eliciting conceptions (Cox, Steegen & Cock, 2016). Therefore, teachers do not endeavor to examine AC or do not let learners replace conceptions. Furthermore, teachers refuse

to search for possible ACs that learners might have from literature, which is not challenging. Additionally, they can observe their learners and exchange inferences from these observations with their colleagues, but they are far from researching ACs.

As mentioned above, ACs may occur before the instruction is mentioned. However, they may also arise spontaneously during learning due to class discussions, group work, and teachers' explanations. For this reason, teachers must be ready to identify and cope with them as soon as possible (Hoppe et al., 2020; Shavelson et al., 2008). At this juncture, they first need to pay attention and follow learners' feedback, whether verbal or not, and then interpret them (Hoppe et al., 2020) if they are getting AC. If so, they should diagnose it as soon as possible since it is the primary condition for replacing AC (Fischer et al., 2021; Larkin, 2012; Nussbaum, 1981). Consequently, all these requirements narrate the importance of teachers' knowledge and skills for AC and pedagogic actions.

2.4 Teacher Knowledge and Models

No one can deny that teachers as guides in science education have one of the most influential powers on learners' understandings (Committee on Science and Mathematics Teacher Preparation, 2001), so that it is not surprising for society to expect from teachers to be knowledgeable as much as possible (Sadler et al., 2013). On account of this, education researchers concentrated on teachers' knowledge since the 1960s. It is examined only for their formal knowledge, which accounts for subject matter knowledge. Along with the 80s, besides their formal knowledge, their practical knowledge started to be examined, too (Abell, 2014). Specifically, in 1987, Shulman and his colleagues revealed one of the most impressive studies on teachers' knowledge (Shulman, 1987; Wilson, Shulman, & Richert, 1987, cited in Chen et al., 2020). It is very influential due to being the first model that differentiates teachers' knowledge for teaching from the subject matter knowledge (Chen et al., 2020). Subsequently, in this model, pedagogical content knowledge (PCK) is defined as an "amalgamation of content and pedagogy that is uniquely the province of teachers" (Shulman, 1987, p. 8). After Shulman's model, Grossman (1990) stated that PCK was influenced by subject

matter knowledge (SMK), pedagogical knowledge (PK), and knowledge of the context (KofC) (Grossman 1900 2014). Afterwards, other researchers proposed different models (Cochran et al, 1993; Veal & MaKinster, 1999; Magnusson et al, 1999; Park & Oliver, 2007; Gess-Newsome, 2015; Carlson & Daehler, 2019). Although many researchers elaborate, extend, and indicate different relations for the content of teachers' knowledge, the core stays constant (Chen et al., 2020; Sadler et al., 2013). Even today, models for teachers' knowledge are tried to be improved for the better implication of research purposes (Carlson et al., 2019).

For this study, the investigated PCK depends on the model of Magnusson, Krajcik, and Borko (1999). Magnusson et al. (1999) explained PCK as “the transformation of several types of knowledge for teaching (including subject matter knowledge), and that as such it represents a unique domain of teacher knowledge” (p. 95). As seen from Figure 1, they revealed five components for teachers' PCK, which were orientations to teaching science: knowledge of science curricula, knowledge of assessment, knowledge of instructional strategies and knowledge of learners (Magnusson et al, 1999).

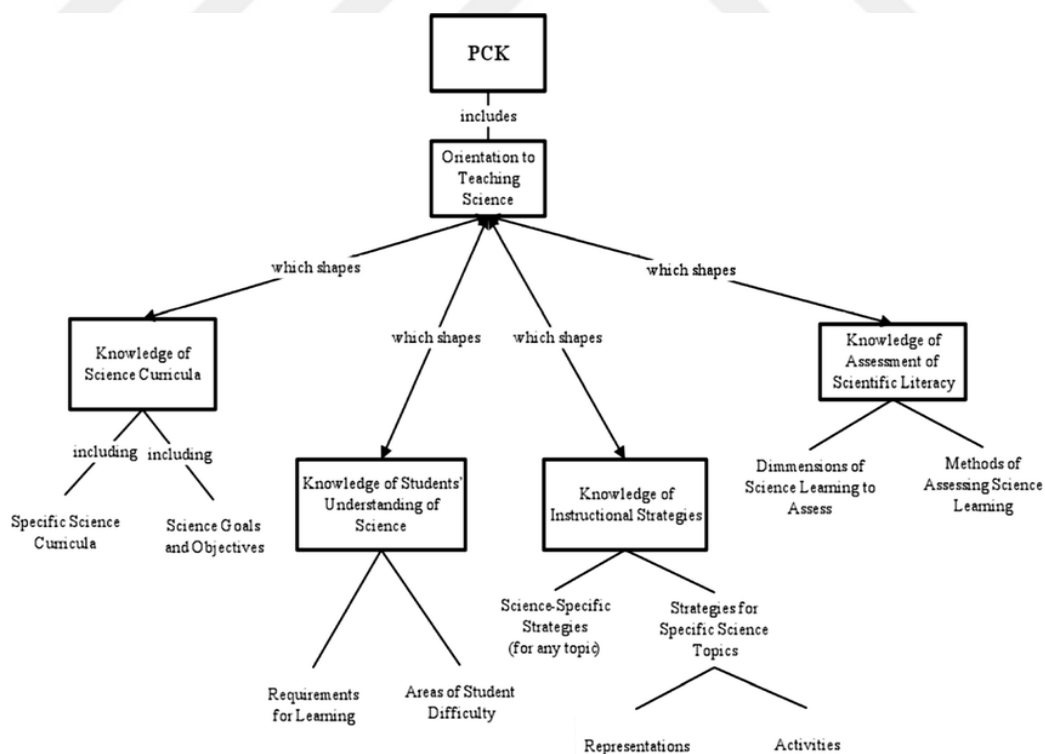


Figure 2.1. Components of PCK for Science Teaching (Magnusson et al., 1999, p. 99)

Orientation to teaching science involves “teachers’ knowledge and beliefs about the purposes and goals for teaching science at a particular grade level” (Magnusson et al, 1999, p. 97). Teachers’ teaching orientation may shape and influence other PCK components. To clarify, teachers’ beliefs about the purpose of science teaching may influence their choice of instructional strategies, assessment techniques, etc. For example, teachers with didactic orientation may prefer teacher-centered instruction and choose their instructional strategies accordingly. Knowledge of curriculum refers to teachers’ knowledge of objectives necessary to teach a specific topic. Moreover, “knowledge of the programs and materials that are relevant to teaching a particular domain of science and specific topics within that domain” is also included in the knowledge of curriculum component (Magnusson et al, 1999, p.103). Knowledge of assessment includes teachers’ knowledge about methods of assessment (how to assess) such as quiz, portfolio, laboratory reports etc. and dimensions of science learning to be assessed (what to assess) such as content understanding, science process skills, nature of science etc. Knowledge of learner involves teachers’ knowledge about prerequisite knowledge required to understand the topic and students’ difficulties experienced in that particular topic. Magnusson et al (1999) stated that one of the students’ difficulties in learning science arises from the influence of students’ misconceptions on the learning process. Therefore, students’ misconceptions are some of the knowledge that teachers should have. Knowledge of the learner component involves teachers’ knowledge of students’ prerequisite knowledge and students’ difficulties and misconceptions with respect to the specific topic. Knowledge of instructional strategy components includes teachers’ knowledge of subject-specific strategies and topic-specific strategies necessary to teach a particular topic. Subject-specific strategies involve general approaches used for the implementation of science instruction. The 5E learning cycle model can be one of the examples for subject-specific strategy. On the other hand, topic-specific strategies include both topic-specific representations such as illustrations, models, analogies etc. used to teach the

topic and topic-specific activities such as experiments, simulations, investigations, problems used in the implementation of the topic. It is possible to associate all components with each other; however, this research explicitly emphasizes pre-service teachers' knowledge of students' alternative conceptions, a sub-component of knowledge of learner component, and knowledge of instructional strategies that can be used to deal with students' alternative conceptions.

2.5 Teachers' Knowledge in Studies

Literature agrees on the need to possess sufficient teacher knowledge to be an effective teacher. As indicated above, it is associated with the term PCK which indicates the importance of the subject matter and pedagogical knowledge. Although much research has been conducted on PCK (Sadler et al., 2013), education literature could not become neater to agree on one particular result (Abell, 2014; Sadler et al., 2013) since PCK has many constructs that can be investigated. For example, while some researchers studied PCK overall, some tried to focus more specifically on specific constituents (Abell, 2014). Additionally, teachers' PCK has been seen as arduous to investigate since it has a complex nature (Martin & Jamieson-Proctor, 2019; Morrison & Luttenegger, 2015; Sadler et al., 2013). However, it is not only the reason for the difficulty, but also PCK having a tacit and cognitive structure causes the difficulty. Moreover, teachers generally do not reply to these types of investigations candidly. Thus, it can be easier to work with pre-service teachers who have nothing to lose regarding disrepute.

Subsequently, the literature reveals much research investigating the relationship between experience and PCK. Initially, Shulman (1987) suggested that experience was directly related to teachers' PCK. As the experiences of teachers in education increases, PCK is developed more. Similarly, Großschedl et al. (2015) indicates a positive relation for pre-service teachers who have instructional practices; however, others could not identify any impact of gaining experience for in-practice teachers (Olfos et al., 2014; Schmidt et al., 2007). They suggest that since pre-service teachers have more opportunities to do reflective practice than in-service teachers (Großschedl et al.,

2015), their PCK can be found to increase with experience, which is pretty apprehensible. Also, it can be commented that in-practice teachers do not prefer to improve themselves but continue what they are doing as the year passes. As seen above, it could be stated that as pre-service teachers' experience increases, their PCK increases.

The literature generally does not rely on PCK as a whole but investigates the constituents specifically. Due to the relatedness of this research, literature on teachers' knowledge of learners' AC and knowledge of instructional strategies are reviewed.

2.5.1 Teachers' Knowledge of Learners' ACs

Many researchers (Hill et al., 2018; Park & Oliver, 2007; Sadler et al., 2013; Shulman, 1986) validate knowing learners' AC as one of the important constituents of teachers' PCK. It is not surprising since knowing them should accompany instructions to handle them when considering the impact of conceptions on learners' learning (Wandersee et al., 1994). However, the literature is dispersed.

For example, researchers cannot agree on the measurement of this knowledge. While some researchers focus on more qualitative methods, such as representing scenarios (Carpenter et al., 1988; Bell et al., 2010; Krauss et al., 2008); some also use quantitative measurement strategies by applying multiple-choice tests and surveys (Hill, Ball, & Schilling, 2008; Pine et al., 2001). Additionally, the literature reveals inconsistent findings regarding teachers' awareness of their students' AC despite lack of investigation (Cox et al., 2016; Sadler et al., 2013). Nussbaum (1981), studied with 94 pre-service teachers in science education and administered some materials which contained possible explanations of learners. Findings indicated that pre-service teachers could not detect possible ACs that learners have. Likewise, other researchers asked teachers to diagnose potential ACs for different subject areas and found insufficient returns (Kokkotas et al., 1998; Frederik et al., 1999). For example, in 1998, Kokkotas and Vlachos studied with 70 pre-service teachers to reveal whether they

could find out students' ACs in the particulate nature of matter. At the end, it was found that pre-service teachers were not able to detect AC, and they also had potential pupils' ACs. Additionally, research conducted by Frederik, Van der Valk, and Leite (1999) specifically investigated pre-service teachers' knowledge of students' conceptual difficulties in the context of heat and temperature. Most of the pre-service teachers had some difficulties in some concepts such as the distinction between heat and temperature. Researchers also found that if teachers have or had the alternative conceptions before, they expect their students to have misconceptions too. As an implication, researchers mentioned the importance of making pre-service teachers aware of their conceptual difficulties. Similarly, Hartelt et al. (2022), tried to find how biology teachers knew students' alternative conceptions in the evolution topic. For this, they studied with 182 pre-service and in-service teachers. At the end, they found that most of the participants could only detect half of the alternative conceptions in the survey. Additionally, they investigated that pre-service teachers' results were not as good as in-service teachers. Although the number of samples, domains, and methods were different in studies, they agreed on the ineligibility of teachers in terms of identifying knowledge of learners' AC (Sequeira et al., 1993; Halim & Meerah, 2002; Berg & Brouwer, 1991).

On the other, as stated above, studies that state the ingenuity of teachers are irrefutable. For example, in England, Pine, Messer, and St. John (2001) surveyed 122 teachers to give examples of learners' possible conceptions in an introductory science course. First researchers wanted teachers to list topics from easy to hard ones. They found teachers generally indicated hard topics as abstract concepts. Later, they also witnessed that 90 teachers could state 130 ACs which students could bring to courses, so teachers were conscious about learners' ACs.

In a different aspect, Sadler et al. (2013), studied how teachers' knowledge of AC was related to learning outcomes of their learners. For this, they worked with 620 teachers and more than 9000 learners. The test that contained 20 multiple-choice items in physics was applied to teachers and learners. Subjects in the items were properties and changes in properties of matter; motions and forces; transfer of energy which indicate

the first three NRC (National Research Council) standards. Unlike learners, teachers needed to indicate right and wrong answers so that researchers could comment on their subject matter knowledge and the knowledge of their learners' AC. In the end, researchers found that learners who have teachers more knowledgeable about their students' AC were more successful. Here, it can also be concluded that teachers are able to handle learners' AC besides the diagnosis of them.

Another study by Juhaevah et al. (2020), investigated how teachers' experiences affect both teachers' knowledge of AC and their ability to diagnose them. In this study, researchers observed and interviewed two mathematics teachers, and one was more experienced. According to their findings, the teacher with more experience could identify more AC and diagnose them in their learners more easily. However, teachers without experience could not show efficient practice. Thus, this study again shows the advantage of experiences although there are only two participants.

In a recently published study by Yildiz (2024), awareness of prospective teachers about the AC was found to be very high. In the study, there were 75 pre-service physics teachers, and they were given a statement about force concepts and wanted to label it as “paradigm, theory, scientific law, misconception and principle” (p.40). 90.7% of the samples could identify it as a misconception. Moreover, pre-service teachers stated concept maps as tools that can be used in the elimination of alternative conceptions.

Finally, it can be concluded that many studies investigate (pre-service) teachers' knowledge of learners from different points of view and make varied conclusions. Despite the different investigations, it is essential to emphasize that teachers' knowledge of learners significantly affects learners' conceptions, so it is worth examining it.

2.5.2 Teachers' Knowledge of Instructional Strategies for AC

Besides investigating teachers' knowledge of their learners' AC, studies that considered how these teachers' knowledge affects their instructions, and correspondingly, learners' outcomes are also substantial. Despite this, few studies investigated teachers' instructional strategies (Cox et al., 2016; Hill & Chin, 2018; Juhaevah et al., 2020; Hartelt et al., 2022) in order to deal with ACs. Like teachers' knowledge of learners, knowledge of instructional strategies to deal with learners' AC in literature is scattered. Studies indicated different findings as negative, positive, and no relationship between teachers' knowledge of AC and their instructional methods. For example, Cox, Steegen and Cock (2016), investigated 27 teachers' consciousness of their learners' AC in astronomy. Focus group interviews were conducted with teachers. In the end, they concluded that teachers were aware of learners' possible AC. However, they were not willing to be responsible for replacing conceptions. They did not show any actions by hiding behind the excuses, such as lack of time and difficulty in diagnosing conceptions.

By contrast, Carpenter, Fennema, Peterson, & Carey (1988) studied with both teachers and learners. They investigated both teachers' knowledge of AC and their instructional strategies besides the learners' outcomes in the computation test and solving word problems. Surprisingly, they found no evidence that higher teachers' knowledge of learners brought higher understandings in students' minds. As a result, it can be said that learners generally make their own way while learning. Although it is disappointing for teachers' efforts, researchers also mention that if teachers are aware of instructional techniques, they tend to understand learners' answers more and be willing to use questioning techniques.

On the other hand, literature also indicated a positive correlation between these constructs of knowledge. For instance, the previously mentioned study by Sadler et al. (2013) found that teachers with more knowledge of learners resulted in more outcomes in physical science for their learners. Subsequently, although they did not investigate the teachers' instructional method to replace conceptions, researchers suggested that

teachers with more knowledge about AC showed more effectiveness in teaching since they indicated instructional methods such as demonstrations, experiments, or discussions. This is such an important notion since without any attempt to handle AC, high knowledge of teachers' conceptions does not make any sense.

Similarly, Hartelt et al. (2022), studied with both in-service and pre-service biology teachers to find how their ability to detect ACs was related to dealing with ACs in evolution topics. For this they surveyed 182 teachers. At the end of the study, they stated the positive correlation with the ability to find ACs and deal with ACs. Their samples dealt with ACs by using different ways such as using analogy, helping students by giving hints or explaining the concept correctly.

Additionally, the literature comprises few studies investigating the teachers' knowledge of learners and specific instructional methods to deal with AC such as conceptual change (Dega et al., 2013; Sinatra et al., 2008; Tao & Gunstone, 1999; Vosniadou, 2013), inquiry (Peterson et al, 1989). For instance, the above-stated study conducted by Cox, Steegen & Cock (2016), indicated teachers' apprehension on the existence of AC and revealed many enlightening results. They stated that although teachers were fully knowledgeable of the significance of AC, they did not use particular methods to manage learners' AC and instructional methods to replace them.

However, conscious teachers with more knowledge of the AC showed more importance on conceptual change and indicated some strategies. Additionally, it is suggested that teachers should notice the persistence of these conceptions so that they show more appreciation for instructional methods that bring conceptual change. Peterson et al. (1989) also indicates pro-arguments, with the correlational and case analyses. They worked with teachers and their learners to relate teachers' knowledge of learners and their learners' outcomes. Consequently, they found a significantly positive relationship with each other. They stated that teachers with more awareness of learners' knowledge showed more importance to their learners' answers and adopted more inquiry-based techniques to question them, which is very promising for dealing with AC in practice.

2.6 Approaches to Deal with ACs

It is stated that learners' AC is essential for their learning, and without external urge, they cannot realize that they hold alternative understanding. At this point, teachers' knowledge of AC and dealing with them by using instructional knowledge earns meaning. However, although many educators and education researchers try to find a way to handle AC, as indicated by Wandersee, Mintzes, & Novak (1994), it is still in "an embryonic stage" (p.191). The theory of cognitive conflict is one of the answers where many researchers agreed on, thereby cognitive conflict became the core for the classical conceptual change model (Driver, 1989). According to this, first, learners should experience cognitive conflict where they are dissatisfied with their existing knowledge and want to acquire new, understandable, and pleasurable ones. Nevertheless, it must also be expanded and carried to other conceptions (Posner et al., 1982). As a result, learners disapprove of their alternative conception and hopefully get the intended one. Many studies investigated the impact of the conceptual change method on the learners' AC and these studies revealed positive findings (Baser & Geban, 2007; Kural, 2015; Guzzetti et al., 1993; Yang & Hung, 2012). However, the literature needs to be more comprehensive in examining teachers' attempts to use the conceptual change method. Thus, teachers may not decide how to use this technique to handle AC and correspondingly they may give up without implementing them (Cox et al., 2016). This gap is mentioned in the study of Berry and Milroy (2002), too. They stated that even though literature prioritizes finding ACs of students and teachers, the exact value is not given to investigating methods to handle them. Teachers need to be informed about the proper ways to use conceptual change by specifying examples of AC (Pringle, 2006). Therefore, they can see the impact of their instruction on learners' outcomes and try to arrange their instructional techniques by being willing to implement conceptual change.

What is the reason for teachers not considering conceptual change methods much? Although many researchers indicate the efficiency of conceptual change models, some

negative aspects exist that people do not emphasize. According to researchers, since conceptual change takes much time, environmental factors may affect the cognitive process during the instructions (Sinatra et al., 2008; Vosniadou, 2013). Therefore, in addition to the conceptual change model, many ways based on the cognitive conflict are developed to deal with AC, such as

"learning cycles (Karplus, 1981), bridging analogies (Clement, 1988; Perschard & Bitbol, 2008), microcomputer-based laboratory experiences (Thornton & Sokolof, 1990; Thornton, 1987), disequilibrating techniques (Minstrell, 1989; Dykstra, Boyle, & Monarch, 1992), an inquiry approach coupled with concept substitution strategies (Harrison et al., 1999), metaconceptual teaching on inducing a particularly problematic aspect of the conceptual changes (Wiser & Amin, 2001), and a teaching model (Thomaz et al., 1995)."

(Indicated by Wenning, 2008, p. 14.). Additionally, one might get a particular emphasis on transferring science concepts into everyday situations. Hence, learners might become interested and build new knowledge on the existing one (Sinatra et al., 2008). Nevertheless, cognitive conflict can seem reasonable here; learners themselves can realize that what they know daily is different from the concept that school science says.

Despite the many methods mentioned above, teachers are still not paying enough attention to dealing with AC issues. They even explain concepts with false scientific explanations or tell what is correct (Uhren, 2014 cited in Hartelt et al., 2022). As a result, it can be concluded that although teachers know learners' AC and instructional methods, their actions to deal with them are required. At this time, this can emerge for some reasons realized by teachers when they use the methods based on cognitive conflict theory. Firstly, cognitive conflict requires forgetting prior conceptions that are not relatively easy for learners and teachers to actualize, even if it feels unsatisfactory (Wenning, 2008). Secondly, as Dega et al. (2013) stated, cognitive conflict can cause learners to be discouraged, even if it seems only a reasonable way to deal with AC. Before them, this problem is also mentioned by Frankenstein (1979), indicating that

the long, broad cognitive conflict process may result in becoming annoying so that learners give up overcoming AC, especially those with poor performance (as cited in Chen et al., 2019). Additionally, it is confirmed in Aharon-Kravetsky's (2005) study that cognitive conflict instructions are only helpful for learners with a high performance rather than being useful for all of them (Chen et al., 2019). To conclude, there are many reasons why teachers are discouraged from implementing methods based on cognitive conflict; however, it might seem the first step to cope with learners' AC. At this point, although the literature indicates helpful findings and developments about AC, teachers' knowledge, and ways for dealing with them, much research is needed to develop teachers' knowledge in practice.

Though providing dissatisfaction through cognitive conflict is the first step, it may not be enough to provide conceptual change. As Posner et al (1982) state, new conceptions should be intelligible, plausible, and fruitful for the need of conceptual change. Therefore, in order to exchange prior knowledge that is not scientifically correct with the new scientifically correct knowledge, new concept should be intelligible so that students understand the new conception, new concept should be plausible by having the “capacity to solve problems generated by its predecessors” (Posner et al, 1982, p. 213) and new concept should be fruitful so that it should be effective to open new fields of investigation. As Stojanovska, Petruševski, Köller and Karlsen (2015) state, the use of several techniques such as experiments, discussions, analogies, concept maps, molecular models, animations, and simulations can help to provide conceptual change. Effective use of these techniques may help students to face and revise their ideas.

2.7 Development of Pre-service Teachers' Pedagogical Content Knowledge

In the literature there have been many research studies that investigate (pre-service) teachers' pedagogical content knowledge (PCK). Though some of these studies

focused on all components of PCK, findings about (pre-service) teachers' knowledge of learner and instructional strategy will be explained in this part. Most of the research samples in the below studies were formed from the preservice teachers.

For example, in 2013, Aydın, Demirdöğen, Tarkin, Kutucu, Ekiz, Akın, Tuysuz and Uzuntiryaki studied to investigate the effect of content representation based mentoring enriched practicum course on the development of pre-service chemistry teachers' PCK. For this, the topic was reaction rate and there were three preservice chemistry teachers as a sample. At the end of the study, researchers found when pre-service teachers were subjected to more practice, they were able to connect subject knowledge with teaching methods more. Pre-service chemistry teachers' knowledge of students' misconceptions enhanced. Though pre-service chemistry teachers could not identify students' misconceptions about reaction rate at the beginning of the course, all of them could state possible misconceptions of students after completing the course. Another finding was that pre-service chemistry teachers made some progress in overcoming students' misconceptions in their instruction. In terms of knowledge of instructional strategy, at the beginning, pre-service chemistry teachers focused on subject-specific instructional strategies such as 5E learning cycle model, predict-observe-explain more, however, without giving details and they had limited knowledge about topic-specific strategies, i.e. they used limited number of topic-specific strategies as analogy and simulation. However, at the end of the course, pre-service teachers gave detailed explanations of subject-specific instruction strategies, e.g., 5E learning cycle model and they used a richer repertoire of topic specific instructional strategies as daily life examples, graphs, experiments, analogies and graphical representations and they gave detailed explanations. Additionally, researchers also explored the factors influencing pre-service chemistry teachers' PCK development. Mentoring, teaching experiences and observation of their peers' instruction were found to be factors that influenced pre-service chemistry teachers' knowledge of learners and knowledge of strategies. Mentoring involved giving guidance to pre-service chemistry teachers in terms of preparation of their CoRes and instruction. Moreover, mentoring also involved helping pre-service teachers reflect on their instruction and giving feedback to them. Mentors

also guided pre-service teachers to use student-centered instruction and consider students' misconceptions and difficulties in their instruction.

Similarly, there was a study conducted by Brown, Friedrichsen and Abell in 2013. In this study researchers tried to find how four preservice biology teachers developed their teacher knowledge with respect to science teaching orientation, knowledge of learner and knowledge of instructional strategy throughout the teacher education program after bachelor's degree. The program involved introductory education courses, three methods of science teaching courses and teaching practicum courses. According to the results, it was seen that preservice teachers' knowledge of learners increased as year passes. Their awareness of students' difficulties enhanced during the teacher education program. In terms of instructional strategies, though pre-service teachers added more instructional strategies during the program, they still believed that science learning occurs through transmission of knowledge to students. It was also found that pre-service teachers' science teaching orientation influenced their knowledge of learner and instructional strategy.

In addition, there was also a study that investigated the development of preservice chemistry teachers' PCK in 2014. Adadan and Oner (2014) studied with two pre-service chemistry teachers and investigated these pre-service teachers' development of PCK in the context of behavior of gases during methods of chemistry teaching course by collecting data through content representations and interviews. It was found that pre-service teachers' knowledge of students' alternative conceptions enhanced as they completed methods courses. They were more aware of students' possible alternative conceptions at the end of the course. Pre-service teachers stated that reading articles about students' alternative conceptions and discussing them with their peers during forming CoRes influenced development of their knowledge of students' alternative conceptions and difficulties. In terms of instructional strategies, though one of the pre-service teachers made progress by implementing a more inquiry approach at the end of the course, the other participant continued on using a teacher-centered approach. Therefore, the development of PCK showed differences for each pre-service teacher. Their development was not the same.

Moreover, there was a study that had more sample sizes than previous ones. Subramaniam, in 2021 studied with 22 pre-service physics teachers to investigate improvement of their PCK within a science methods course. In the science methods course, firstly, pre-service teachers drew a picture of them teaching science and wrote a narrative about their drawings in order to reveal their prior knowledge and beliefs. Then, they made lesson plans and wrote a narrative about it. In the next weeks, they implemented lesson plans as microteaching instruction and reflected on that instruction. Finally, they wrote a narrative about their experiences, what they learnt from planning, teaching, and reflecting on teaching and they also discussed what they would do for their future instruction in their narratives. It was found that science teaching orientation influenced other PCK components and pre-service teachers' prior knowledge about teaching science had an influence on their PCK. Moreover, though pre-service teachers thought teacher-centered instruction is essential to tutor students at the beginning of the course, they mentioned the importance of providing student engagement in classes at the end of the methods course.

Specifically, Kiran, Boz and Oztay (2021) studied to find the effectiveness of using PCK tools to improve PCK of pre-service chemistry teachers in the context of chemical equilibrium during a school experience course. These tools were CoRe lesson plans, observation of mentor teachers in terms of PCK components, discussion and reflection of these observations, teaching practices in high school and reflection on teaching. According to the results, all participants' knowledge of learner and instructional strategies enhanced at the end of the course. Though pre-service teachers could list students' misconceptions and alternative conceptions based on their experiences at the beginning of the course, in addition to their experiences, related literature also helped them to list students' misconceptions and alternative conceptions at the end of the course. Moreover, pre-service teachers could give detailed explanations with respect to the sources and reasons of alternative conceptions. Preparation of CoRes and observation of mentors' instruction by considering PCK components helped them to focus on students' alternative conceptions and difficulties, thereby enhancing their knowledge of the learner. Regarding instructional strategy, pre-service teachers' repertoire of instructional strategies increased since they included

more instructional strategies and gave more detailed and topic-specific explanations. Preparation of CoRes, observing their mentors' instruction in terms of PCK components, teaching experience and reflection on teaching helped the development of pre-service teachers' knowledge of instructional strategy. To illustrate, pre-service teachers could understand the strengths and weaknesses of their instructional strategies and enhance their knowledge of instructional strategy.

Likewise, Belge-Can and Boz (2022) investigated how taking PCK courses affected the development of preservice chemistry teachers' PCK in the context of the temperature effect on reaction rate. Moreover, factors affecting the development of pre-service teachers' PCK were explored. Two pre-service chemistry teachers participated in the study. Researchers traced these participants as they took PCK courses at four different times. Time 1 refers to the time that pre-service teachers did not take any PCK courses. At time 2, pre-service teachers completed methods of science teaching I, curriculum development and laboratory applications in science education courses. While participants completed methods courses and school experience courses at time 3, they completed all PCK courses at time 4. At the end, it was found that taking PCK courses improved pre-service teachers' PCK, this improvement was not the same for each component and each of the pre-service teachers. Regarding pre-service teachers' knowledge of students' alternative conceptions, both participants showed improvement. Though both participants' knowledge of students' misconceptions was the same at time 2 and time 3, their knowledge of learners' misconceptions enhanced especially after completing all PCK courses, with respect to knowledge of instructional strategy, pre-service teachers' knowledge of subject-specific strategies increased, especially after completing all the methods courses. They stated the use of the 5E learning cycle model. In terms of topic-specific strategies, both participants' knowledge of topic-specific strategies showed gradual development as they took PCK courses. They mentioned various topic-specific strategies and could give more detailed explanations about the content of these strategies and how they would be used in class.

In terms of factors affecting development of pre-service teachers' instructional strategy, "methods courses, teaching at high school, preparation of lesson plans and microteaching at the university, feedback from the tutors, mentors, and students, and observations of their peers' instruction" were found (Belge-Can & Boz, 2022, p.991). Factors influential for the development of pre-service teachers' knowledge of learner were discussion of students' misconceptions in the theoretical courses, observation of peers in the microteaching sessions, preparation of CoRes and observation of high school students in the practicum courses.

Moreover, Evens, Elen, and Depaepe (2015) conducted a systematic review study regarding intervention studies that had the purpose of PCK development. They also explored the sources that contribute to PCK development. Teaching experiences, reflection on teaching and interaction with cooperating teachers were found to have a positive contribution on the development of pre-service teachers' PCK.

CHAPTER 3

METHODOLOGY

The study aims to investigate pre-service chemistry teachers' conceptions, their knowledge of learners' alternative conceptions (AC) and their approaches to deal with them in the reaction rate concept. In this circumstance, qualitative research is conducted to examine this purpose (Merriam & Tisdell, 2016). Subsequently, pre-service chemistry teachers at a university are administered a questionnaire and interviewed to see their knowledge. The research questions below are examined in parallel with the research aim:

1. What are pre-service chemistry teachers' conceptions about reaction rate concepts?
2. What is pre-service chemistry teachers' knowledge about the learners' AC in reaction rate?
3. How do pre-service chemistry teachers deal with learners' AC in reaction rate?
4. How does pre-service chemistry teachers' knowledge about learners' AC change concerning PCK courses taken in teacher education programs?
5. How does pre-service chemistry teachers' ways of dealing with learners' AC changes concerning PCK courses taken in teacher education programs?

3.1 Research Design

The primary purpose of this research is to investigate pre-service chemistry teachers' conceptions, their understanding of learners' alternative conceptions (AC) and

methods of addressing them in the context of reaction rates. Qualitative research design was employed in this study. As Merriam and Tisdell (2016) state, qualitative study aims to explore and comprehend “how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences” (p. 6). It employs methods such as interviews and observations and data come as words and pictures rather than numbers. Since in this study, pre-service chemistry teachers’ conceptions, their knowledge of learners’ AC and teaching methods to eliminate ACs regarding reaction rate concepts will be explored by use of open-ended questionnaires and semi-structured interviews, it fits with the qualitative research design. Merriam and Tisdell (2016) described six qualitative research designs, which were basic qualitative research, phenomenology, ethnography, grounded theory, narrative inquiry, and qualitative case studies. This research employed a basic qualitative research design, focusing on pre-service chemistry teachers’ understanding related to reaction rates. The aim of basic qualitative research is to explore “how people make sense of their experiences” by using interviews, observations, and documents in the collection of data (Merriam & Tisdell, 2016, p. 42), that is compatible with the present study. The other five qualitative research designs also have the characteristics of basic qualitative research, but they also have an additional dimension. For example, narrative inquiry is about the stories of people, ethnography investigates culture of people while grounded theory is about building a theory through the analysis of data, phenomenology investigates people’s affective and emotional experiences and case study is in-depth investigation of a bounded system.

3.2 Participants

Twenty pre-service chemistry teachers at a university in Ankara were involved in this research. Among them, 17 were female, and three were male. All of the pre-service chemistry teachers were enrolled in a four-year chemistry program. Pre-service chemistry teachers take general chemistry, mathematics, and physics courses in the first year. In the second year, they take some content courses such as analytical

chemistry, analytical chemistry lab, physical chemistry I, physical chemistry lab, organic chemistry I, organic chemistry lab. They also take some pedagogical courses, which were “Introduction to Education” and “Theories of Teaching and Learning in Science and Mathematics. In the first semester of the third year, pre-service teachers begin to take pedagogical content knowledge courses “Curriculum Development and Instruction in Science Education” and some content courses such as organic chemistry II and inorganic chemistry. In the second semester of the third year, they take methods of science teaching I and assessment of learning in science teaching courses and content courses as instrumental analysis, instrumental analysis lab and physical chemistry II. In the first semester of the fourth year, pre-service teachers take more pedagogical content knowledge courses as methods of science teaching II, practice teaching I, instructional technology and material development and laboratory applications in science education. In the last semester, they take practice teaching II and chemistry daily life as pedagogical content knowledge courses. Table 3.1 shows chemistry-related courses as well as pedagogical and pedagogical content knowledge courses in the chemistry teacher education program.

Table 3.1 Chemistry, Pedagogical and Pedagogical Content Knowledge Courses in Chemistry Teacher Education Program

Years	First Semester	Second Semester
First year	General Chemistry I General Chemistry Lab I	General Chemistry II General Chemistry Lab II
Second year	Analytical Chemistry Analytical Chemistry Lab Introduction to Organic Chemistry Introduction to Education	Organic Chemistry I Organic Chemistry Lab I Physical Chemistry I Physical Chemistry Lab I Theories of Teaching and Learning in Science

Table 3.1 (continued)

Years	First Semester	Second Semester
Third year	Organic Chemistry II Inorganic Chemistry I Curriculum Development and Instruction in Science Education	Instrumental Analysis I Instrumental Analysis Lab I Physical Chemistry II Assessment of Learning in Science Methods of Secondary Science Teaching I
Fourth year	Classroom Management Instructional Technology and Material Development Lab Applications in Secondary Science Education Practice Teaching I Methods of Secondary Science Teaching II	Guidance Practice Teaching II Chemistry in Daily Life Inorganic Chemistry II/Quantum Chemistry

Purposive sampling was used in this study. As Patton (2015) states, in qualitative research, sample sizes are relatively small, that were selected purposefully in order to examine the phenomenon in depth. Purposeful sampling involves the selection of information-rich cases that provide the researcher with in-depth information related to the purpose of the research. Since one of the purposes of the present study was to find out the change in pre-service chemistry teachers' conceptions, knowledge of students' AC and their ways of remedying these ACs in the context of reaction rate concepts with respect to the pedagogical content knowledge courses taken in teacher education program, three groups were selected purposefully based on different pedagogical content knowledge courses they took.

Table 3.2 Demographic Information of Pre-service Teachers

Gender	n
Male	3
Female	17
Groups	
Group 1	7
Group 2	6
Group 3	7

As seen from Table 3.2, group 1 students involved seven pre-service chemistry teachers. They were all female. Group 2 consisted of six pre-service chemistry teachers. Among them, two were male while there were four female participants in this group. Group 3 was composed of seven pre-service chemistry teachers. There was only one male participant whereas six of them were female in that group. Group 1 involved students who were in the first semester of the 3rd year and did not take any PCK courses. Group 2 was composed of students who were at the end of the first semester of the 4th year and completed some pedagogical content knowledge courses such as Curriculum Development in Science Education, Methods of Science Teaching Courses, Assessment and Evaluation in Science Education, Laboratory Application in Science Education and Teaching Practice I course, and Group 3 included students who completed Teaching Practice II course and Chemistry in Daily Life course in addition to the courses group 2 took. Table 3.3 shows the description of pedagogical content knowledge courses taken in chemistry teacher education program.

Table 3.3 Description of Pedagogical Content Knowledge Courses in Teacher Education Program

PCK Courses	Description of the Course
Curriculum Development and Instruction	Fundamental concepts of curriculum design, taxonomies regarding educational objectives, evaluation of National Chemistry Curriculum, brief information about instructional strategies and methods
Assessment of Learning in Science	Development and use of different assessment tools that can be used in chemistry instruction.
Methods of Secondary Science Teaching I & III	Explanation of different teaching methods such as 5E learning cycle, inquiry, argumentation etc., discussion of nature of science, conceptual change strategies, STEM. Microteaching of chemistry topics based on different teaching methods. Preparation of lesson plans by considering students' alternative conceptions regarding chemistry topics. Consideration of these alternative conceptions in the microteaching instruction.

Table 3.3 (continued)

Instructional Technology and Material Development	Discussion of different instructional technologies such as animation, simulation, video etc. in chemistry teaching, development of instructional materials such as worksheet, slides etc. in chemistry teaching
Lab Experiments in Science Education	Conducting high school chemistry experiments, discussion of theoretical part of the experiments, daily life applications and high school students' possible alternative conceptions about chemistry concepts
Practice Teaching I & II	Microteaching of chemistry topics, preparation of CoRes as lesson plans, teaching practice in high schools. Consideration of students' alternative conceptions about chemistry topics both in the preparation of CoRes and microteaching as well as teaching practice in high schools
Chemistry in Daily Life	Daily life applications of chemistry, place of chemistry in daily life, industry, environment, health.

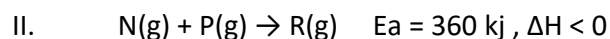
3.3 Data Collection Instruments

In this study, pre-service chemistry teachers' conceptions about reaction rate, their knowledge of students' ACs about this concept and knowledge of strategies to deal with students' ACs were examined. For this, data collection was carried out through questionnaires and semi-structured interviews.

3.3.1 Questionnaire

For the questionnaire, scenario-based questions were used to assess pre-service chemistry teachers' conceptions, their knowledge of learners' AC and methods used to eliminate these ACs regarding reaction rate concepts. Initially, literature was searched about alternative conceptions related to reaction rate. Alternative conceptions regarding reaction rate, specifically the concept of reaction rate, relationship between activation energy and reaction rate, collision theory, effect of temperature, catalyst and surface area on reaction rate were determined. Afterwards, considering these alternative conceptions, questions used in the study of Tastan et al., (2010) were adapted as scenario-based questions that fit with the purpose of the present study, which is finding out pre-service chemistry teachers' conceptions, knowledge of students' alternative conceptions and methods used to eliminate these alternative questions. 5 scenario-based questions were developed. Question 1 was about interpreting reaction rate-time graph, how reaction rate changed with time depending on the concentration of a reactant. Question 2 assessed pre-service teachers' understanding of the relationship between activation energy, enthalpy, and reaction rate. Question 3 was about the effect of temperature on rate of reaction for exothermic reactions. Question 4 assessed pre-service teachers' understanding of roles of catalysts in chemical reactions. Question 5 was about the effect of surface area on reaction rate. (Appendix A). Scenarios were inspired from the study of Cakmakci et al. (2005). In the scenarios, there was a question about reaction rate concepts and two or three people were talking about their solutions to the question. One of the responses was correct. However, others involved alternative conceptions related to the question. Pre-service chemistry teachers were expected to find the correct explanation and detect alternative conceptions in the scenarios. Moreover, they were asked to explain their strategies to eliminate the ACs. One of the questions was presented below:

Question 2: Activation Energy



Which of the two reactions occurs first? Discuss with reasons.

Ali: Reaction II is exothermic, and exothermic reactions occur faster than endothermic reactions.

Melisa: I disagree with you. The speed of a reaction is not determined by whether it is exothermic or endothermic but by the amount of activation energy. Reaction I have a lower activation energy, so it occurs faster.

İlayda: Enthalpy explains the energy released at the end of the reaction, and the more it is, the faster the reaction. Therefore, Reaction I occur faster than Reaction II.

Osman: In the second case, the kinetic energy of the reacting molecules is higher, so it occurs faster.

- Which student has given the correct information about the option they defended?
- Which students have misconceptions, and what are these misconceptions?
- How can you eliminate the misconceptions you mentioned?

Misconception 1:

Elimination method:

Misconception 2:

Elimination method:

Misconception 3:

Elimination method:

The question was linked to several alternative conceptions in literature. Table 3.4 below states the examples of common alternative conceptions in the test according to each question.

Table 3.4 Common Alternative Conceptions in the Questions and Their Coding

Questions	Number of Alternative Conception	Alternative Conceptions
1. Rate-Time Graph	AC1	Many of the students assumed that as long as certain factors (e.g., temperature, concentration, or catalysts) were not altered, the reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).
	AC2	As reactants are used up, the formation of product increases and accordingly the reaction rate increases until all reactants are consumed where the reaction rate is constant. (confusion of the reaction rate and the amount of product) (Çakmakçı, 2005).
2. Relationship between Rate and Enthalpy-Activation Energy	AC3	Exothermic reactions occur faster than endothermic reactions (Çakmakçı, 2005).
	AC4	The faster a reaction, the more energy is released (Çakmakçı, 2005).
	AC5	Activation energy is the kinetic energy of reactant molecules (Çakmakçı, 2005).

Table 3.4 (continued)

3. Temperature Effect on Rate	AC6	When the temperature is increased, the rate of the endothermic reaction increases but the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003).
	AC7	An increase in temperature (temperature change) does not affect (change) the rate of exothermic reactions. Since exothermic reactions release energy, they do not need energy to proceed and a rise in temperature would not affect the reaction rate (Çakmakçı, 2005).
	AC8	A rise in temperature would not affect the reaction rate, because the reaction rate is independent of temperature. Reaction rate only depends on the rate constant and molarities (Çakmakçı, 2005).
4. Property of Catalyst	AC9	A catalyst speeds up only the forward reaction (Voska & Heikkinen, 2000).
	AC10	Students do not anticipate that a catalyst lowers both the forward and reverse activation energies; rather they believe that a catalyst just reduces the forward activation energy and as a result they may reach the conclusion that the catalyst favors the yield of the product. (Hackling & Garnett, 1985; Garnett et al., 1995; Voska & Heikkinen, 2000; Çakmakçı, 2005).
	AC11	Catalyst increases the average speed of the molecules (Kingır & Geban, 2006).

Table 3.4 (continued)

5. Surface Area Effect on Rate	AC12	Reaction rates are the same whether the reactant is granulated or powdered since the molarities are equal for both cases (Çakmakçı, 2005).
	AC13	Surface area of reactants does not affect reaction rate (İcık, 2003).
	AC14	Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).

To enhance the content validity of a questionnaire in qualitative research, several strategies can be employed. Initially, conducting a comprehensive literature review helps identify the key dimensions and elements of the construct being measured, ensuring that all relevant aspects are included (Hinkin, 1995). That is why, in the study, literature was reviewed to ensure content validity of the topic. Additionally, because consulting subject matter experts is crucial, as they can provide feedback on the relevance, clarity, and comprehensiveness of the questions (Lynn, 1986), five chemistry educators examined the questions in the questionnaire in terms of clarity and suitability of questions with respect to alternative conceptions they assess. They suggested minor revisions in order to enhance clarity of questions. According to these opinions, questions were revised, and it was believed that the comprehensiveness and relevance of the questionnaire was improved, thereby enhancing its content validity.

3.3.2 Semi-structured Interviews

After examination of pre-service chemistry teachers' responses given to the questionnaire, 6 of the 20 pre-service teachers were interviewed. The goals of the semi-structured interviews were to obtain in depth and detailed information about pre-service chemistry teachers' reasonings and clarify their responses in the questionnaire. Interviewed samples were selected according to the responses to the questionnaire ensuring that diverse viewpoints were represented. Two pre-service chemistry teachers from each group (Group 1, Group 2, and Group 3) were selected to be interviewed. Since the interviews were semi-structured, some of the questions were prepared before and these questions were designed to explore in depth specific areas highlighted by the questionnaire, seeking to clarify and expand on the initial findings. (see Appendix B). Some sample interview questions are as follows:

In the 3rd question, you stated that you would use experiments to eliminate the alternative conception "Reaction rate of exothermic reactions decreases with increase in temperature". Would you explain the content of the experiment? What kind of experiment would you use?

Why did you prefer to use experiments to eliminate this alternative conception? Do you think it would be effective? Why or why not?

Each interview lasted between 40 to 60 minutes and was conducted via Zoom. The Zoom sessions were recorded with the participants' consent to ensure accuracy in capturing their responses. This recording also facilitated thorough analysis and verification of the data during the transcription process.

3.4 Data Analysis

Data analysis is a crucial element in basic qualitative research. It helps researchers understand and interpret the collected data in order to find answers to research

questions. Data analysis is a systematic process that occurs through the formation of codes and categories in order to make sense of data (Merriam & Tisdell, 2016). For the analysis of data from the questionnaire, first, the responses were read carefully. The first step was whether participants indicated correct conceptions or not regarding reaction rate concepts. When pre-service teachers' written responses were examined, it was seen that some of them did not indicate any responses, some pre-service teachers gave the correct response but with incorrect explanations involving some alternative conceptions. Some pre-service teachers gave incorrect responses involving alternative conceptions. These alternative conceptions were also coded. Based on the examination of participants' responses in the questionnaire, some categories and subcategories were formed. Below table (Table 3.5) shows examples of the categories and sample responses under these categories for Question 5.

Table 3.5 Finding Correct Conceptions (For the Question 5)

	Anchor example
No response	
Correct response	
Correct conception and correct explanation	"Increasing the surface area increases the rate of reaction."
Correct conception and no explanation	P9, P11
Correct conception and false explanation	P10
<i>Alternative conception</i>	"Crushing the substances increases the amount of matter."

Table 3.5 (continued)

False response	
False response and false explanation	P5
- <i>Alternative conception</i>	“Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).”
False response and no explanation	P4
- <i>Alternative conception</i>	“Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).”

After the formation of categories and sub-categories, the below table Table 3.6 (example for Group 1) was created to see the distribution of answers for each participant in each group clearly, since all questions can be seen there. P in the table refers to participant. For example, P4 means participant 4.

Table 3.6 Distribution of Answers According to Question

	Question 1	Question 2	Question 3	Question 4	Question 5
No response		P7		P4	
False response					
False response and false explanation	P1		P3, P1, P2		P5
Alternative Conception	The reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).		P1, P3: When the temperature is increased, the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcık, 2003). P2: Reaction rate only depends on the rate constant and molarities (Çakmakçı, 2005).		Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).
False response no explanation	P2		P4		P4

Table 3.6 (continued)

	Question 1	Question 2	Question 3	Question 4	Question 5
False response no explanation	P2		P4		P4
Alternative Conception	The reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).		When the temperature is increased, the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003).		Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).
Correct response					
Correct response but incorrect explanation				P1, P2, P5	
Alternative Conception				Catalyst increases the average speed of the molecules (Kıngır & Geban, 2006).	
Correct response and correct explanation	P3, P4, P5	P1, P6, P5	P5		P1, P2

Table 3.6 (continued)

Correct response with no explanation	P6, P7	P3, P4, P2	P6, P7	P6, P3, P7	P6, P3, P7
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Afterwards, pre-service chemistry teachers' responses to detect alternative conceptions and teaching strategies that they used were analyzed. At first, alternative conceptions in the questionnaire were coded as AC1, AC2, to AC14. Even if they could not find the correct conception before, stated alternative conceptions were coded in the table since one scenario question indicated more than one alternative conception. According to the given explanations, teaching strategies were categorized as seen from Table 3.7. In some cases, pre-service teachers mentioned more than one teaching method. In this case, mentioned teaching methods were coded. Moreover, even though pre-service teachers could specify alternative conceptions, some participants did not express their teaching strategies to eliminate ACs. As a result, this was coded as No Strategy Explained (NSE).

Table 3.7 Examples of Coding for Methods

Methods	Anchor examples
Explanation	"I will review the characteristics of physical and chemical changes and explain them with examples. Then, I will reinforce this information by explaining the correct answer."
Animation	"Using animations, students can visually see how the reaction takes place."
Simulation	"Coarse MgO particles are not more strongly bonded to each other; even in the crushed MgO compound, the molecules are bonded to each other by ionic bonds. At this point, since the bond strengths of both crushed and coarse MgO molecules are the same, a simulation showing this at the particulate level will help students understand better."
Experimentation	"By conducting an experiment related to the topic, I aim to show that endothermic or exothermic reactions do not affect the reaction rate."
Daily-life examples	"I can provide real-life examples where catalysts are used and help students understand how catalysts increase the reaction rate."

Table 3.7 (continued)

Demonstration of graphs	“There is no continuous increase observed during the reaction because the concentrations of A(g) and B(g) decrease as they are consumed. Therefore, I aimed to show through the graph that there is a decrease in the concentration of the reactants over time.”
Video Demonstration	“Video of an experiment can be shown to reinforce the concept.”
Analogy	“When explaining reaction rate, students should focus on activation energy, which is the minimum energy a particle must have to overcome the threshold. I aim to help students better understand this concept by using the analogy of a mountain.”
Drama	“It should be emphasized that an increase in temperature increases the kinetic energy of particles, leading to a higher number of effective collisions between them. In other words, the student's response described the condition necessary for the start of an exothermic reaction, which indicates a misconception. To address this, I would use collision theory and organize a drama activity for students. I would ask them to demonstrate to their peers what they would observe in the movement of molecules as the temperature rises.”
Discussion	"I would like to provide the reaction rates at different temperatures for exothermic and endothermic reactions and ask them to discuss."
Exemplification	“A catalyst is explained, including how it works, with an example”

Just like in the first step, to detect the popularity of strategies for each group simply one table was designed. Below table (Table 3.8) demonstrates the detected alternative conceptions and teaching strategies stated by the participants for Group 1 in Question 1.

Table 3.8 Methods used to Eliminate AC According to ACs.

	Methods:	Explanations	Animations	Simulation	Experimentations	Daily-Life Examples	Demonstrations of Video, Pic. vs Video	Video	Analogy	Drama	Discussion	Exemplification	No Strategy
AC Number:	Question 1												
1	Many of the students assumed that as long as certain factors (e.g., temperature, concentration, or catalysts) were not altered, the reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).				P1, P4								P3, P5, P6

Table 3.8 (continued)

2	As reactants are used up, the formation of product increases and accordingly the reaction rate increases until all reactants are consumed where the reaction rate is constant. (confusion of the reaction rate and the amount of product) (Çakmakçı, 2005).	P1				P1, P4, P6							P3, P5, P7
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For the interviews, firstly, interviews were transcribed and then analyzed by forming codes and categories. Moreover, pre-service chemistry teachers' explanations were given as quotes.

3.5 Data Collection Procedure

First of all, Web of Science, Educational Resource Information Center (ERIC) databases, Google Scholar and YÖK National Thesis Center were searched with the keywords “alternative conceptions”, “misconceptions”, “reaction rate”, “alternative conceptions in reaction rate”, “pedagogical content knowledge”, “pre-service teachers”, “teachers’ knowledge of learner”, and “teachers’ knowledge of instructional strategies for alternative conceptions”. After literature review, the questionnaire was constructed. The research was carried out in the spring term of 2022-2023 and fall term of 2023-2024 at a university with the pre-service chemistry teachers. At the end of the spring term of 2022-2023 academic year, group 3 participants completed the questionnaires. At the beginning of the fall term of 2023-2024 academic year, questionnaires were given to group 1 participants while at the end of the fall semester of 2023-2024, group 2 students took the questionnaires. It took about 30 minutes for pre-service chemistry teachers to answer the questions in the questionnaire. Six pre-service teachers, two from each group, were chosen for the interviews. The semi-structured interviews were conducted with them two weeks after the first data collection. No more than two weeks was preferred because of the consistency of questions between questionnaire and interview items. Interviews lasted about 40 to 60 minutes. Responses were audio-recorded with the consent of the participants.

3.6 Ethical Issues

Before starting the study, all ethical consents were taken from the Human Subjects Ethics Committee (HSEC) in the Middle East Technical University (see Appendix C). The purpose of the study was explained to the pre-service chemistry teachers, and it was stated that they can leave the study any time they want. Participants voluntarily took part in the study. In reporting data, pseudonyms were used instead of their real

names. Only the researcher and the supervisor had access to the data. The consent of the participants was taken before recording the interviews.

3.7 Trustworthiness

Validity and reliability issues need to be addressed in any research study. In quantitative research, validity and reliability terms are used. However, they have different names in qualitative research. Credibility and transferability refer to internal validity and external validity, respectively. Dependability refers to reliability while confirmability is related with the objectivity of the research (Lincoln & Guba, 1985). Credibility, transferability, dependability, and confirmability of the study indicate trustworthiness in the qualitative research. Providing trustworthiness is important for the accuracy of the findings and applicability of study to other settings. In the present research, several ways were used to enhance trustworthiness of the study.

3.7.1 Credibility

Credibility is one of the important components of trustworthiness in the qualitative study, ensuring that the findings accurately reflect the participants' experiences and perspectives. According to Lincoln and Guba (1985), credibility is important for confirming the authenticity and accuracy of qualitative research. Without it, the research findings may be questioned, undermining their reliability and validity (Shenton, 2004). Credible findings also increase applicability and allow researchers to transfer them confidently in similar contexts (Morse, 2015). Moreover, when participants trust that their ideas are accurately represented, this causes trust in the research process, encourages participation and the provision of authentic data (Patton, 2015).

Some strategies are applied to enhance the credibility of qualitative research. Triangulation that refers to using different data sources, methods, and investigators to cross-verify data is one of the key strategies (Shenton, 2004). In this study, both questionnaires and semi-structured interviews were used to check participants' voices. Additionally, researcher and supervisor coded the data independently and differences were discussed. Member checking allows participants to verify the data and findings, ensuring accuracy with their experiences (Lincoln & Guba, 1985). Another strategy to enhance credibility of the research is the prolonged engagement of the researcher in the research that helps to build trust and provide a deeper understanding of the context (Creswell & Poth, 2018). Additional techniques such as peer review also increase credibility. During the research, the supervisor and the researcher studied together to discuss the data collection and analysis processes. Consequently, both triangulation and peer review strategies were used to enhance credibility in the present study.

3.7.2 Transferability

Transferability is a critical aspect of trustworthiness in qualitative research, referring to the application of findings of a study to other contexts or groups. In the quantitative research, statistical methods are used to provide generalizability while in qualitative research, depth and richness of data are described to ensure the applicability of findings beyond the immediate study (Lincoln & Guba, 1985). This detailed contextual information allows other researchers to make informed judgments about the applicability of the study's results (Merriam, 1998). That is why profiles of pre-service chemistry students in the university, taken courses by the participants, were indicated in detail in the study. With this way, the usefulness and relevance of qualitative research findings were extended (Shenton, 2004), and it can contribute to broader knowledge and practice. Additionally, in this research, purposive sampling was used which is crucial for selecting participants and settings that represent the

phenomenon under study, thereby enhancing the applicability of the findings (Merriam, 1998).

3.7.3 Dependability

Dependability is a critical aspect of trustworthiness in qualitative research, referring to the stability and consistency of the research processes over time. Ensuring dependability involves providing a detailed description of the research methodology that allows for the study to be replicated under similar conditions (Lincoln & Guba, 1985). Several techniques such as an audit trail, triangulation and peer debriefing can be used to provide dependability. Audit trail involves keeping comprehensive records of all research decisions while peer debriefing involves discussing both the research process and findings with colleagues (Creswell & Poth, 2018). In this study, dependability was enhanced by using several techniques. For data triangulation, both questionnaires and semi-structured interviews were used that caused the collection of diverse data providing a comprehensive understanding of the research topic. Detailed documentation of all research activities, including data collection and analysis procedures, was maintained to provide a clear audit trail.

Additionally, peer debriefing sessions were held, where supervisor and the researcher discussed and reviewed the research process and findings, the supervisor offered some critical feedback to the researcher to minimize biases and enhance the study's credibility. Moreover, both supervisor and the researcher discussed the codebook before making data analysis. Afterwards, they independently coded the data. Inter-coder agreement was calculated as 0.92 by using the formula of Miles and Huberman (1994):

Interrater reliability = $\text{Number of agreements} / (\text{Total number of agreements} + \text{disagreements}) \times 100$

In some cases, there were conflicts between the categories of the researcher and the supervisor. In these cases, they discussed and reached a consensus.

3.7.4 Confirmability

Confirmability is about the objectivity of the research that refers to the degree to which the findings of a study are shaped by the respondents and not researcher bias, motivation, or interest. There are different techniques such as an audit trail and triangulation to promote confirmability of a research study. Audit trail refers to providing detailed and clear documentation of the research process so that it allows other researchers to trace the data back to its original sources and verify the interpretations while triangulation consists of triangulation of data, method, and investigator (Lincoln & Guba, 1985).

In this study, for the audit trail, all data was conserved including semi-structured interviews from the zoom while triangulation of data was provided by the use of both questionnaire and semi-structured interview. Moreover, for the investigator triangulation, the supervisor and the researcher had meetings where they discussed the formation of research questions, instruments, data analysis and reporting the findings. All these techniques helped to enhance the confirmability of the research, thus promoting the trustworthiness of the study.

3.8 Limitations

There are some limitations of this study. The study was conducted with pre-service chemistry teachers enrolled in a university in Ankara, which may limit the generalizability of the findings to other pre-service chemistry teachers in other universities. Though it is not the aim of generalizing research findings in qualitative research, since the pre-service chemistry teachers who participated in the study were

all from a particular university in Ankara, it could influence their conceptions and teaching approaches. As a result, the findings may not represent pre-service chemistry teachers in other universities (Creswell, 2014).

The data collection instruments, which were questionnaires and interviews, may have inherent limitations. Researchers may not fully have obtained the depth of the participants' conceptions and teaching approaches in the Reaction Rate questionnaire. Similarly, the researcher conducted interviews with the participants. The interviews, though providing rich data, could be influenced by researcher bias or the participants' perceptions of what the researcher wanted to hear.

3.9 Assumptions

There were some assumptions made in this study. Firstly, all pre-service chemistry teachers were assumed to be sincere in their responses to both the questionnaires and interviews. This is vital for obtaining a true representation of pre-service chemistry teachers' conceptions of reaction rate concepts, their knowledge of learners' alternative conceptions in the rate of reaction topic, and their approaches to deal with these alternative conceptions. Another assumption was that participants were information-rich cases and provided rich data.

CHAPTER 4

RESULTS

4.1 Findings and Results

This study had three main issues of interest. The first was whether pre-service chemistry teachers could detect students' alternative conceptions. If not, what were their alternative conceptions? If so, how do they deal with these alternative conceptions, and which method(s) do they use? The last point is how these two issues changed according to given PCK courses in chemistry teaching departments.

4.1.1 Identifying Alternative Conceptions of Participants

In this study, there were three main groups: Group 1 involved students who did not take any PCK lessons. Group 2 was composed of students who took some pedagogical content knowledge courses such as Curriculum Development in Science Education, Methods of Science Teaching Courses, Assessment and Evaluation in Science Education, Laboratory Application in Science Education and Teaching Practice I courses and Group 3 included students who completed all PCK courses. Table 4.1 shows responses of group 1 students for each question.

Table 4.1 Answers of Group 1 According to Questions

	Question 1	Question 2	Question 3	Question 4	Question 5
No response		P7		P4	
False response					
False response and false explanation	P1		P3, P1, P2		P5
Alternative Conception	The reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).		P1, P3: When the temperature is increased, the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003). P2: Reaction rate only depends on the rate constant and molarities (Çakmakçı, 2005).		Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).
False response no explanation	P2		P4		P4

Table 4.1 (continued)

<i>Alternative Conception</i>	The reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).		When the temperature is increased, the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003).		Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).
Correct response					
Correct response but incorrect explanation				P1, P2, P5	
<i>Alternative Conception</i>				P1: Catalyst decreases the energy of activation complex. P2, P5: Catalyst decreases activation energy.	
Correct response and correct explanation	P3, P4, P5	P1, P6, P5	P5		P1, P2
Correct response with no explanation	P6, P7	P3, P4, P2	P6, P7	P6, P3, P7	P6, P3, P7

For group 1, there were seven students, and they did not take any PCK lessons. In the first question, there was a scenario in which students talked about the reaction rate-time graph. Participants who did not take any PCK classes generally were able to detect the correct answer and found misconceptions. Among the seven students, five of them could give the proper response. However, two participants gave a false answer, and one of them could not even explain. When it was investigated, it was analyzed that two participants had the same alternative conception: "Unless factors such as concentration temperature, catalyst, etc. were not changed, reaction rate remains constant."

For the second question, the scenario was about the relationship between enthalpy-activation energy and reaction rate. Even though no participants answered falsely, one participant did not give any answer, and though six of them gave the correct response, three of them did not explain the reason for the proper response. In the third question students are generally confused about reaction rates concerning changes in temperature for exothermic reactions. Therefore, it was unsurprising that only 3 group members identified the correct conception; only one explained it correctly. In group 1, 4 participants had alternative conceptions, and one did not explain her choice. Although the alternative conception of participants was mainly on the "When temperature increases, rate of exothermic reaction decreases," one participant thought, "Reaction rate only depends on the concentration of reactants and rate constant."

Question four was about the roles of catalysts in chemical reactions. In group 1, no one could answer the question with the correct explanation. However, three participants from the group 1 selected the correct conception without giving any explanation. Therefore, whether or not they have alternative conceptions could not be identified. While one participant did not select any conception for the question, three participants responded correctly by giving incorrect explanations. When it was analyzed, two participants had an idea that "Catalyst decreases activation energy." and one thought, "Catalyst decrease the energy of the activation complex."

In question five, the effect of surface area on the reaction rate was studied. Among seven participants, even though five selected the correct explanation, only two explained their reasons correctly. On the other hand, it could not be stated that since 3 of them did not give any explanations, they had an alternative conception or not. Moreover, while two participants selected the wrong conception, among them, one did not make any explanation, their alternative conceptions were analyzed as “Since solid molecules in large pieces are more strongly bonded to each other compared to their crushed form, it is more difficult for them to react.”

In group 2, six students participated in the study. They took some pedagogical content knowledge courses such as Curriculum Development in Science Education, Methods of Science Teaching Courses, Assessment and Evaluation in Science Education, Laboratory Applications in Science Education and Teaching Practice I. Table 4.2 shows responses of group 2 students for each question.

Table 4.2 Answers of Group 2 According to Questions

	Question 1	Question 2	Question 3	Question 4	Question 5
No response		P8		P10	
False response					
False response and false explanation	P8				
Alternative Conception	As reactants are used up, the formation of product increases and accordingly the reaction rate increases (Çakmakçı, 2005).				

Table 4.2 (continued)

False response no explanation	P13	P9	P11, P12, P13		P12, P13
<i>Alternative Conception</i>	The reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).	Exothermic reactions occur faster than endothermic reactions (Çakmakçı, 2005).	P13, P11: Reaction rate only depends on the rate constant and molarities (Çakmakçı, 2005). P12: When the temperature is increased, rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003).		P12: Reaction rates are the same whether the reactant is granulated or powdered since the molarities are equal for both cases (Çakmakçı, 2005). P13: Surface area of reactants does not affect reaction rate (İcik, 2003).
Correct response					
Correct response but incorrect explanation				P8	P10
<i>Alternative Conception</i>				Catalyst decreases the activation energy.	Crushing the substances increases the amount of matter.
Correct response and correct explanation	P10, P11, P12	P10	P8, P10		P8
Correct response with no explanation	P9	P11, P12, P13	P9	P9, P11, P12, P13	P9, P11

In the first question, participants who took some pedagogical content knowledge courses were similar to the participants who did not take any pedagogical content knowledge courses in terms of the number of false responses. Among six participants, two could not give correct answers. On the other hand, one participant had a different alternative conception than the previous group: "Because the amount of product constantly increases, the reaction rate increases, too."

For the second question, Surprisingly, this group's (Group 2) participants showed worse performance than the Group 1 students. Although most of the group truly answered the question, among six participants, four answered correctly; one participant left blank; one participant gave a false response and thought, "Exothermic reactions are faster than endothermic reactions." It seems that taking pedagogical content knowledge courses did not affect the pre-service students' alternative conceptions in a positive way.

For the 3rd question, in this group, 3 participants gave the correct answer; among them, only one could explain it correctly while two of them did not give any explanations. On the other hand, the number of false responses was 3, less than the previous group, their alternative conceptions were more on the "Reaction rate only depends on the concentration of reactants and rate constant." than "When temperature increases, the rate of exothermic reaction decreases."

In question four, different from Group 1, no participants selected the wrong answer. On the other hand, there were no explanations for correct responses. While four students did not explain their correct conceptions, one could not select any conception. The number of participants in this group who selected the correct answer was higher than in the previous group. Surprisingly, one participant, even though they selected the correct answer, explained the reason wrongly. When it was analyzed, it was concluded that she had an alternative conception: "Catalyst decreases the activation energy."

For the last question, while only one participant could correctly explain her reason, two participants only chose the correct answer. There were two participants who selected the wrong conception without any explanation. When analyzed, in addition to "Since solid molecules in large pieces are more strongly bonded to each other

compared to their crushed form, it is more difficult for them to react.” alternative conception, one participant had the alternative conception of “Surface area did not affect the reaction rate since amounts and volume of substance are equal.” Surprisingly, a participant chose the correct conception; however, her explanation showed she had a different alternative conception: "Crushing the substances increases the amount of matter.” With this result, it can be concluded that even though students can decide on the correct answer, they may have an alternative conception, too. That is why it is important to examine their reasons.

Group 3 involved seven pre-service chemistry teachers who completed all PCK courses. Table 4.3 shows responses of group 3 students for each question.

Table 4.3 Answers of Group 3 According to Questions

	Question 1	Question 2	Question 3	Question 4	Question 5
No response					
False response					
False response and false explanation	P14			P16	
Alternative Conception	The reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).			Catalyst increases the average speed of the molecules (Kingir & Geban, 2006).	

Table 4.3 (continued)

False response no explanation	P15				
Alternative Conception	The reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).				
Correct response					
Correct response but incorrect explanation					
Alternative Conception					
Correct response and correct explanation	P16, P17, P18, P19, P20	P14, P16, P17, P18, P19, P20	P14, P16, P17, P18, P19, P20	P14, P17, P18, P19, P20	P14, P16, P17, P18, P19, P20
Correct response with no explanation		P15	P15	P15	P15

For question 1, although this group completed all the PCK courses, there was not much difference between the other groups. Among seven students, five students answered correctly and two could not identify correct response, and they had the alternative conception: "Unless factors such as concentration temperature, catalyst, etc. were not changed, reaction rate remains constant." Therefore, we cannot state that the completion of PCK courses had an effect on participants' alternative conceptions about the reaction rate-time graph ideas.

For the second question, all participants who completed all PCK courses identified the correct concept. Although one participant did not explain why, this result states that as pre-service teachers completed the PCK courses, their alternative conceptions decreased, even eliminated, in terms of the relationship between the activation energy, enthalpy and reaction rate.

For the 3rd question, all participants in this group could detect correct conceptions. Although one of the participants did not give any explanation for the answer, six of them explained it correctly.

In question four, it was obvious that when pre-service students completed PCK courses, their alternative conceptions were eliminated. Among the seven participants in this group, six could select the correct conception. Again, five of the participants explained their selection correctly, while one of them did not give any explanation. Interestingly, one of the participants chose the wrong answer in the group, and her alternative conception differed from the other groups' participants: "The catalyst increases the average speed of the molecules and therefore increases the energy of the activated complex."

For the fifth question, all participants had selected the correct conception. While six of them explained their reasons correctly, only one of them did not give any explanation.

However, it could be agreed that when preservice teachers completed PCK courses, their alternative conceptions of surface area and reaction rate relationship decreased.

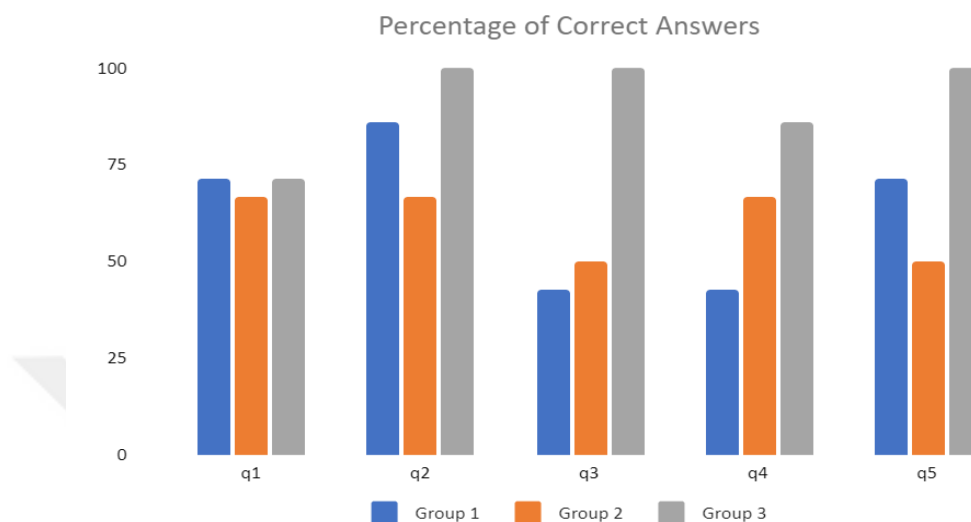


Figure 4.1 Overall Percentage of Correct Answers

The Figure above indicates the correct answer percentage of the group in accordance with questions. While the correct answer was computed, even though participants did not give an explanation, if they chose the correct conception, their answers were accepted correctly. This is because providing no explanation cannot determine whether or not they had an alternative conception. When the Figure was analyzed, it was clear that participants who took all PCK courses were the most successful group. Only for the 1st question, the percentage of correct answers was the same as the group who did not take any PCK courses. On the other hand, it is not expected that group 1, who did not take any pedagogical content knowledge courses, did better than the group 2 students, who took some pedagogical content knowledge courses. When analyzed, only questions 3rd and 4th had higher percentages for group 2 than group 1. Therefore, it can be concluded that when preservice teachers took some PCK courses, they got confused regarding the reaction rate time graph, enthalpy, activation energy, and surface area - reaction rate relationship. On the other hand, it was not a longitudinal study, and participants may have had different characteristic properties. Moreover, if

a final judgment could be established, all properties should be analyzed, and all participants should have been interviewed. In addition, group 1, with No PCK, was expected to perform worse. Participants in this group for the 3rd and 4th questions, where the effect of temperature and catalyst on reaction rate were analyzed, had much more alternative conceptions than other groups. When group 2 was analyzed on its basis, they had a quite stable performance. Unlike the other groups, the group 3 students who completed all PCK courses did not do well in the first questions, where reaction rate-time graphs were analyzed. However, again, they did not perform worse than other groups for this question. Therefore, it can be concluded that even though participants have their own characteristic properties, taking all PCK courses affects preservice teachers' conceptions of reaction rate in a good way.

4.1.2. Finding Alternative Conceptions and Methods Used to Eliminate Them

In this part, alternative conceptions that the participants detected were categorized. When it was analyzed, it was seen that alternative conceptions were generally from the students in the scenarios. Therefore, each alternative conception was numbered. Some participants stated that the correct conception was an alternative conception. That is why their responses were not recorded. Moreover, methods they used to eliminate alternative conceptions were examined and categorized. Each alternative conception was marked with its method. If participants did not explain their method, it was coded as NME, and no method was explained (NME).

Below table (Table 4.4) shows identified alternative conceptions and categorized the methods used by Group 1 participants to deal with cancel ACs according to questions.

Table 4.4 Methods used to Eliminate AC According to ACs for Group 1

	Methods:	Explanations	Animations	Simulation	Experimentations	Daily-Life Examples	Demonstrations of Video, Pic. vs	Video	Analogy	Drama	Discussion	Exemplification	No Strategy Explained
AC Number:	Question 1												
1	Many of the students assumed that as long as certain factors (e.g., temperature, concentration, or catalysts) were not altered, the reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).				P1, P4								P3, P5, P6

Table 4.4 (continued)

2	As reactants are used up, the formation of product increases and accordingly the reaction rate increases until all reactants are consumed where the reaction rate is constant. (confusion of the reaction rate and the amount of product) (Çakmakçı, 2005).	P1			P1, P4, P6							P3, P5, P7
Question 2												
3	Exothermic reactions occur faster than endothermic reactions (Çakmakçı, 2005).				P1, P6	P4						P3, P5
4	The faster a reaction, the more energy is released (Çakmakçı, 2005).				P1, P4	P4						P3, P5, P7

Table 4.4 (continued)

5	Bigger the activation energy, the faster a reaction occurs (Çakmakçı, 2005).	P1, P4			P1								P3, P5, P7
Question 3													
6	When the temperature is increased, the rate of the endothermic reaction increases but the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003).												P5
7	An increase in temperature (temperature change) does not affect (change) the rate of exothermic reactions. Since exothermic reactions release energy, they do not need energy to proceed and a rise in temperature would not affect the reaction rate (Çakmakçı, 2005).				P1, P4								P3, P5
8	A rise in temperature would not affect the reaction rate, because the reaction rate is independent of temperature. Reaction rate only depends on the rate constant and molarities (Çakmakçı, 2005).				P1								P3, P5

Table 4.4 (continued)

Question 4												
9	A catalyst speeds up only the forward reaction (Voska & Heikkinen, 2000).			P1								P5
10	Catalyst just reduces the forward activation energy and as a result they may reach the conclusion that the catalyst favors the yield of the product. (Hackling & Garnett, 1985; Garnett et al., 1995; Voska & Heikkinen, 2000; Çakmakçı, 2005).			P1								P5, P7
11	Catalyst increases the average speed of the molecules (Kıngır & Geban, 2006).	P1										P5
Question 5												
12	Reaction rates are the same whether the reactant is granulated or powdered since the molarities are equal for both cases (Çakmakçı, 2005).										P7	P3, P5, P6
13	Surface area of reactants does not affect reaction rate (İcik, 2003).	P1		P1								P3, P4, P5, P6, P7
14	Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).											P3, P4, P6, P7

In the first question, the participants stated two alternative conceptions. One was “Unless factors such as concentration, temperature, catalyst, etc. are changed, the reaction rate remains constant.” coded as AC1. The other one was “As the amount of product increases through the reaction, the reaction rate constantly increases,” which is AC2. Among seven participants, only five of them stated the AC1. Although this number seems high, while two indicated a method to eliminate alternative conception, three did not explain the technique. Additionally, for this alternative concept, two participants preferred to use experiments to eliminate the alternative conception.

Different from the AC1, AC2 was detected by six participants. On the other hand, the number of participants who did not explain their method was the same as the number of participants for AC1. While others chose the method of experimentation, one also indicated an extra method: explanation.

For the second question, participants indicated three alternative conceptions. The first was “Exothermic reactions occur faster than endothermic reactions.,” coded as AC3. The second alternative conception, categorized as “The greater enthalpy, the faster the reaction.,” was named AC4. The last one indicated as AC5 was “Reactions with higher activation energy have more kinetic energy in their molecules, so they occur faster.” When it was analyzed, only five participants could indicate the AC3. Among them, three did not explain how to eliminate this alternative conception; two chose the use of experiments. However, one indicated that the graphs, pictures, etc., were used to eliminate the alternative conception.

The number of participants who could identify the alternative conception, AC4, was the same as AC3. On the other hand, there were three answers without any method explained. Again, while two indicated the use of experiment to eliminate AC4, the same participant in the AC3 stated an additional method, and it was the demonstration of graphs, pictures, AC5 was stated with the same participants in

AC4, and the same three students did not propose any method to eliminate this AC. Different from the previous conception for the second question, two participants indicated the explanation method. It may be because this alternative conception is more challenging to be realized by students using experiments. Nevertheless, one participant who stated the explanation also chose to use the experiment. In the 3rd question, participants determined three main alternative conceptions. They were: "In exothermic reactions, as the temperature increases, the forward reaction rate decreases.", coded as AC6; "Exothermic reactions, since heat is released, do not require energy to continue, so temperature increase does not affect their rates.", coded as AC7; "Since the reaction rate depends only on the rate constant and the concentration of the reactants, temperature increase does not affect their rate.", coded as AC8. It was observed that the first alternative conception of this question was only identified by one participant, who did not explain any method. This result can be explained because only 3 participants answered the third question.

AC7 was the conception that could be determined by this group primarily for question 3. Although the number of participants who indicated the alternative conception was four, two did not explain their method. On the other hand, two participants chose to use an experiment to eliminate this alternative conception. Better than AC6, AC8 was indicated by 3 participants. While the same two participants in the AC6 did not state any method, only one could introduce the experiment method to eliminate this conception.

For question 4, participants were expected to find three alternative conceptions. These alternative conceptions were coded as AC9, AC10, and AC11. While AC9 indicates, "The catalyst changes the enthalpy of the reaction because it only lowers the activation energy of the forward reaction but does not change the activation energy of the reverse reaction.", AC10 shows, "Since the catalyst affects the rate of both forward and reverse reactions differently, it changes the product yield." and AC11 states "The catalyst increases the energy of the activated complex by increasing the average speed of the molecules." A few participants indicated AC9,

AC10, and AC11 in this group. While only two recognized the AC9, one did not explain any method, and one chose the experiment to eliminate it.

Better than AC9 results, one also could identify AC10. However, she did not prefer to explain her method.

When the last alternative conception for this question was analyzed, there was a change in the method chosen. Two participants could identify AC10. While one wanted to explain for the elimination of AC10, one did not suggest any method. In the end, alternative conceptions in this question were challenging for this group of participants to detect.

In question 5, there were three alternative conceptions. They were “Since the amount of substance and volumes are equal, the surface area does not affect the reaction rate.” “The contact surface has no effect on the reaction rate.” the last one was, “Since the molecules of MgO in large pieces are more strongly bonded to each other than in its crushed form, it is more difficult for it to react.” They were coded as AC12, AC13, and AC14, respectively. When the results were analyzed, it was seen that the number of participants was four out of seven for the first conception. On the other hand, although the number seemed moderate, only one participant indicated that the method was exemplification. The other three students did not propose any method to eliminate AC12.

Better than AC12 numbers, AC13 was identified by six participants. Although the number of participants reached four who did not indicate any method, one chose more than one method: experimentation and explanation. When it was analyzed, the participant who indicated these could not detect AC12.

Lastly, AC14 was indicated by only four out of seven participants. Unfortunately, unlike AC12 and AC13, nobody has explained any method to eliminate this concept.

As a result, it can be concluded that for all questions, detected alternative conceptions were not eliminated by choosing any method most of the time. When they indicated a method, generally, they selected the use of experiments as a method. It may be because they thought that experiments could eliminate alternative conceptions even though the subject was not available to them.

Table 4.5 below indicates the detected ACs, and methods preferred by Group 2 participants to eliminate ACs.

Table 4.5 Methods used to Eliminate AC According to ACs for Group 2

AC Number:	Methods:	Explanations	Animations	Simulation	Experimentations	Daily-Life Examples	Demonstrations of Video,	Video	Analogy	Drama	Discussion	Exemplification	No Strategy Explained
		Question 1											
1	Many of the students assumed that as long as certain factors (e.g., temperature, concentration, or catalysts) were not altered, the reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).	P8, P12			P9								P1 1

Table 4.5 (continued)

Question 3													
6	When the temperature is increased, the rate of the endothermic reaction increases but the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003).	P8, P9,	P8	P13			P9, P10					P11	
7	An increase in temperature (temperature change) does not affect (change) the rate of exothermic reactions. Since exothermic reactions release energy, they do not need energy to proceed and a rise in temperature would not affect the reaction rate (Çakmakçı, 2005).	P8				P9	P11					P12	
8	A rise in temperature would not affect the reaction rate, because the reaction rate is independent of temperature. Reaction rate only depends on the rate constant and molarities (Çakmakçı, 2005).	P9	P8	P13	P8, P9, P10, P13	P10						P9, P12	

Table 4.5 (continued)

Question 4												
9	A catalyst speeds up only the forward reaction (Voska & Heikkinen, 2000).	P9, P11		P9, P12				P13	P9			
10	Catalyst just reduces the forward activation energy and as a result they may reach the conclusion that the catalyst favors the yield of the product. (Hackling & Garnett, 1985; Garnett et al., 1995; Voska & Heikkinen, 2000; Çakmakçı, 2005).	P11, P12			P8, P13			P8			P11	P9
11	Catalyst increases the average speed of the molecules (Kıngır & Geban, 2006).	P9		P12			P11	P9				

Table 4.5 (continued)

Question 5												
12	Reaction rates are the same whether the reactant is granulated or powdered since the molarities are equal for both cases (Çakmakçı, 2005).			P9	P8, P9, P10, P12			P8				
13	Surface area of reactants does not affect reaction rate (İcık, 2003).				P8, P9, P10, P11, P12			P8		P11		
14	Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).	P8, P9, P11	P9	P10	P9, P13							

For this group, in the first question, alternative conceptions stated by the participants were the same number. Alternative conception 1(AC1) was realized by four out of six, similarly, four participants indicated the second alternative conception. For the first alternative conception (AC1), while two participants stated a method of explanation, one indicated the use of the experiment, and one did not explain any method. Therefore, the methods used by the participants differed from the previous group preferences. Although this group took more PCK courses than the previous group, their selection changed into being assumed to be a more straightforward method. This may be because participants realize that time management for the use of experiments is harder than the explanation method.

In the group, responses were scattered for AC2. While four participants could detect the AC2 from the six, the methods they wanted to use were explanation, use of experiment: analogy, and discussion. While each method was preferred by one participant, the explanation was chosen by two. This result was also different from the previous group's responses for AC2. That may be due to the fact that why taking PCK courses, especially methods courses may widen their horizons about the methods that can be used to eliminate alternative conceptions.

As indicated above, three alternative conceptions were coded as AC3, AC4, and AC5 for the second question. Unfortunately, only 3 participants could indicate the AC3. This number for AC3 was less than the previous group. However, one participant indicated more than two methods: explanation, discussion, and demonstration of graphs and pictures. While one wanted to eliminate conception using experiments, one did not make any explanation.

AC4 coded for the second question could be detected by four participants, which was more than AC3. However, two participants chose the explanation method this time, and one did not explain anything. Additionally, and interestingly, the same participants who used the same methods in the AC3 preferred the same methods in the elimination of AC4. To illustrate, one person who indicated experimentation, and the other who

decided the explanation, discussion, and demonstration of graphs and pictures before, indicated the same ways again in the AC4, too. For AC5, the number of participants who could recognize the AC5 was three, less than the number for AC4. Two chose the use of explanation, one chose discussion, and one did not choose any method; one participant stated an additional method coded simulation. Also, no one preferred experimentation. This may be because one who decided on the experimentation in AC4 could not suggest this conception.

For the 3rd question, this group did not state any additional alternative conceptions to coded ones AC6, AC7, and AC8. Different from the previous group, although the number of correct responses was the same, AC6 was identified by five out of six participants. Therefore, they were successful in recognizing this concept. When the study was analyzed deeply, two participants chose the video method, and one participant indicated the use of the experiment. While one did not explain any method, one chose simulation. Moreover, two participants who chose the simulation and video indicated they would also use the explanation method. This indicates that their ability to detect alternative conceptions increased as pre-service teachers took PCK courses.

Unlike the previous group, AC7 was determined by most of the group members. On the other hand, responses for methods were spread. While all participants indicated only one technique, methods were chosen: explanation, demonstration of graphs and pictures, daily life examples, and exemplification. The last two methods were suggested for the first time in this group.

AC8 results were better than AC7 numbers. While five participants could detect the alternative conception to eliminate it, four chose two methods. Methods of explanation, animation, simulation, and daily life examples were shown only once. However, exemplification was stated two times, while the use of experiment was stated four times. Therefore, most of the participants in this group believed that eliminating AC8 could be possible using experiments rather than other methods.

In question 4, more participants in this group detected AC9 compared to group 1. Four participants recognized AC9 out of six. One participant indicated three methods: analogy, simulation, and experiment. Others, however, chose only one method: video,

explanation, and simulation. As a result, the methods of simulation and explanation were indicated twice, making these the mostly stated methods.

The number of participants who could indicate the AC10 in group 2 increased compared to group 1 students. Five out of six participants could identify this alternative conception. Indicated methods also changed. While two preferred the use of experiments, one chose exemplification. Two participants preferred to explain the concept, the other wanted to show a video, and the other did not describe any method.

The number of participants who indicated AC11 was less than AC10 in the group. Only four participants recognized it. Different methods were preferred only once: explanation, simulation, demonstration of graphs, pictures, and video.

For the 5th question, alternative conceptions detected were the same as the previous group and coded with the same numbers. On the other hand, in AC12, this group could be assumed to be more successful than group 1 since there were no participants who did not explain their methods. Four participants identified AC12. While four participants proposed the use of experiment, one of them also indicated the use of simulation. Only one participant chose the video demonstration.

The result of AC13 was much better than AC12 in terms of numbers. While six participants could detect the conception, five proposed the use of the experiment as a method. From them, while one indicated video demonstration, the other one chose the discussion method. Unlike the group that preferred the use of the experiment, only one student preferred the explanation method.

Finally, AC14 could be detected by five participants, and, one participant chose animation, and one chose simulation. Additionally, the use of experiments was preferred two times while explanation was chosen three times.

To conclude, it could be stated that, different than the previous group, participants in group 2 tended to select different methods to eliminate conception. There were fewer participants who did not explain any method when they could determine the alternative conception. This could be because of the positive effect of taking some PCK courses.

Table 4.6 below shows the detected ACs, and methods used by Group 3 participants to eliminate ACs.

Table 4.6 Methods used to Eliminate AC According to ACs for Group 3

	Methods:	Explanations	Animations	Simulation	Experimentations	Daily-Life Examples	Demonstrations of Video, Pic. vs	Video	Analogy	Drama	Discussion	Exemplification	No Strategy Explained
AC Number:	Question 1												
1	Many of the students assumed that as long as certain factors (e.g., temperature, concentration, or catalysts) were not altered, the reaction rate would remain constant or remain the same during a reaction (Çakmakçı, 2005).	P18, P19											P15, P17, P20

Table 4.6 (continued)

2	As reactants are used up, the formation of product increases and accordingly the reaction rate increases until all reactants are consumed where the reaction rate is constant. (confusion of the reaction rate and the amount of product) (Çakmakçı, 2005).	P14	P16		P16, P19		P18 , P19						P17, P20
Question 2													
3	Exothermic reactions occur faster than endothermic reactions (Çakmakçı, 2005).	P14	P16	P18, P19	P14, P16		P19	P18					P17, P20
4	The faster a reaction, the more energy is released (Çakmakçı, 2005).	P14 , P18	P16		P16								P17, P19, P20
5	Bigger the activation energy, the faster a reaction occurs (Çakmakçı, 2005).	P19						P18 , P19					P17, P20

Table 4.6 (continued)

Question 3												
6	When the temperature is increased, the rate of the endothermic reaction increases but the rate of the exothermic reaction decreases (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003).	P14		P19	P14, P18, P19	P20						P15, P17
7	An increase in temperature (temperature change) does not affect (change) the rate of exothermic reactions. Since exothermic reactions release energy, they do not need energy to proceed and a rise in temperature would not affect the reaction rate (Çakmakçı, 2005).				P14				P18, P19			P15, P17, P20
8	A rise in temperature would not affect the reaction rate, because the reaction rate is independent of temperature. Reaction rate only depends on the rate constant and molarities (Çakmakçı, 2005).	P18, P19			P14					P19		P15, P17, P20

Table 4.6 (continued)

Question 4											
9	A catalyst speeds up only the forward reaction (Voska & Heikkinen, 2000).	P14	P16	P16		P18 , P19					P15, P17, P20
10	Catalyst just reduces the forward activation energy and as a result they may reach the conclusion that the catalyst favors the yield of the product. (Hackling & Garnett, 1985; Garnett et al., 1995; Voska & Heikkinen, 2000; Çakmakçı, 2005).			P14	P16	P18 , P19					P17, P20
11	Catalyst increases the average speed of the molecules (Kıngır & Geban, 2006).	P14					P18 , P19				P17, P20
Question 5											
12	Reaction rates are the same whether the reactant is granulated or powdered since the molarities are equal for both cases (Çakmakçı, 2005).			P14, P18		P19					P17, P20
13	Surface area of reactants does not affect reaction rate (İcik, 2003).	P14	P18	P14, P16, P18, P19		P19					P17, P20
14	Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones (Çakmakçı, 2005).	P14	P18			P19					P17, P20

For the 1st question, different than the other groups, in addition to the same two alternative conceptions, one stated a different alternative conception. It was: “During the reaction between A and B gases, only A or B is consumed.” To eliminate this AC, the participant preferred to use two methods: animation and conducting an experiment. Moreover, for the detection of AC1, the results were the same as those of the first group. Among seven participants, five could recognize it. Again, the same happened with the 1st group; while three did not explain their technique to eliminate AC1, two introduced a method. However, this differed from the 1st group, which was the explanation. Again, the same as group 1, AC2 could be detected by six out of seven participants. Two participants chose two methods at the same time. One chose animation and conducting an experiment; the other chose the use of experiment and demonstration of graphs, pictures. Using animation and demonstrating graphs, pictures were indicated for the first time in this group.

In the second question, alternative conceptions detected by this group were the same as the other groups and coded the same. When analyzed, six of the group members could identify the AC3. While two of them did not explain their methods, others chose two methods. Conducting experiments and simulations were selected by two participants. The other methods, explanation, animation, demonstration of graphs, pictures, etc., and video were indicated only once. When it was analyzed, it was concluded that participants who chose two methods indicated them as an alternative. Only one student who chose the use of experiment and explanation thought to use methods simultaneously.

Similarly, AC4 was indicated by six participants. However, methods to eliminate this alternative conception were less split than AC3 methods. While three participants could not identify any methods, two chose the explanation method. Also, one student preferred the use of experiment and animation to

eliminate AC4, and this person chose the same methods for the elimination of AC3.

On the other hand, for AC5, four participants could identify it. On the other hand, participants chose methods different from AC3 and AC4. While the same two people did not prefer to indicate their methods, the two students chose analogy. One participant stating the analogy as a method also chose the explanation method. That student seemed to use explanations to improve the effect of analogy. In the end, only four participants out of seven could identify this alternative concept, and it can be assumed as a low performance for the group who completed their PCK courses.

For the 3rd question, different from other groups, there was an additional alternative conception stated by a participant who also declared an additional alternative conception in question 1. This conception was that “Temperature does not affect the rate directly.” To eliminate this alternative conception, the participant indicated the method of conducting an experiment and explanation.

When AC6 results were analyzed, it was seen that although six participants could detect it, four could propose a teaching method to eliminate it. While conducting an experiment was the method chosen by the three participants; only one participant indicated explanation, simulation, and demonstration. Additionally, two participants did not explain their techniques. On the other hand, the difference between this group and group 1 was crystal clear. Therefore, taking PCK courses makes pre-service teachers positively realize this alternative conception.

For AC7, only one participant could not identify this alternative conception. However, there were three participants who did not demonstrate any method. While one chose an experiment, two participants indicated a new method called drama. Introducing the drama shows that completing PCK courses affects preservice teachers, enhancing their knowledge about different instructional methods.

The last alternative conception for this question, AC8, could not be indicated by only one student in this group. From the participants who did not explain their methods and chose an experiment to eliminate the AC7, two of them changed their minds and introduced an explanation method, and one of them decided on a discussion method. This type of change is valuable since preservice teachers, as they complete PCK courses, their knowledge of methods increases, and they can decide on a technique according to alternative conceptions.

For the 4th question, the number of participants who could identify AC9 was much better than other groups. All the group 3 participants could detect this alternative conception. On the other hand, three of them did not indicate how to eliminate this alternative concept. Two participants stated a demonstration of graphs, pictures, etc, and one indicated two methods, which were conducting an experiment and simulation. On the other hand, one only chose an explanation method to eliminate conception.

When AC10 results were analyzed, it was seen that six out of seven participants could detect alternative conception successfully. While the same two participants wanted to eliminate conception by demonstrating graphs, pictures, etc., conducting an experiment was chosen by a different participant. Additionally, one suggested giving daily life examples, and two did not state any method.

The number of participants who could detect the alternative conception AC11 was different from AC10 in the group. Five could identify it. While the same two did not propose any method, interestingly, two participants chose the analogy technique. However, one also indicated the explanation method.

In question 5, alternative conceptions identified by this group were the same as other groups, so they were coded as AC12, AC13, and AC14. There were five participants who could identify the alternative conception; however, this group has seven participants, and two of them did not explain their method even though they detected the conception. Two participants indicated the method of conducting experiments, but differently; one chose the demonstration of graphs and pictures.

From seven participants, six could state the AC13. On the other hand, while the same two did not explain their methods to eliminate this alternative conception, one of the participants indicated the demonstration of graphs and pictures for AC13, and this participant also stated the same in the elimination of AC12. Additionally, one chose an explanation, and one selected the simulation method. Also, these two wanted to use experimentation methods with the other two participants. As a result, most of the indicated methods to solve the alternative conception in this question were conducting experiments.

In the last conception, AC14, there were five participants who could detect it. Not surprisingly, the same two participants in the AC13 did not explain their method, and the same ones chose explanation, simulation, and demonstration of graphs and pictures separately.

As a result, when the table was investigated, the same participants tended to choose the same methods, and the same ones avoided explaining their way of eliminating conceptions. On the other hand, it could be seen that the distribution of selected methods increased when participants completed all PCK courses.

Figure 4.2 below shows the percentage of groups that could identify the alternative conceptions in the questions.

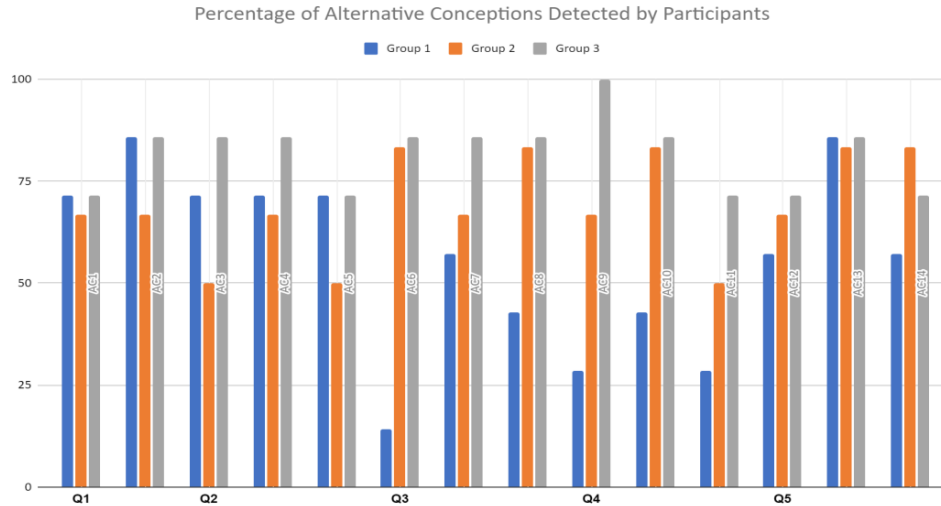


Figure 4.2 Percentage of Detected Alternative Conceptions by Groups

When analyzed, the percentage of detecting ACs for the group 3 was much higher than that of other groups. However, some percentages changed interestingly when it was examined question by question. For question 1, there were AC1 and AC2. These conceptions were identified by the exact percentages of group 1 and 3. What is interesting is that the percentage of group 2 students who took some PCK lessons did not identify as well as group 1 students who did not take any PCK courses. Additionally, it was seen that AC2 was more accessible to detect than AC1 for the group 1 and group 3. However, the performance of group 2 was constant.

In question 2, conceptions were coded as AC3, AC4, AC5. When they were investigated, percentages of AC3 and AC4 were the best in group 3 students who completed all PCK courses. However, for AC5, group 1 students who did not take any PCK courses reached the performance of group 3. Although it was expected that group 2 should be between the group 1 and group 3, it got behind them. Additionally, while the group 3 students showed the same high performance in AC3 and AC4, they could not identify AC5 as well as others.

On the other hand, group 2 students had the best performance for AC4 in question 2. Group 1 students performed the same in all conceptions for the second question.

AC6, AC7, and AC8 were the alternative conceptions coded for question 3. For all alternative conceptions, while group 3 students who completed all PCK courses indicated the best performance, the performance of group 2 students who completed some PCK courses, was between group 1 and group 3 students. However, group 1 students had the worst performance in identifying alternative conception AC6 among all alternative conceptions. Other than that, while the percentage of detected alternative conceptions for question 3 was the same in group 3, Group 2 performed better for identifying alternative conceptions AC6 and AC8 than AC7. However, detecting AC7 was easier than finding AC6 and AC8 for the group 1 students.

The same best performance was displayed by group 3 in question 4, where alternative conceptions were coded as AC9, AC10, AC11. Moreover, as it was expected, the worst percentages were obtained by group one students who took no PCK courses. When results were analyzed according to the groups, it was seen that all group 3 participants indicated the AC9, while their performance decreased from the AC10 to AC11. On the other hand, AC10 was the concept that was performed best by the other groups, which were group 1 and group 2.

In the last question, coded as AC13 and AC14, were not displayed best by the group 3. Only AC12 could be identified better by group 3 students than other groups. In AC14, group 2 had the best percentages. Additionally, it was stated that participants in this group had same percentages in the AC13 and AC14 conceptions. Lastly, the group 1 and group 3 showed the best performance in AC13 for the 5th question.

To conclude, it could be said that the best percentages for most of the alternative conceptions have been shown by the group 3 students who completed all PCK

courses, while the 2nd and 3rd group changed from time to time. Moreover, AC9 was detected by all group 3 students who completed all PCK courses, AC6, AC9, and AC11 were not identified as good by the group members of the group 1.

In order to display what participants preferred to choose methods to eliminate alternative conceptions, the below figure (Figure 4.3) was created.

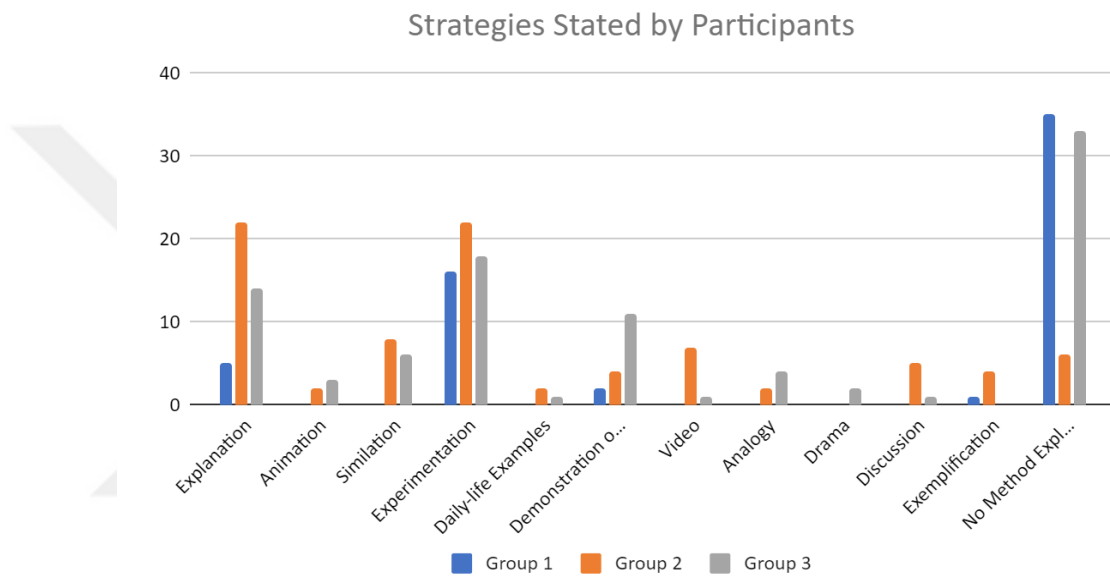


Figure 4.3 Methods Indicated by the Groups for the Eliminations of ACs.

According to this figure, at first sight, most of the participants preferring a method indicated the method of explanation and experimentation. These are the methods that came to mind first. Since explanation is the easiest and most direct way to explain why their conceptions are not true, participants would choose this way. Other than that, experimentation is another preferred method because chemistry means experimenting for most of the students and they could think teaching students' chemistry is easier by use of experiments. When these two methods were analyzed on their own merits, they were selected by group 2 most. The Number of people choosing these two methods was the same. After group 2, group 3 preferred to indicate explanation and experimentation. However, this group indicated the experimentation more than explanation. Even though group 1 selected the method of explanation and experimentation less than other groups, when it was examined, their first choice was experimentation, and second was explanation. Moreover, most of the group 1 students did not state any method. Although number of group 3 students who did not indicate any method was less than group 1, it was still high. Additionally, just to clarify, group 1 also went with demonstration of graphs, pictures, etc. and exemplification methods. However, these numbers were very low according to the previous two methods and no explanation method. The distributions of methods chosen by group 2 and group 3 were much higher. It can be stated that group 2 and group 3 indicated every method mentioned in the table at least once. However, while group 2 did not select drama technique, group 3 did not prefer exemplification to eliminate conception. However, these results indicate that taking PCK courses increased the preferences of pre-service chemistry teachers to eliminate alternative conceptions. Their knowledge and options to deal with alternative conceptions became distinct from experimentation and explanation.

4.1.3 Analysis of Interviews

In addition to questionnaires, in each group, two participants were selected and interviewed to understand how they thought about alternative conceptions in questions and wanted to eliminate them by using methods in detail. In group 1, both interviewed students did not take any PCK courses in their education. Students were coded as

Participant 1 (P1) and Participant 6 (P6), In group 2, Participant 8 (P8), and Participant 11 (P11) completed some of the PCK courses such as methods courses, teaching practice I. Lastly, in group 3, Participant (14), and Participant (16) took all PCK courses.

4.1.3.1 Identifying Alternative Conceptions of Participants

In question 1, group 1 answers for the correct conception were different. While Participant 6 (P6) selected the correct conception, Participant 1 was not successful. She selected the wrong explanation but was unsure about her decision. Although she knew she might be wrong somewhere, she could not explain why she chose the false choice. She said, "The concentration also changes during the reaction. There is a certain amount of substance, which may decrease over time, so the reaction rate may slow down. But does this concentration also include what happens during the reaction, or do we consider this, or do we not? I could not perceive that part, so the second one seemed more logical then." Even though Participant 6 (P6) indicated the correct conception, she did not explain why her choice was correct. She thought of the reaction equation as an equilibrium reaction, and after some time, although the amount of reactant decreases at the end, concentration becomes an equilibrium point and stays constant. She said: "As reactants entered the reaction, the concentration decreased, reaching equilibrium at some point. Because it reached equilibrium, well, perhaps we could not see this because it is a more microscopic event. As far as I know, the rate eventually stabilized for the reactants. A reverse graph was also formed for the products. I remember they were equalizing at some point." That is why even though the participants choose the correct answer, they might think differently and may have an alternative conception, too.

In the second group, different from the general answers, Participant 8 (P8) indicated the different conception as a correct explanation. She stated, "Because of the rate equation, the reaction rate must increase as time passes." Although she took some of the PCK courses, she got confused about the rate of the equation, so she chose the false explanation. She thought that in the rate of equation, concentration of products was

used, not the reactants. On the other hand, she realized that she might be wrong somewhere at the end of the interview. By asking questions herself, she decided on a correct conception.

Participant 8 (P8): It seemed to me that I might have made a mistake regarding the rate constant in the first question.

P8: I had mentioned that I would show the reactants in the equation. I had considered the equilibrium constant there, but I remember we were writing the reactants and the rate constant. That is why I got confused. Either my previous answer is wrong, or the current one. I do not know anymore, but I remember writing the reactants because I recalled writing something like $k[A]$. $[B]$.

Researcher(R): So, does that mean Meltem's answer here was not correct?

P8: Yes, Meltem's answer was not correct.

R: Then what would be the correct answer here?

P8: I am currently thinking about it. Actually, I believe Kerem's answer is correct. I had previously stated it as a conceptual mistake, but because when we multiply k , which represents the constant speed, a is also included, and the change decreases gradually. Since k is constant, I think both the concentration of a and the speed will decrease.

R: So, you said Kerem was right, and Meltem was wrong.

P8: Yes.

As a result, even though she selected the wrong conception in the questionnaire at the beginning of the interview, she has been grappling with and engaging with what has been bothering her and found the correct answer by utilizing the formula.

Additionally, Participant 11 (P11) could demonstrate the correct conception and was confident about her decision.

In group 3, the results were interesting too. Participant 14 (P14) indicated that the false conception was correct. However, when investigated, it was understood that she thought, like Participant 1, the reaction was an equilibrium reaction. On the other hand, she could not select the correct conception. She thought the rate must be constant since it is an equilibrium reaction. During the interview, even though she realized there was no equilibrium, she did not change her answer. She said, "I believe that even if the concentration decreases, the rate does not decrease." Lastly, Participant 16 (P16) could indicate the correct conception pertinaciously.

For question 2, all participants could select the correct conception in the questionnaire. Group 1 students gave correct explanations during the interview. For example, Participant 6 (P6) indicated her reason precisely. She said, "To enable a reaction to occur, an activation energy needs to be surpassed. As the student also mentioned, it does not depend on whether the reaction is exothermic or endothermic. I know that the lower the activation energy, the faster the reaction can proceed." However, there was an exception between the participants. Surprisingly, Participant 8 (P8) in group 2 did not explain the proper conception in the questionnaire. When asked about her explanations during the interview, it was realized that she had alternative conceptions of this subject, too. She did not know what activation energy and threshold energy actually are. She indicated the correct conception as an alternative conception.

P8: I could not clearly identify the alternative conception here. I also could not pinpoint the correct answer precisely because I also have some conceptual misunderstandings regarding these matters.

R: Okay, is there a correct answer you can give now?

P8: Unfortunately, I could not.

R: Then you mentioned that as a conceptual misunderstanding, Melisa might be confusing the threshold energy and activation energy. Are threshold energy and activation energy different things?

P8: Right now, it feels like I have given a very wrong answer. I could not decide the definition I consider it as the minimum energy required for a reaction, the threshold energy. And when I think of activation energy as a definition, it is like, you know, something a bit more. These words are different, but actually, they seem to lead to the same point. So, it is like I feel like I might have made a mistake here.

As a result, she did not decide whether she was true and wanted to skip the question. On the other hand, group 3 students explained question 2 correctly during the interview.

In question 3, all the participants in group 1 gave incorrect explanations during the interview. Participant 1 indicated the false conception as the correct answer. It was because she thought the reaction was an equilibrium reaction again, so when temperature increases, since it is an exothermic reaction, the rate will decrease. Additionally, and surprisingly, even Participant 6 (P6) chose the correct conception in the questionnaire; when she was interviewed, she changed her mind and thought as Participant 1. She said, "In exothermic reactions, heat is released in the products. Therefore, if we increase the temperature, the reaction should shift to the left. Consequently, the speed decreases, essentially." As a result, this demonstrates that even if questionnaires are answered correctly, participants may not be sure about their decision, so they may have an alternative conception. The opposite could also be encountered. While Participant 8 (P8) chose the correct conception, Participant 11 (P11) indicated a false explanation for the proper conception in the questionnaire. However, during the interview with Participant 11 (P11), it was observed that her opinion was changed in the right direction. She said: "The increase in temperature affects the reaction rate because as the kinetic energies increase, the interactions also increase. Yes, actually, what Akin said currently seems to me like a more reasonable

answer." Therefore, all the participants in group 2 explained this question correctly during the interview. Likewise, in group 3, both participants unwaveringly indicated the correct explanations during the interview. They used the same explanations in the questions scenario.

For question 4, all participants demonstrated the correct conception by sure except participant 6 in the questionnaire. For example, when asked Participant 6 (P6) about her decision, she indicated: "I don't think the catalyst would change the product yield because it lowers the activation energy, allowing the reaction to proceed faster. Does it also change the reaction enthalpy? If it is an endothermic reaction, do we need to reduce the heat we provide? I do not remember. Only the relationship with speed is what I recall. So, I believe my answer is correct." On the other hand, Participant 6 mentioned her alternative conception: "I used to think that the catalyst lowered the energy of the activated complex, but I learned in class that the catalyst actually prefers the lower energy pathway. Therefore, I chose the option: 'The use of a catalyst in a chemical reaction changes the activation energy because it speeds up the reaction process by increasing the reaction rate.' Although she knows the exact reason behind the catalyst increase the rate, she could not indicate the correct response in the questionnaire.

Question 5 was about the effect of surface area on reaction rate. When interviews were analyzed, it was seen that all participants in all groups had mastery over the subject. They indicated the correct conception. They did not even doubt it and used the same explanations in the scenario.

4.1.3.2 Determining Alternative Conceptions and Chosen Methods

4.1.3.2.1 Question 1 Chosen Methods

For question 1, there were two alternative conceptions that needed to be detected. These were AC1 and AC2. In group 1, Participant 1 detected both of them and stated the use of conducting experiments as a method irrespective of the alternative

conceptions. To illustrate, AC2 was about the increase in reaction rate due to an increase in the reaction product. Though participant 1 suggested the use of experiments, she could not describe the experiment in detail:

We can only conduct a single experiment without altering the variables. So, I had thought that while the amount of reaction increases, the product amount would also increase accordingly, but the reaction rate would either remain constant or decrease, meaning it would not increase.

She mentioned that she preferred the use of experiments to eliminate alternative conceptions since she would learn better by experiencing the event with the help of experiments rather than the explanation of the event orally:

When I usually give my answers, I have followed the path of experimentation. I prefer to see through experimentation because it is the most effective method, even for myself. Explaining something verbally does not always suffice for understanding. Experiencing it individually and witnessing the moment of the development of the event seems more practical.

Similar to Participant 1, Participant 6 (P6) mentioned the use of experiments to get rid of AC1 and AC2. To illustrate, she explained the experiment she would use to eliminate AC2:

R: So, you said you would explain this through experimentation.

P6: Yes. For example, in a task where they can observe the reaction, like putting sodium into water. You know, in small pieces. But here, we will not be able to see the product.

R: Putting sodium into water?

P6: Yes.

R: Do you know how this reaction occurs?

P6: I do not remember, but it was a swift idea.

R: It came to your mind very quickly, so I asked.

P6: No. In the lab, it was entering into the reaction very quickly. So, seeing this reaction might be more beneficial for the student. It is a combination of sodium. They may not see the product, I do not know, but they can see the reaction slowing down gradually. As the product increases, the speed should increase; it should accelerate. But we see that it is slowing down. This way, at least, we can change the misconception.

Although she indicated the use of specific experiments for the elimination of alternative conceptions, the experiment that she illustrated was not appropriate for the classroom conditions and for the alternative conceptions. Because it is known that the reaction between sodium and water is too fast to observe.

For the 1st question, Participant 8 (P8), member of group 2 could not identify the AC1 at first sight. However, she indicated the explanation method to eliminate alternative conception that she thought as an alternative conception, but it was the correct conception. When she realized the AC1 at the end of the interview, she again wanted to explain conception by using a rate equation. In the same reason, it could be stated that Participant 8 (P8) could not detect AC2 at the first sight, however at the end of the interview, she came to result and used explanation method to eliminate AC2 again.

Although Participant 11 (P11) did not explain any method for the AC1 in the survey, when she was interviewed, she preferred using simulation on the Internet.

Participant 11 (P11): So, I can demonstrate this through a simulation.

R: What kind of simulation could it be?

Participant 11 (P11): Well, it could be a simulation showing the decrease of substances A and B over time as they react to form substance C, indicating that

the desire for interaction between A and B decreases as they diminish, just like in the initial stage.

R: I see. Is there a simulation website you could use for this purpose?

Participant 11 (P11): There was something like a 'Science Lab', where you could create your own animations or simulations, but I cannot recall its name.

As a result, even though she did not know the exact simulation for this AC, she introduced the simulation that could be created.

For the AC2 however, she stated the explanation method. On the other hand, when she asked whether the only explanation was enough for eliminating alternative conception, she decided on using simulation additionally.

R: So, would just the explanation method be enough to dispel this misconception?

Participant 11 (P11): Actually, the simulation I used in the previous misconception might also help with this one simultaneously.

R: So, are you using the simulation first and then explaining?

Participant 11 (P11): Actually, because the student's mind is probably perplexed here, I would explain first. Once it is clarified in their mind, they watch the simulation, and afterward, I explain again.

Thus, she could not give up on explaining the conception.

Similar to Participant 11 (P11), Participant 14 (P14) could not detect AC1, but she preferred to use the explanation method for the correct concept she considered as an alternative concept. When she was asked why she chose the explanation method over other methods, she expressed that the subject matter could not be understood by other methods since it was not suitable.

R: So, are you only going to rely on the explanation for this question? Do you think students' alternative conception can only be eliminated through explanation alone?

P14: If I could conduct experiments, I would, but I have not thought of a suitable experiment for this. I could not imagine how to measure the speed, for instance. So, unfortunately, I will have to explain it to the students.

R: Okay. If I were to ask you why you chose this method?

P14: Normally, it is because I want to eliminate alternative conceptions, for example, I could use conceptual change or inquiry-based methods, but I did not see an opportunity for inquiry-based learning in this case, so I would probably stick with just explaining.

R: So, is it because you cannot use inquiry-based methods due to the complexity of the topic?

P14: Yes, because I cannot implement inquiry-based learning here.

R: I see. Do you think the method you described, the explanation method, would be effective? Can it help students correct their alternative conceptions?

P14: It might not be very effective, honestly.

Consequently, even though she thought that just the explanation method is not as effective as other methods, she indicated using explanation because of the topic. Additionally, Participant 14 (P14) had teaching experience. When she mentioned the inquiry and conceptual change methods in the interview, she was asked how her experience affected the methods she wanted to use to eliminate alternative conceptions.

R: Okay. So, let me ask you this. Would you have given different answers if you did not have teaching experience? Could you have said you would use inquiry-based methods?

P14: Well, since I did not have teaching experience, I had not taken any internship courses. I was focused on solving problems with the students then, so I would not have considered using inquiry-based methods. But I realized this when I was giving private lessons. When you encourage students to question things themselves, like what if it were like this, or would it work like that, or when I showed them experiment videos about alternative conceptions, it worked better. So, because of my private tutoring experience, my experiences contributed, especially in using different methods.

Different from the P14, Participant 16 (P16) indicated the experimentation and simulation methods for AC2. However, she did not just say experimentation and simulation. She also indicated why experimenting and simulation are effective for understanding. Also, she mentioned the importance of data collection and inquiring through the methods.

R: So, is there a specific reason for choosing experiments or simulations?

P16: Of course, because they are discovering by observing themselves. So, instead of just coming out of my mouth, the sentence will imply how wrong their alternative concepts might be, and maybe even though I would explain, ultimately their own discovery, observing in the experiment, observing in the simulation, collecting data, and so on, make it more permanent learning.

R: So, during the experiment, you will not just show the experiment, you will also include data collections, as far as I understand.

P16: Exactly, during the experiment, constantly pausing to ask questions or waiting for data collections, asking questions to control their observations, maybe even prompting them to write hypotheses at the beginning. Eventually, the hypothesis can be confirmed. So, rather than just showing the experiment directly, it may be necessary to ask questions to guide them more.

R: So, does not this seem a bit like drifting into argumentation?

P16: Exactly.

R: Okay. If I were to ask why you chose this method?

P16: That is how I learned it, and it is not very possible to do 5E and argumentation without using animation, and simulation experiment videos. It is difficult to implement the exploration part. Actually, the best place to do it is in experiments and simulations, where students are most engaged, can obtain data in the end, and can discuss it. Other than that, I cannot even think of areas that are more visual, more experimental simulation style, and involve data collection. I have always preferred this in lesson presentations because, as I mentioned, it enables more permanent learning, and they interpret according to their data. So, having something in their hands, interpreting based on that, and discovering the nature of science in this way, it all comes together.

4.1.3.2.2 Question 2 Chosen Methods

For question 2, there were three alternative conceptions, AC3, AC4 and AC5. Participant 1 could detect all the alternative conceptions. As a method to eliminate these alternative conceptions, P1 mentioned either the use of explanation or experiments. To illustrate, to eliminate AC3, that was “Exothermic reactions occur faster than endothermic reactions.”, she stated that would use an experiment about two different reactions. When asked about another strategy that may be used instead of experiment, she gave the following explanations:

R: You have always mentioned experiments. Can you think of another method apart from experiments?

P1: Well, since I have not taken a course on methods, the only thing I know for now is to demonstrate through experiments or explain verbally. So, I generally wrote that. Because nothing else came to mind.

The above excerpts reveal that one of the reasons that affected her choice was that she was not aware of the methods since she did not take any PCK courses. She knew either explanation of the topic or conducting experiments related to the topic. To illustrate, in order to eliminate AC5, that was about the assumption of threshold energy as kinetic energy. She stated that she would use the explanation method first and then conduct an experiment. She explained her reasoning about her choice of explanation method in the interview: "So, are there any other methods that are both easier and available, I do not know. I mean, I either lecture or conduct experiments, I just cannot think of anything else, honestly."

Similar to P1, Participant 6 (P6) could detect three alternative conceptions, AC3, AC4 and AC5 and she stated the use of experiments to eliminate AC3 "Exothermic reactions occur faster than endothermic reactions" and AC4, that was "rate of reaction depends on enthalpy". To eliminate AC4, P6 gave explanations during interview regarding the use of experiment:

So, for example, both exothermic and endothermic reactions can be demonstrated using sodium. In both cases, 5 grams can be used. The solutions may vary. In one, we carry out the reaction by heating it, while in the other, it reacts on its own and releases heat. I would demonstrate this to the students. If we can also show that they occur simultaneously, we can clear up the confusion in their minds in about 5 minutes.

In order to eliminate AC5, different from P1, P6 suggested the use a diagram or graph:

P6: I see that students do not understand the concept of activation energy from their responses. Although the energies of reactions are provided, their interpretations lean more towards enthalpy rather than focusing on activation energy. They have interpreted it more in terms of exothermic or endothermic reactions. Therefore, they have not fully grasped what activation energy is actually used for. They see 'activation energy' written there, but they do not understand its purpose. That is why I think showing something like a diagram

would be more beneficial. I believe it would be more accurate to solve it with more visual methods.

R: So, you are talking about a graphical representation, I suppose.

P6: Yes.

Participant 8 (P8), however, could not identify any alternative conceptions. Additionally, she knew she had an alternative conception too; therefore, she could not indicate any method to eliminate AC3, AC4 and AC5.

Different from Participant 8 (P8), Participant 11 (P11) could indicate AC3, AC4 and AC5. When she was asked how to eliminate them, she gave different options for different alternative conceptions. For instance, for AC3, Participant 11 (P11) indicated the explanation and demonstration of potential energy and activation energy graph. In addition to this, when effectiveness of these methods was asked, she added an analogy example without realizing. She mentioned that she can give an example from daily life. She said:

Participant 11 (P11): I can also explain it to students through an exemplification. For example, imagine I want to brew some tea, but instead of putting boiling water directly into one kettle, I put cold water into another. The water in the kettle with cold water needs to boil first, and then the tea can start brewing, whereas the tea starts brewing immediately when I pour boiling water. In reality, both teas need 30 minutes to brew, but in one case, the water needs to boil first. So, there is this difference, and I use this example to illustrate it.

R: I see. So, it is a bit like an analogy, isn't it?

Participant 11 (P11): Yes.

R: Okay. So, what do you pay attention to here? I mean, you are making this analogy, but I remember there are some rules to using analogies, right? Do you have anything to consider when making this analogy?

Participant 11 (P11): Well, here I would equate the process of tea brewing to activation energy in these reactions. I would like them to make connections to that first. So, I would like to emphasize that.

As it is seen that, although she wanted to use analogy, she did not know what analogy is, how to use it or whether alternative conception was suitable for that analogy.

For the AC4 however, she indicated to use of graphs and explanation only. She did not mention any exemplification.

Different from previous conception, she decided on using explanation rather than using any graphs or so on for the AC5. Then she was asked for the effectiveness of this method.

R: I understand. You mentioned that you would use the explanation method when asked how to eliminate this alternative conception. You also said that if they ask why kinetic energy is higher, you will address that. But would that be sufficient to clear up any confusion in their minds?

Participant 11 (P11): Actually, yes, it would, because I did not understand from which perspective they were considering it. Whether a student comes to me thinking that decrease in rate is because of the being exothermic reaction or due to activation energy, first I would learn. Then I would find a solution accordingly and tailor my explanation to them.

R: Understood. So, your approach would be based on the student's perspective and understanding.

Consequently, although she could identify the AC5, she did not realize where this alternative concept originated from, she indicated that she would explain only the concept and ask questions about the alternative conceptions.

Additionally, Participant 14 (P14) indicated only AC3, AC4 for the second question. For these alternative conceptions she chose the experimentation and explanation methods. However, using experimentation method was also implemented by watching the video of experiment. Additionally, she described the experiment in detail:

Ali argues that exothermic reactions occur more rapidly. I can counter his argument by presenting an endothermic reaction that proceeds faster. I believe I can eliminate this alternative conception by providing the activation energies of the reactions. Then they can compare and understand that the rate of reaction is dependent on the activation energy rather than whether the reaction is endothermic or exothermic.

When P14 was asked the effectiveness of using experimentation, she emphasized the captivating nature of it.

P14: When the experiment is demonstrated or conducted, the student's interest is immediately piqued. And once they start observing carefully, they usually do not forget that information. That is why I think misconceptions can be eradicated forever.

R: So, is this the reason for choosing this method?

P14: When students do something on their own or when they watch something, they can grasp the logic more quickly rather than memorizing or being told. That is why.

R: All right. Do you think the experimental method you are using is an effective method? I mean, in terms of time, it could be, or in terms of ease.

P14: Well, for instance, let us say a reaction, one takes 30 minutes, and another takes an hour, not that extreme, but still, let us say one takes 5 minutes, and the other takes 10 minutes. Sometimes in class, we cannot allocate that much time, but if I am short on time, I can show it on the internet in the same way. In terms of time, it definitely becomes effective somehow.

As a result, whether she had time in the class or not, she dedicated herself to use of experimentation because she thought it is more effective than other methods.

Similarly, Participant 16 (P16) could only indicate AC3 and AC5. Additionally, like in the first question, she chose the experimentation and animation method for both of these. Therefore, she was asked whether this selection was on purpose, or she did not know additional methods. She described like that:

R: You mentioned using experiments and animations again. Why did you choose this method? Can you find an experiment for every topic or show an animation for every topic?

P16: I found them after a lot of research. I really noticed that when I search a lot, I find them. I used to wonder how I would find the experiment for this, but somehow it happens when that topic comes up for me. Analogies can be used, but then you have to explain the parts that do not fit. It becomes a more laborious path, in my opinion. I always prefer to explain visually or at least with visuals in experiments, even if they do not collect data. Because, you know, since we are trying to teach conceptually, we need to support it. Then the 5e explore parts or arguments become more useful, more memorable. It attracts children's attention more. That is why I always say experiments and animations.

R: Okay. Is there a significant reason behind your choice of experiments and animations for addressing this misconception? Do you think it is effective?

P16: Maybe nothing else comes to my mind, because besides that, I cannot think of any other technique or so on to address misconceptions. Perhaps providing a research question and then finding it through that could be possible, but its outcome still relies on experiments eventually. I cannot think of anything else in this regard.

4.1.3.2.3 Question 3 Chosen Methods

In question 3 there were three alternative conceptions coded as AC6, AC7 and AC8. Participant 1 could not indicate all of them since she did not know the correct conception for this question. She only indicated AC7 and AC8 and like other alternative conceptions, she preferred to use experimentation methods. On the other hand, P1 did not describe the exact experiment.

Even though Participant 6 (P6), could identify all the alternative conceptions in the questionnaire, she changed her mind, and she only identified AC7 and AC8. However, she again was not sure about her idea. She said: "So, I question myself in every question because my mind is confused. I think it has not been conveyed to us very well either because as I read the students' answers, my mind really gets confused. I wonder, was it like this, was it because of this?" Additionally, like in the other ACs, ACs' of this question, she wanted to use experimentation and explanation methods by saying only exemplifying the exothermic reactions.

Participant 8 (P8) stated all alternative conceptions in this question correctly. Although the method she wanted to use changed for three AC's partially, generally she relied on the experimentation method. For example, while she indicated the experimentation and animation method for the AC6, for AC7, P8 indicated experimentation and discussion. She explained clearly:

I would conduct an experiment where one operates at low temperature while the other operates at high temperature. By comparing the data they obtain and discussing alternatives, they can potentially get rid of alternative concepts.

For the AC8, P8 preferred to use simulation. When asked a specific simulation for this alternative conception she expressed herself in the following way:

R: Okay, as a remediation method and technique, you would demonstrate the effective collision count in simulation, allowing for accurate inference. If unable to do so, you would provide explanations, right?

P8: There is a website I know of a friend of mine who has used it before. You can also increase the concentration of the products there. Basically, the particles are moving in real-time. At the same time, the temperature can be altered, allowing us to observe several different factors. We can keep some things constant and continue with other variables. So, when I open the site, they can see for themselves by adjusting. However, this could be a scenario where experimentation is not feasible, or when this situation arises during real-time instruction. If possible, my preference is for experimentation. Doing a bit more hands-on activity tends to be more memorable. So, if there is an immediate need to address something, I would open the simulation, but otherwise, I would opt for the experiment.

R: Okay, then you are saying the experiment would be more effective, but if our time is limited or if we encounter an instant need, you will resort to simulation and explanations.

D: Yes.

Although her priority was to conduct an experiment, she stated that the time would not be sufficient, so she chose the simulation technique. Therefore, it can be inferred that if she believed the participants would have enough time, her first choice would be the experiment.

Like Participant 8 (P8), Participant 11 (P11) could identify all alternative conceptions in the question. However, she indicated different methods. For AC6 and AC8, she would like to use the same simulation. She described the simulation like that:

Participant 11 (P11): There are simulations for exothermic and endothermic reactions. Here, under student moderation, they can increase and decrease the temperature while also creating a data table for the student to collect data at different temperatures and later interpret it.

R: I see. Would this be an effective method?

Participant 11 (P11): Yes, the student collects the data themselves, they observe it themselves. And they consistently see a change.

R: Would you provide an explanation afterwards?

Participant 11 (P11): Yes, at the end, I would explain to summarize the topic.

For the AC7, differently, she indicated the demonstration of graph. She explained the graph in detail also.

R: I see. As a remediation method, you mentioned explaining activation energy and threshold energy through graphs. Were activation energy and threshold energy the same thing?

Participant 11 (P11): Yes.

R: Okay, so you will only explain through graphs, then?

Participant 11 (P11): Yes, exactly. And afterwards, I would also mention how potential energy is never zero and, for instance, demonstrate the movement of molecules through simulation, showing kinetic energies exist, and emphasize that energy is always required.

Participant 14 (P14) could detect all alternative conceptions too. Although she explained the experimentation methods in the questionnaire she talked about the core theory in the background of rates. She indicated collision theory. For the AC6, when the reason for mentioning the collision theory was asked, she gave the following explanations:

P14: Yes, besides the experiment, we could also touch upon the theory. Because the student might not directly think that the reaction rate increases when the collision frequency increases, so supporting it with theory might be better...

R: So why would you choose this method?

P14: Well, ultimately, there is a background to this thing, and that is the theory. If we delve into its foundation, I believe they can understand that foundation better. I think understanding why the reaction rate increases in both cases would be better.

For the AC7, P14 wanted to indicate graphs by mentioning the collision theory.

P14: Well, here, I can sort of demonstrate it. There is definitely a need for activation energy. How can we reach activation energy more quickly? Through temperature. After all, I can show from the graph that they need energy. When I show it on the graph, I can ask how we can reach this energy more quickly. From there, I might encourage them to think about temperature. Again, I would provide the collision theory. I would ask how we can increase the speed of these collisions. I do not need to use an experiment here.

Lastly, P14 indicated the inquiry method to eliminate AC8 rather than using experimentation and so on:

R: Okay. Would you only use the inquiry method through questioning, or could there be another method geared towards inquiry-based?

P14: Could I do something for conceptual change? Well, it is quite specific, so I guess I would just inquire about it. Yes, it is related to the rate constant, but I would inquire about how we can change the rate constant.”

Participant 16 (P16) could state all alternative conceptions in this question 3. Similar to Participant 14 (P14), she indicated the importance of collision theory and using the 5E learning cycle generally. In the learning cycle, she introduced the use of experimentation and simulation in the exploration part. Also, she described the specific simulation on the Internet:

When you increase the temperature, collisions increase. In fact, there is a simulation where, as collisions increase, the possibility of correct matching also increases. There is a simulation that beautifully demonstrates this. Before that, I would ask what will happen. Will students think that this temperature will affect it, how will they think it will affect it, can there be those who cannot think? For example, some might say temperature will not affect it. I would measure this beforehand and then start the simulation. Afterwards, what happened, what did you observe, did what you think turn out to be correct or not, I can confirm this, but I definitely ask at the beginning. Because this is an important point.

Additionally, when she was asked the reason for choosing simulation she indicated the negative points of other methods:

R: Okay. So, if I ask why, you chose this method, I mean you mentioned animation simulation?

P16: That is the collision theory. For instance, someone in our class explained it through a drama, but the students did not understand why temperature increases and why they should get heat. They just said, 'When the temperature increases, collisions happen faster,' but it makes more sense to delve into kinetic energy and such. That is where the significance lies. Like I mentioned, when temperature increases, you have faster collisions, and with faster collisions, the chance of successful collisions increases, and so on. There is a good resource that demonstrates this well. But besides that, it is difficult to show this with experiments, especially when it comes to the dimension of collisions. It needs to be demonstrated at the particle level. That is why there are good simulations available. We can show the particles, each gas molecule, their movements, and some simulations even provide values like the number of collisions as v^2 . Data can be collected, like 'This happened at 20 degrees.' It becomes more memorable when observed. So, I think using drama or similar methods is more challenging. As I said, when my friend did it, the students did not understand. They were asking, 'Why are we moving faster?'

R: So, you are saying drama did not work, but experiments could be conducted, and simulations could be shown.

P16: There was a video once, with kids in a classroom. It was related to the field, but when the temperature increased, everyone started sweating and running around, but I did not like that either.

R: So, the analogies were not pleasant?"

P16: You need to make them very well. Without explaining the reason there, why someone would run faster with different temperatures, or why they would collide more, it does not seem very relatable to me.

R: Okay, are there any other misconceptions about this topic that you can tell us about?

P16: There might be those who claim that exothermic and endothermic reactions change differently, like for endothermic, maybe the temperature is increased in a certain way, but for exothermic, it is the opposite, where it affects the surroundings. I can say that their effects on temperature are different rather than related to collisions, they may interpret it differently, focusing more on exothermic and endothermic reactions rather than the collision theory.

4.1.3.2.4 Question 4 Chosen Methods

In question 4, there were three alternative conceptions, too. They were coded as AC9, AC10 and AC11. Participant 1 did not change her method to eliminate alternative conceptions again. While she indicated the experimentation method for AC9 and AC10, for AC11 she only preferred to explain conception. However, she also stated the reason for using explanation only as giving a lot of experimentation method answers. Additionally, she did not give clear explanations about both experiment and explanations she would make in order to eliminate alternative conceptions.

Although Participant 6 (P6) could indicate AC9, AC10 and AC11, she did not want to use the same method for all of this. For the AC9, she stated that she wanted to use experimentation, but she did not know the exact experiment that should be applied. For the AC10, she mentioned the use of visuals like graphs. When the reason for this was asked, she explained that using the experiment is not appropriate for this alternative conception. She said:

It is not possible to demonstrate this with an experiment because the reverse activation energy is not something visible. It is not tangible. Here, perhaps using visual diagrams again might be more logical. By incorporating more visuals, we can ensure it sticks in their minds.

In addition, for the last alternative conception, AC11, she indicated the explanation method only because she mentioned the difficulty of introducing this topic by using visuals.

Unlike the first two participants, Participant 8 (P8), could only indicate the AC10. For this alternative conception, she defined the experiment. She said:

P8: I thought about conducting an experiment by showing reactions with and without adding a catalyst, but if that is not feasible, I can still show a video. Nonetheless, there is always observation, but experiencing it themselves would be better of course.

R: Would this method suffice, just conducting experiments or showing videos?

P8: I believe it would be sufficient for high school level.

Participant 11 (P11); however, could identify all the alternative conceptions in this question. Different from the P8, she indicated different methods. While she decided on the explanation for AC10, for AC9 and AC11, she stated the demonstration of graphs besides the explanation. She said: “I would explain this again using the potential energy diagram I have described before. You know, it shows the lowered and unlowered activation energies and touches upon whether it affects enthalpy.” It could be said that her explanations were not clear, and persuasive.

Participant 14 (P14) also determined all alternative concepts and to eliminate them, she stated different methods for different alternative conceptions. She wanted to use experimentation if it was possible, however she also mentioned her experience with AC9 and settled for the explanation method.

P14: Well, if the working principle of catalysts is explained, perhaps I can dispel the misconception here. I used to have one myself. Before taking the lab class, I thought catalysts facilitated reaching the products quickly. That is why I thought we used catalysts. But it turns out that is not the case. They actually find a new pathway for themselves, which is why we say the reaction occurs faster. If I explain it the same way, by emphasizing that it is not dependent on reaction enthalpy and does not alter it, I believe the student will understand that catalysts simply find a new pathway.

R: So, by explaining it to the student. Why did you choose this method?

P14: The root of the misconception here is that the student incorrectly understood the principle of catalyst usage, thinking about it in a wrong way. If I explain the correct version, I believe they will understand.

Additionally, when reason of using the experimentation method was asked for the AC10, she explained like this:

Here, dispelling the misconception is straightforward. For instance, I could conduct an experiment that forms a precipitate. Measuring the amount of product is easier in this case because it is tangible. So, I would conduct one experiment without using a catalyst and another with a catalyst. Then, when they measure the precipitate in both experiments, they will see that they have the same amount. Therefore, conducting experiments becomes a much more effective method. They will directly observe that the amount of product is the same, so they will realize that the product yield does not change, and the product remains the same, I believe it will stick in their minds permanently.

Additionally, P14 preferred to use the explanation method for the AC11 since there was no available way to demonstrate by using experimentation and demonstration. She said:

In this case, I cannot use an experiment or any other method. The catalyst goes in and comes out unchanged, etc. I am thinking about whether I can do something about this, but I cannot. I also cannot demonstrate or use a theory-based approach here. Just like before, I can explain the catalyst principle here.

Different from the others, Participant 16 (P16) could only indicate the AC9 and AC10. For these alternative conceptions, she indicated the daily life example in the questionnaire; on the other hand, in the interview she explained it by using experimentation and simulation. She mentioned using daily life examples in the experiment. Also, she emphasized the demonstration on particle movement. When she was asked to state another method, she expressed that finding experiments is easier than conducting analogy. She said:

It would be nice if an analogy could be found. Why not? I always find it more difficult to produce analogies. Experiments and simulation come to mind more often. Still, if an analogy can be found, that could be nice as well.

4.1.3.2.5 Question 5 Chosen Methods

In question 5, alternative conceptions were coded as AC12, AC13, and AC14. Unfortunately, P1 could not state all the alternative conceptions. Alternative conception that she stated was only coded as AC13 and she wanted to use experiment in the question and explain the mindset behind which was not surprising for P1. When effectiveness of these methods was asked, she said:

It seems like using both of them together would be sufficient. I mean, other methods can be used, of course, but I cannot think of any. No single method may be sufficient on its own. When you conduct an experiment, you can sometimes wonder, "What now?" It is more effective when both the theoretical and practical aspects are combined.

Different from the P1, Participant 6 (P6) determined all alternative conceptions truly. Furthermore, the methods that she wanted to use differed according to AC's. For example, for AC12 and AC13, she only used experimentation in the question since it was easy to see and grasp the conception by doing. However, for the AC14 she decided on the use of animation method. She expressed herself like that:

P6: So, we need to provide a more micro-level explanation. A concrete study demonstrating that the bonding forces are the same could be used.

R: Do you think this method would work?

P6: Well, the student probably will not be very satisfied. But how else can I demonstrate it? Since it is at a micro level, and we cannot visually perceive bonding forces, the student most likely will not grasp it well. They believe there must be a greater bonding force because it is more significant. So, I suppose I need to use something more tangible, like animations.

R: Yes.

Like P6, P8 stated all alternative conceptions too. On the other hand, she only indicated the experimentation and explanation methods to eliminate these alternative conceptions. Explanations that she used changed according to AC's. For example, for the AC12, she said: "If observing the time doesn't suffice for the experiment, I can also explain it mathematically by relating it to surface area and correlating it with the number of collisions." Additionally, she mentioned the possible source of alternative conception 14. She indicated used analogies may be the reason for AC14. She stated:

It probably stemmed from something like this. We were given some analogies beforehand. For instance, they used to say something like breaking one matchstick is easy, but breaking several at once is not. They used such analogies to explain bonds to us. I thought maybe they were mixing up chemical and physical bonds, but ultimately, the substance is the same, and size does not have any effect there. So, actually, I believe the misconception for all three can be corrected by conducting the same experiment in the scenario. However, I think a bit more explanation is needed at the particle size level here.

Participant 11 (P11) could not determine the AC14. For other alternative conceptions in this question, unlike the other participants, she preferred using simulations by showing reactions in micro and macro levels. Although she did not indicate the experimentation, simulation that she wanted to use was fundamentally based on the experiment in the question and daily life examples.

There is a video simulation available demonstrating the dissolution of a sugar cube at the micro level in water. Then, I would show how it dissolves, for example, by illustrating how the particles come into contact with water and blend in one by one. Additionally, I would show a simulation or video of its dissolved state. There are already many simulations available for the dissolved state. This way, I would discuss the impact of surface area on reaction rate. For instance, I would add examples from daily life, such as adding a sugar cube versus adding powdered sugar.

Participant 14 (P14) stated all alternative conceptions that were AC12, AC13 and AC14. Similar to other participants, she preferred the experimentation and explanation methods. In addition, she also emphasized on the demonstration of micro level and collision theory:

P14: I believe I could draw something on the board for this. They drew it for us in the laboratory as well, and that is when it clicked for me. So, I can actually

use this method. For example, I would draw larger particles. There are molecules inside, of course, but collisions are a bit harder there. However, when we break it down into tiny, tiny particles, I would draw something to show that collisions can occur from different directions, in every direction.

R: I see. So, there would be a representation at the micro level here. Why did you choose this method if I were to ask you?

P14: When students do not understand at the micro level, they usually do not understand much else either. Chemistry is somewhat related to this. Therefore, simply saying that surface areas increase and therefore speed increases is not enough. So, if I reinforce this with the micro level, students can see it, and logically, it is harder for larger particles to collide compared to smaller particles. Yes, they could say there could be collisions from every direction, and so on. That is why I chose this method, because they can see it, and because it is at the micro level, I believe it will be effective.

Lastly, Participant 16 (P16) found all alternative conceptions in the question. For the AC12, and AC13 she decided on the use of experimentation. Additionally, she indicated that using simulation and video demonstrations are not efficient as setting up experiment. Also, for these conceptions she mentioned the ease of preparing an experiment and understanding through it. She stated like that:

They can also do it themselves when you give them the materials. But there are also nice animations where a substance is being broken down, showing its surfaces being fragmented one by one. Then it says, 'Now it has more surfaces.' Then it shows collisions on those surfaces and demonstrates all their interactions. It also shows the substance as a whole being collided with. Then it says, 'Look, now the spaces in between and the corners have also collided with. So, there have been faster interactions, more collisions, and so on.' There are animations where this is nicely demonstrated. I have used one of them

before as well. But of course, experiments are more lasting since they see and do it themselves. I would say I have done that.

Different from the other AC's however, for the AC14, she preferred to use explanation method only. She explained her explanation by using numbers. She said:

I would say that actually, you think that the one with a larger volume has a larger surface area and thus more collisions occur. But when I break down this substance into smaller pieces, it undergoes more collisions because it interacts with corners as well. So, there are more collisions, more reactions, more interactions. Consequently, the reaction rate increases. I believe it can still be explained with collision theory. Because otherwise, when showing it directly, if there are only four surfaces, it can only collide from the front, back, right, and left. But now, if I divide it into ten pieces, there will be 40 edges and corners. Now, all of them start colliding from every direction, and so on.

CHAPTER 5

DISCUSSION, CONCLUSION, AND IMPLICATIONS

This chapter presents the discussions of findings as well as implications based on the findings. The final section involves recommendations for future research.

5.1 Discussion and Conclusion

The findings will be discussed under two headings. Firstly, findings about pre-service chemistry teachers' alternative conceptions with respect to reaction rate concepts will be discussed in the light of related literature. Secondly, pre-service chemistry teachers' knowledge of learners' alternative conceptions and instructional methods to remedy these alternative conceptions will be discussed.

5.1.1 Identifying Alternative Conceptions of Participants

This study explored pre-service chemistry teachers' conceptions about reaction rate concepts, their knowledge of learners' alternative conceptions and instructional methods to eliminate these alternative conceptions in the context of reaction rate concepts. Regarding rate of reaction topic, concepts of rate-time graphs; the relationship between enthalpy, activation energy, and reaction rate; effect of temperature on reaction rate, properties of catalysts, and the effect of surface area on reaction rate were investigated.

As mentioned previously, five scenario-based questions related to reaction rate concepts were asked to the pre-service chemistry teachers. In the questions, two or three people were talking about their responses to the questions. Firstly, pre-service

teachers were wanted to detect the correct response concerning reaction rate concepts. First question was about interpreting the reaction rate-time graph, how reaction rate changed with time depending on the concentration of a reactant. Findings indicated that though most of the pre-service teachers (about 75% of them) in group 1 had correct understanding, few of them had alternative conceptions. They thought that unless factors such as concentration, temperature, catalyst, etc. were not changed, reaction rate remains constant. Since pre-service chemistry completed some content knowledge courses such as general chemistry courses and physical chemistry I course, before taking any PCK courses, pre-service chemistry teachers were expected to be knowledgeable about reaction rate concepts. When the responses of group 2 students were examined, though students were expected to have more correct conceptions about reaction rate concepts, it was not the case. Less than 70% of group 2 students had correct understanding. They had worse performance than group 1 students. Again, as an alternative conception, they thought that reaction rate would remain constant in the graph of reaction rate versus time. Moreover, one of the pre-service teachers thought that the reaction rate would increase due to increase in product, which was also found in the studies of Garnett et al. (1995) and Cakmakcı (2005). Interviews indicated that this alternative conception occurred due to not knowing the relationship between reactants, products, and reaction rates. Additionally, it might be because of not remembering the reaction rate equation correctly. Similarly, the percentage of correct responses of group 1 and group 3 students were the same though group 3 students completed all content knowledge and PCK courses. This indicates evidence for the stability of alternative conceptions. As stated by research findings, despite instruction, alternative conceptions exist that reveals the resistant nature of alternative conceptions to change (Cox et al, 2016; Driver & Easley, 1978; Viennot, 1979; Lelliott & Rollnick, 2010; Miller & Brewer, 2009; Nazé & Fontaine, 2014; Starakis & Halkia, 2014). Likewise, alternative conceptions of students in these groups were the same. They thought the reaction rate was constant unless factors such as concentration, temperature, catalyst, etc. were not changed. This common alternative conception in the present study was also confirmed by the research studies of Cakmakcı (2005) and Taştan et al. (2010). Kolomuç and Tekin (2011) found that even some chemistry

teachers had difficulties in understanding reaction rate concept, and they mentioned reaction rate as stable from start to finish. Interviews with participants revealed reasoning behind this alternative conception as the confusion of reaction with chemical equilibrium reactions. This confusion was also supported by the study of Taştan et al. (2010) that was conducted with high school students. Similarly, Cakmakcı (2005) also confirmed this confusion in his research study. As a conclusion, it can be stated that pre-service teachers' alternative conceptions about reaction rate-time graph were not eliminated as they completed PCK courses.

The second question assessed pre-service teachers' understanding of the relationship between activation energy, enthalpy, and reaction rate. Most of the group 1 students (approximately 85% of them) gave the correct response while one participant did not answer the question. Like question 1, less than 70% of group 2 students had correct understanding, which makes the performance of group 2 students worse performance than group 1 students. One of the participants in group 2 had the alternative conception of exothermic reactions being faster than endothermic reactions. Students may have memorized this as a rule and thought that exothermic reactions are faster than endothermic reactions. This is actually a common alternative conception encountered in the related literature (Cakmakcı, 2005; Kolomuç & Tekin, 2011; Taştan-Kırık & Boz, 2012). During the interview, the participant who could not give any response in the questionnaire was asked to respond to this question, it was realized that this student in group 2 did not know the concepts of activation energy and threshold energy. She used threshold energy in place of activation energy. It could be stated that she had a lack of conceptual understanding with these concepts. Group 3 students had the best performance compared to the other two groups. All of the group 3 students could identify the correct response.

The third question was about the effect of temperature on the rate of reaction for exothermic reactions. Pre-service teachers in group 1 had problems with the relationship between temperature and reaction rate for exothermic reactions. Less than half of them gave the correct response in the questionnaire. The common alternative conception found among group 1 students was the decrease in reaction rate of

exothermic reactions with the increase in temperature that was also found in the research studies of the related literature (Hackling & Garnett, 1985; Nakiboğlu et al., 2002; İcik, 2003). When delved into student's reasoning during the interview, it was understood that confusion of chemical kinetics with chemical equilibrium was seen as the reason for this alternative conception. She applied Le Chatelier's principle to state the effect of temperature on reaction rate. Application of Le Chatelier's principle to chemical kinetics was also mentioned by Cakmakcı (2005). One participant stated that reaction rate would not change with temperature due to the dependency of reaction rate on only the concentration of reactants and rate constant. Group 2 students were slightly better in their responses. Half of them gave the correct response in the questionnaire. Half of them had similar alternative conceptions as the students in group 1. Common alternative conception in group 2 was that reaction rate would not change with temperature since reaction rate was dependent on concentration of reactants and rate constant only. This alternative conception may probably stem from applying the formula of reaction rate equation, however, not considering the temperature dependence of rate constant. This may result from rote learning, just memorizing the formula without thinking about it conceptually. This kind of thinking was also confirmed by the study of Cakmakcı (2005). On the other hand, group 3 students were noticeably better than the other two groups. All of them answered the question correctly and no alternative conceptions were detected.

The fourth question assessed pre-service teachers' understanding of roles of catalysts in chemical reactions. Group 1 students had problems in understanding the role of catalysts in chemical reactions. Only less than half of the participants gave the correct response without giving any explanations. Most of them had alternative conceptions. One of the common alternative conceptions was the decrease of activation energy by the catalyst. Another alternative conception was the change of the energy of the activated complex by catalyst. Lack of understanding in reaction mechanisms may also cause the formation of this alternative conception. As Cakmakcı (2005) reported, most students did not know the effect of catalyst on reaction mechanism though they could state that a catalyst would increase reaction rate by lowering activation energy.

These alternative conceptions may probably result from the simplified explanations in high schools. School textbooks usually do not explain the effect of catalysis on reaction mechanism rather give simplistic explanations (Van Driel and De Vos, 1989, as cited in Justi, 2002). Haim (1989) also mentioned that representations and diagrams that do not offer enough evidence for the reaction mechanism in textbooks may cause students' alternative conceptions regarding role of catalysts in chemical reactions. Students may think that both reactions (catalyzed and uncatalyzed) follow the same reaction mechanism. On the other hand, there was an improvement concerning the role of catalysts in chemical reaction with group 2 students. Most of them gave the correct response but did not give any explanations. The alternative conception of "catalyst decreases activation energy" was also mentioned by one participant in group 2. This was a common alternative conception also found among group 1 students. However, group 3 students had the best performance regarding this question. Only one alternative conception, which was catalyst increases average speed of molecules was mentioned. Taştan Kırık and Boz (2012) and Kınır and Geban (2006) found this alternative conception in their studies, too. This student may have confused the role of temperature with the role of catalyst.

Question 5 evaluated pre-service chemistry teachers' comprehension of the effect of surface area on reaction rate. Similar to other questions, group 3 students had the best performance compared to the other groups. All of the students could give the correct response, and no alternative conception was detected among these students in group 3. Moreover, most of them gave scientific explanations regarding the effect of surface area on reaction rate concept. On the other hand, group 2 students had lack of conceptual understanding and had the worst performance though they completed more PCK courses compared to group 1 students. Only half of them had correct understanding. Several alternative conceptions were found. One of the participants thought that crushing the substances increased the amount of matter that can interact so the reaction rate would increase. This student did not think about surface area, instead may have thought intuitively that crushing something caused more leading to increase in the amount of matter. This kind of thinking was also found by Cakmakcı

(2005). Another participant had lack of conceptual understanding with the concept of chemical bonding. He thought that solid molecules in large pieces were more strongly bonded to each other compared to their crushed form. This makes solid molecules in large pieces more difficult to react with, which was confirmed by research studies (Çakmakçı, 2005; Kırık & Boz, 2012). Another alternative conception was that surface area does not affect reaction rate, which was also confirmed by İcık (2003). Another participant did not consider the surface area of reactant, rather she thought that reaction rate was the same due to the fact that molarity of reactants was the same. The thought that the rate of reactions being the same due to the same amount of MgO in both reactions was also found by Cakmakcı (2005). Cakmakcı (2005) stated that students applied reaction rate equations to explain and thought the reaction rate would be the same due to the same concentration of reactants in both reactions. More than half of the participants in group 1 stated the correct answer but half of them giving the correct response did not give any explanations. The only alternative conception among group 1 students was that “Molecules of granulated MgO were more strongly bonded to each other than those of powdered ones making it more difficult to react”, that was also present in group 2 students. (Çakmakçı, 2005; Kırık & Boz, 2012).

As a conclusion, compared to group 1 and 2 students, most of the group 3 students had fewer alternative conceptions about most of the concepts: relationship between activation energy, enthalpy and reaction rate, effect of temperature on rate of reaction for exothermic reactions, role of catalysts in chemical reactions, effect of surface area on reaction rate. However, they still had problems in conceptual understanding and had alternative conceptions with respect to interpreting reaction rate-time graphs, how reaction rate changed with time depending on the concentration of a reactant despite having completed all courses. Their conceptual understanding of reaction rate-time graph was the same as the students in group 1. Compared to group 1, group 2 students had fewer alternative conceptions regarding effect of temperature on rate of reaction for exothermic reactions, role of catalysts in chemical reactions. On the other hand, compared to the other groups, group 2 students had more alternative conceptions related to interpreting reaction rate-time graph, relationship between activation energy,

enthalpy and reaction rate and effect of surface area on reaction rate. This indicated that pre-service teachers' conceptual understanding did not always enhance for each reaction rate concept as they completed PCK courses. Another finding was that insufficient understanding of other chemistry concepts such as chemical equilibrium and chemical bonding were effective in understanding reaction rate concepts.

Another finding of the present study was related to research instruments, which were questionnaire and interviews. It was observed that though some students gave correct response with no explanation in the questionnaire, during the interview, they changed their conception into wrong conception with alternative conceptions. Similarly, some students gave the incorrect answer in the questionnaire, but they correctly explained the concepts when their thinking was questioned during the interview. It shows the importance of getting access to students' thinking through their explanations. In this sense, interviews give valuable and rich data to reveal students' alternative conceptions. As Gurel, Eryilmaz and McDermott (2015) state the important role of interviews among different diagnostic methods to reveal misconceptions to provide in-depth inquiry of students' cognitive structure. Though interviewing has also its own weaknesses as being time consuming and impossibility to interview large sample size, it gives valuable data to reveal students' thinking.

5.1.2 Detecting Alternative Conceptions and Methods Used to Eliminate Them

5.1.2.1 Detecting Alternative Conceptions

In terms of identifying students' possible alternative conceptions, more than half of group 1 students could identify nine alternative conceptions (out of fourteen) successfully. However, they had problems in detecting some alternative conceptions, which were AC6, AC8, AC9, AC10, AC11. These were related with the effect of temperature on reaction rate for exothermic reactions and roles of catalysts in chemical reactions. Actually, these concepts were the ones group 1 students had lack of conceptual understanding. Group 1 students had alternative conceptions regarding

these concepts. Their identification of alternative conceptions regarding interpretation of reaction rate-time graph, were similar with group 3 students. Conceptual understanding of this concept was similar between groups 1 and 3. Therefore, subject matter knowledge may have an influence on the identification of alternative conceptions. On the other hand, group 2 and group 3 students were better in identifying alternative conceptions while group 3 students had the best performance. Though group 2 students could identify most of alternative conceptions better than group 1 students, they were worse in identification of alternative conceptions related with the relationship between activation energy, enthalpy and reaction rate and interpreting reaction rate-time graph, how reaction rate changed with time depending on the concentration of a reactant. Group 2 students had alternative conceptions with these concepts. This may be evidence for the importance of robust understanding of concepts in pre-service teachers' knowledge of students' alternative conceptions. Some research studies stated the difficulty of pre-service chemistry teachers with weak content knowledge on detecting students' alternative conceptions (Käpylä et al., 2009; Kutucu, 2016; Oztay & Boz, 2022).

On the other hand, the majority of group 3 students could identify most of alternative conceptions better than group 1 and 2. This states that as pre-service teachers completed PCK courses, their ability to detect alternative conceptions. This finding is consistent with several research studies (Aydın et al, 2013; Brown et al, 2012; Adadan & Oner, 2014; Kiran et al, 2021; Belge-Can & Boz, 2022). As factors, these studies reported discussions of alternative conceptions in courses in the university, mentoring, preparation of CoRes, observation of peers' and mentors' instruction and teaching experiences were reported to enhance pre-service teachers' knowledge of students' misconceptions. Group 2 students completed methods courses where they prepared lesson plans and conducted microteaching considering students' alternative conceptions. Moreover, they completed practice teaching I where they had the opportunity to consider students' alternative conceptions by preparing CoRes and had teaching experience both in the university and high school. In addition, pre-service teachers discussed students' possible alternative conceptions regarding different

chemistry concepts in the laboratory in science education course. All these may be the reason for having more ability to identify alternative conceptions than group 1 students. Since group 3 students had more experience with preparing CoRes and teaching practice due to the fact that they also completed teaching practice II course, this may have affected their identification of students' alternative conceptions more. Methods courses and teaching practice courses Probably, group 1 students' content knowledge about chemistry concepts may have helped them to detect students' alternative conceptions since they did not take any course where misconceptions were mentioned. Though group 1 had more problems in detecting alternative conceptions, more than half of them could still detect most of the alternative conceptions. Therefore, pre-service chemistry teachers in the present study did not have many problems in detection of students' alternative conceptions, which is consistent with some research studies (Pine et al, 2001; Yildiz, 2024) and conflicts with some research studies (Kokkotas & Vlachos, 1998; Frederik et al., 1999).

5.1.2.2 Methods used to eliminate alternative conceptions.

When the findings were compared with respect to groups, it was seen that as pre-service teachers took some PCK courses, the preferred methods became diverse. Most of the group 1 participants could not state any teaching methods and strategies. The other participants in group 1 mentioned use of experiments as a first choice to remedy alternative conceptions. However, during the interviews, they could not give explanations regarding the use of the experiment. Moreover, some of the experiments they preferred were not suitable. To illustrate, the experiment between sodium and water participant 1 mentioned during the interview to eliminate the alternation conception of "Reaction rate increases due to an increase in the reaction product" was not suitable and dangerous to conduct. As a second preferred method, they preferred giving explanations to eliminate alternative conceptions. Explanation may have been chosen since it was a known strategy and easy to use.

Another finding was that group 1 students did not change their method according to alternative conceptions. They used mostly explanations or experiments irrespective of alternative conceptions. They did not judge whether the method was suitable to eliminate alternative conceptions. Since they did not take any PCK courses, e.g., methods courses, they were not aware of the teaching methods. They stated that they knew two methods: explanation and experimentation. Interviews indicated their preferred way of learning caused the selection of experimentation as a method. Therefore, instead of PCK courses, their learning preferences as a student influenced the choice for selection of teaching methods. Aydın, Boz and Boz (2010) also found pre-service teachers' preferred learning strategy was found as a factor influencing their choices of instructional strategies. When group 2 students' responses were analyzed, they preferred different teaching methods such as analogy, discussion, simulation, use of daily life events, simulation, animation, and video. Their explanations included more details about the content of teaching strategies such as experiments, simulation etc. This difference may probably be due to the effect of PCK courses such as methods courses and teaching practice I. In the methods courses, their knowledge about various instructional strategies to eliminate alternative conceptions may have enhanced and they could have had the chance to apply these strategies in their instruction both in methods and teaching practice I courses. However, though they learnt different teaching strategies, they used explanation strategy more than the other groups, which was a teacher-centered instructional strategy and was not considered as effective to eliminate alternative conceptions. This was also supported by literature. It was found that teachers just told the correct conception in order to eliminate misconceptions despite they were aware of different teaching methods (Uhren, 2014 as cited in Hartelt et al., 2022). This may be due to the fact that explanation was an easy and straightforward strategy.

Compared to the other groups, group 3 students used various teaching strategies similar to group 2 students. However, they also mentioned drama as a teaching strategy different from group 2. Group 3 students changed their strategy based on the alternative conceptions. They decided the teaching strategy based on the nature of the

topic. Moreover, they could judge the advantages and disadvantages of teaching strategies. They mentioned more student-centered strategies such as conceptual change, 5E and inquiry-based strategies as effective to eliminate students' alternative conceptions. Their explanations regarding both content and use of teaching strategies were more detailed compared to group 2. It was evident that group 3 teachers preferred teaching strategies more consciously. Another difference was that group 3 students' explanations emphasized the importance of collision theory that is required for conceptual understanding of reaction rate concepts. However, though pre-service teachers enhanced their instructional strategies, none of the group 3 participants mentioned providing cognitive conflict, which is necessary for conceptual change. The development of pre-service teachers' knowledge of instructional strategy as they took PCK courses was also supported by several research findings (Belge-Can & Boz, 2022; Kiran et al, 2021; Aydın et al, 2013). Teaching methods course, teaching experience, preparation of CoRes, observation of peers' instruction, mentoring was mentioned as factors that influenced development. Since group 3 students made use of these experiences more, most of them were more conscious of selecting the appropriate teaching strategy. Interestingly, the number of students in group 3 who did not state any teaching method was high. When the questionnaire was examined, it was observed that the same two pre-service teachers did not state any method for each alternative conception in all questions at all. They may not give enough attention for answering questions in the questionnaire. Another reason may be that their knowledge of instructional strategy may not have developed though they completed all PCK courses. Several research studies revealed differences in the development of PCK for different pre-service teachers (Adadan & Oner, 2014; Belge-Can & Boz, 2022).

As a conclusion, taking PCK courses enhanced pre-service teachers' ability to identify students' alternative conceptions and their selection of various teaching strategies. However, identification of students' alternative conceptions by pre-service chemistry teachers does not guarantee the use of suitable methods to eliminate these alternative conceptions. To illustrate, in some cases, though pre-service teachers could identify the alternative conceptions, they did not offer any teaching method at all. Moreover,

in some cases, although they could offer a teaching method, it was not effective to remedy alternative conceptions. This finding is also confirmed by research in the related literature (Cox et al, 2016). However, research of Peterson et al (1989) revealed that awareness of students' misconceptions led teachers to use more inquiry-based strategies to eliminate them.

5.2 Implications

Based on the findings, this study has some implications for teacher education programs and researchers. Despite taking all courses in the teacher education program, pre-service chemistry teachers had a lack of conceptual understanding and still had alternative conceptions about reaction rate concepts. Another finding was that pre-service chemistry teachers had a lack of robust understanding with the other chemistry concepts such as chemical equilibrium and chemical bonding. This shows the need for instruction that enhances pre-service chemistry teachers' conceptual understanding in the courses of teacher education programs. Therefore, it is important to reveal pre-service teachers' alternative conceptions and make pre-service teachers dissatisfied with these alternative conceptions in the courses of teacher education programs. Moreover, discussing the relationships among other chemistry concepts is vital to promote conceptual understanding as Stern, Ferraro, and Mohnkern (2017) stated. To illustrate, there was a common alternative conception, that was "The reaction rate was constant unless factors such as concentration, temperature, catalyst, etc. were not changed" among all group students. Even though pre-service teachers completed all the courses in teacher education program, they still had this alternative conception. The reason was found to be the confusion of chemical equilibrium with reaction rate. Discussion of both the relationship and the distinction between these concepts would be beneficial in teacher education programs. Moreover, providing pre-service teachers experiments where they find the rate of reaction as the reaction progresses would be helpful. Additionally, pre-service teachers should be given the chance to question the underlying reasons of phenomena in the courses. To illustrate, use of a catalyst enhances reaction rate. Discussing the reasons for this is important to improve conceptual understanding.

Another suggestion may be that pre-service teachers should be made aware of students' possible alternative conceptions in PCK courses. Discussions of students' probable alternative conceptions and effective teaching strategies to eliminate them in PCK courses would be valuable. Moreover, pre-service chemistry teachers should be given the opportunity to practice several instructional strategies such as simulation, animation, experiment, cognitive conflict etc. to eliminate alternative conceptions in the microteaching sessions and high school. Afterwards, feedback given by mentors and tutors as well as pre-service teachers' reflection on their teaching would help them to enhance their future instruction to eliminate alternative conceptions.

Another implication the present study provided is related to research instruments. In this study, since interviews were found to reveal more in-depth information about pre-service teachers' conceptions and reasonings, the use of interviews is suggested in revealing alternative conceptions.

5.3 Recommendations for Future Studies

The present study revealed pre-service chemistry teachers' knowledge of students' alternative conceptions and instructional strategies to eliminate alternative conceptions at different levels in a teacher education program. Since characteristics of pre-service teachers differ from each other, longitudinal studies can be useful to understand the development of pre-service teachers' knowledge of students' ACs and instructional strategies to remedy them as a future study. Moreover, this study was based on pre-service teachers declared PCK. As a future study, pre-service teachers' instruction can be observed in real classrooms to get information about how they eliminate students' alternative conceptions in reality. As another suggestion, teachers' knowledge of students' ACs and instructional strategies to remedy those can be investigated as a future study. Finally, as a future study, factors influencing the development of (pre-service) teachers' knowledge of students' ACs and instructional strategies can be explored. Since PCK is content-specific, this study can also be conducted in the context of different chemistry topics.

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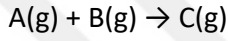


APPENDICES

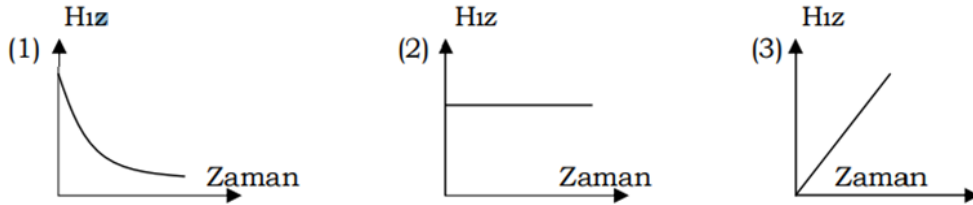
A. Questions in the Survey

Bir grup öğrenciye kimyasal tepkimelerde hız konusunda bir test dağıtılıyor ve testte bulunan soruları kendi aralarında tartışmaları isteniyor. Aşağıda sorular ve her bir öğrencinin düşünceleri belirtilmiştir. Lütfen her soru için istenilen bilgileri uygun yerlere yazınız.

Soru 1:



Tek adımda gerçekleşen yukarıdaki tepkime için A(g)'nin derişiminin zamanla deęişimine göre hız – zaman grafięi aşığıdakilerden hangisi gibi olur?



Gamze: Doğru seçenek 2. şık olmalı çünkü derişim, sıcaklık, katalizör, vb. gibi etmenler deęiştirilmedięi sürece tepkime hızı sabit kalır.

Kerem: Sana katılmıyorum. Bence kesinlikle 1. Grafik doğru çünkü zaman geçtikçe A(g)'nin derişimi azalır ve hız da buna baęlı olarak düşer.

Meltem: Bence 3. seçenek olmalı. Ürün miktarı tepkime boyunca arttıęından tepkime hızı da sürekli artar.

a. Hangi öğrencinin cevabı doğrudur, neden?

b. Öğrencilerden hangileri kavram yanlışlarına sahiptir ve bu kavram yanlışlarını belirtiniz.

c. Belirttiğiniz kavram yanlışlarını nasıl giderebilirsiniz? Kullanacak olduğunuz öğretim yöntem ve tekniğini ayrıntılarıyla belirtiniz.

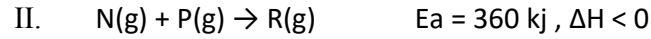
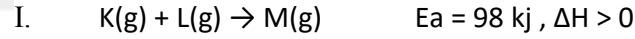
Kavram yanlışsı 1:

Giderme yöntem ve tekniği:

Kavram yanlışsı 2:

Giderme yöntem ve tekniği:

Soru 2:



Yukarıda iki tepkimeden hangisi daha önce gerçekleşir nedenleriyle tartışınız.

Ali: II. tepkime ekzotermiktir ve ekzotermik tepkimeler endotermik tepkimelerden daha hızlı gerçekleşir.

Melisa: Sana katılmıyorum. Tepkimenin hızı ekzotermik ya da endotermik olmasına değil aktivasyon enerjisinin miktarına bağlıdır. I. tepkimenin de aktivasyon enerjisi daha küçük olduğundan daha hızlı gerçekleşir.

İlayda: Entalpi tepkime sonunda çıkan enerjiyi açıklar ve ne kadar fazlaysa tepkime o kadar hızlı olur. Bu nedenle I. tepkime II. tepkimeden hızlı gerçekleşir.

Osman: II. durumda tepkimeye giren moleküllerin kinetik enerjisi daha fazladır bu nedenle daha hızlı gerçekleşir.

a. Hangi öğrencinin cevabı doğrudur, neden?

b. Öğrencilerden hangileri kavram yanlışlarına sahiptir ve bu kavram yanlışlarını belirtiniz.

c. Belirttiğiniz kavram yanlışlarını nasıl giderebilirsiniz? Kullanacak olduğunuz öğretim yöntem ve tekniğini ayrıntılarıyla belirtiniz.

Kavram yanlışsı 1:

Giderme yöntem ve tekniği:

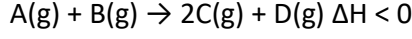
Kavram yanlışsı 2:

Giderme yöntem ve tekniği:

Kavram yanlışsı 3:

Giderme yöntem ve tekniği:

Soru 3:



Yukarıdaki tepkimede sıcaklık arttırılırsa tepkime hızı nasıl değişir?

Bulut: Bu bir ekzotermik tepkimedir. Ekzotermik tepkimelerde sıcaklık arttıkça tepkime hızı azalır.

Akın: Sana katılmıyorum. Sıcaklık arttırıldığında taneciklerin kinetik enerjileri ve dolayısıyla etkin çarpışma sayısı artar. Bu nedenle tepkime hızı artar.

Ceren: Hayır, bu tepkimeler sonucu ısı açığa çıktığından devam etmek için enerjiye ihtiyaç duymazlar ve dolayısıyla sıcaklık artışı hızlarını etkilemez.

Zeynep: Size katılıyorum ama bence tepkimenin endotermik ya da ekzotermik olmasıyla bir alakası yok. Tepkime hızı sadece hız sabitine ve girenlerin derişimine bağlı olduğu için sıcaklık artışı hızlarını etkilemez.

a. Hangi öğrencinin cevabı doğrudur, neden?

b. Öğrencilerden hangileri kavram yanlışlarına sahiptir ve bu kavram yanlışlarını belirtiniz.

c. Belirttiğiniz kavram yanlışlarını nasıl giderebilirsiniz? Kullanacak olduğunuz öğretim yöntem ve tekniğini ayrıntılarıyla belirtiniz.

Kavram yanlışsı 1:

Giderme yöntem ve tekniği:

Kavram yanılması 2:

Giderme yöntem ve tekniğı:

Kavram yanılması 3:

Giderme yöntem ve tekniğı:

Soru 4:

Kimyasal bir tepkimede katalizör kullanılırsa aşağıdakilerden hangisi değışir?

- (1) Tepkimenin ürün verimi
- (2) Tepkime entalpisi
- (3) Aktifleşmiş kompleksin enerjisi

Akın: Bence tepkime entalpisi çünkü katalizör sadece ileri yöndeki tepkimenin aktivasyon enerjisini düşürürken geri yöndeki tepkimenin aktivasyon enerjisini değıştirmez.

Neşe: Hayır, katalizör hem ileri ve hem de geri tepkimenin hızını farklı şekilde etkilediğinden ürün verimini değıştirir.

Begüm: Size katılmıyorum. Katalizör, daha düşük aktivasyon enerjili bir yol sağladığından aktifleşmiş kompleksin enerjisini de değıştirmiş olur.

Dağhan: Bence de doğru seçenek aktifleşmiş kompleksin enerjisi ama nedeni katalizörün moleküllerin ortalama hızını arttırması ve dolayısıyla aktifleşmiş kompleksinin enerjisini de arttırmasıdır.

a. Hangi öğrencinin cevabı doğrudur, neden?

b. Öğrencilerden hangileri kavram yanlışlarına sahiptir ve bu kavram yanlışlarını belirtiniz.

c. Belirttiğiniz kavram yanlışlarını nasıl giderebilirsiniz? Kullanacak olduğunuz öğretim yöntem ve tekniğini ayrıntılarıyla belirtiniz.

Kavram yanlışsı 1:

Giderme yöntem ve tekniği:

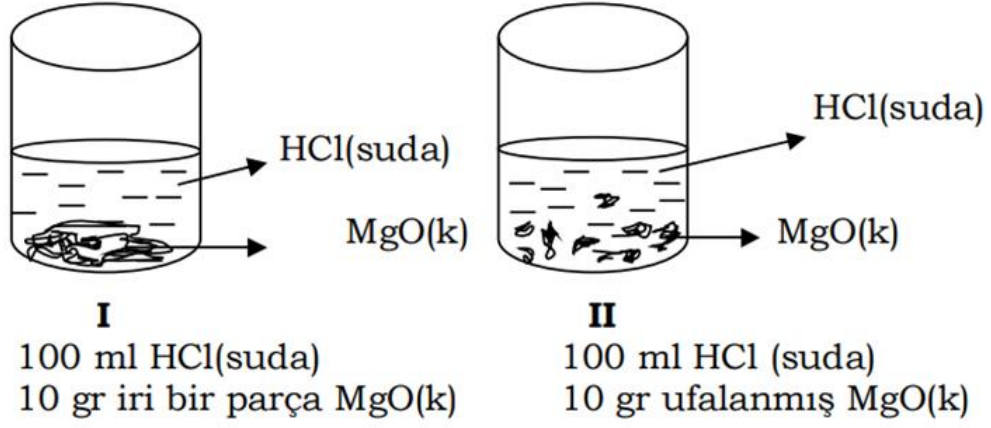
Kavram yanlışsı 2:

Giderme yöntem ve tekniği:

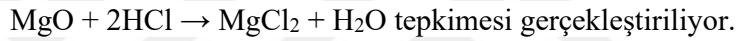
Kavram yanlışsı 3:

Giderme yöntem ve tekniği:

Soru 5:



Şekildeki gibi 2 ayrı özdeş kaba 100'er ml HCl(suda) konuyor. Daha sonra I. kaba 10gr iri bir parça MgO(k), II. kaba 10gr ufalanmış MgO(k) eklenerek



Buna göre

- (1) I. kaptaki tepkime daha hızlı gerçekleşir
- (2) II. kaptaki tepkime daha hızlı gerçekleşir.
- (3) Her iki kaptaki tepkimenin de hızı birbirine eşittir.

Onur: Her iki durum için de maddelerin miktarları ve hacimler eşit olduğundan her iki kaptaki tepkime aynı hızda gerçekleşir.

Gönül: Bence tepkime II. Kaptaki daha hızlı gerçekleşir çünkü II. kaptaki MgO(k)'nin yüzey alanı daha büyüktür. Bu nedenle tepkimeye girenler arasındaki çarpışma sayısı ve dolayısıyla etkin çarpışma sayısı artar.

Cansu: Hayır. Temas yüzeyinin tepkime hızına etkisi yoktur. Her iki kaptaki tepkimenin de hızı birbirine eşittir.

Defne: Sana katılmıyorum. MgO'nun temas alanı tepkime hızı için önemli bir etkidir fakat iri parçalar halindeki MgO(k) molekülleri ufalanmış haline kıyasla birbirine daha kuvvetli bağlı olduğundan tepkimeye girmesi daha zordur. Bu nedenle tepkime I. kapta daha yavaş gerçekleşir.

a. Hangi öğrencinin cevabı doğrudur, neden?

b. Öğrencilerden hangileri kavram yanlışlarına sahiptir ve bu kavram yanlışlarını belirtiniz.

c. Belirttiğiniz kavram yanlışlarını nasıl giderebilirsiniz? Kullanacak olduğunuz öğretim yöntem ve tekniğini ayrıntılarıyla belirtiniz.

Kavram yanlışsı 1:

Giderme yöntem ve tekniği:

Kavram yanlışsı 2:

Giderme yöntem ve tekniği:

Kavram yanlışsı 3:

Giderme yöntem ve tekniği:

B. Interview Questions

Structured questions in accordance to Question 1 from Appendix A:

Question (1):

- A. How can you define the activation energy?
- B. What do you think about the relatedness of activation energy and rates of reactions?
- C. How can you explain that which student(s) have alternative conception about the activation energy? Why?
- D. How would you handle this conception if you experience in your students?

C. Ethical Permission

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER



ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr
www.ueam.metu.edu.tr

07 NİSAN 2023

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof. Dr. Yezdan Boz

Danışmanlığımı yürüttüğünüz Şerife GÜRLER'in "Kimya öğretmen adaylarının kimyasal tepkimelerde hız konusu ile ilgili alternatif konsept bilgisi ve bunlarla başa çıkma yolu" başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek **0212-ODTÜİAEK-2023** protokol numarası ile onaylanmıştır

Bilgilerinize saygılarımla sunarım.