JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

HEURISTIC REASONING OF PRE-SERVICE SCIENCE TEACHERS IN CHEMISTRY TOPICS

Mustafa Ugras

Abstract. *The aim of the present research is to explain how the heuristics utilized by the students in a multiple choice examination on the general chemistry subject of "chemical bonding theories and molecular structures" caused biases on intuitive judgment and decision making processes, using the three characteristics of associative memory (attribute substitution, fluency process and associative coherence). A mixed-methods approach, both qualitative and quantitative research methods, were used in this research. Therefore, both questionnaire and individual interview were utilized to collect data. The results of the current research demonstrated that the participants used 4 different decision making strategies. Detailed evaluation of these strategies demonstrated that most of the participants did not prefer the processes related to the use of chemical knowledge and thus, were not able to assess the target attribute. Furthermore, it was identified that most of the students' decision making processes were dependent on one or more of these three associative memory processes. It was also determined by this research that the most dominant of these three associative memory processes is the fluency effect, since participants often prefer to use superficial features. The dependence of participants on associative memory processes caused various biases, so participants often responded incorrectly to questions.*

Keywords: *chemistry education, chemical reasoning, intuitive judgments, science education.*

Mustafa Ugras
Firat University, Turkey

Introduction

The concept of decision making draws interest of researchers from different fields of expertise. Therefore, the concept of decision making has been defined in different ways by different scholars (Connor & Becker, 2003; Harris, 1998). In general, decision making could be defined as making a choice among several alternatives. Individuals develop habits during the decision making behaviour. These habits create the decision making style of the individual. Driver defined the decision making style as a learned habit (Driver, Brousseau & Hunsaker, 1990; Tasdelen, 2001). A literature review would demonstrate that "decision making style" and "decision making strategy" terms are intermingled. For instance, the concept of "procrastination behaviour" was sometimes discussed in studies related to decision making process as decision making style and sometimes as decision making strategy (Ferrari & Dovidio, 2000). Several decision making styles were defined within the concept of decision making process. For example, Scott and Bruce defined four decision making styles within the decision making process (Scott & Bruce, 1995; Tasdelen, 2002); 1) Rational decision making style (where alternatives are evaluated and investigated rationally), 2) Intuitive decision making style (where intuitions and emotions are trusted), 3) Dependent decision making style (where recommendations and guidance of others are valued), 4) Evasive decision making style (where decision making is avoided). Intuitive decision makers are faster than others in decision making and use their intuitions (Scott & Bruce, 1995).

Several studies that investigated judgment and decision making processes of individuals from different perspectives were reported and different theories were developed on judgment and decision making processes as a result of these studies (Gilovich, Griffin & Kahneman, 2002; Talanquer, 2014; Todd & Gigerenzer, 2000). One of these theories is the "dual-process model," which explains the reasoning processes that individuals use in their judgments and decisions (Evans, 2008; Evans, 2013; Gigerenzer & Goldstein, 1996; Kahneman, Tversky & Slovic, 1982). According to this model, there are two types of reasoning processes that individuals use, called Type 1 and Type 2.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Type 1 processes include processes that do not emphasize working memory and have a tendency to be automatic, fast and extremely independent from cognitive abilities (Stanovich, 2004; Stanovich & West, 2003). There is no need to spend an effort to trigger and implement the Type 1 processes. One of the most significant characteristics of Type 1 processes is that they are autonomous. Type 1 processes include both naturally occurring reasoning and learned strategies (Stanovich & West, 2000). On the other hand, Type 2 processes require a working memory to process and have the tendency to be slow and consecutive. A special effort is needed for Type 2 processes and implementation and performance of Type 2 processes are generally related to the measurement of general intelligence. While Type 1 processes are related to the general intuitive thinking emotions, hypothetical thinking and cognitive simulations play a significant role in Type 2 processes. Type 2 processes are related to our analytical or reflective thinking styles and conscious interventions and cognitive efforts are required for the functioning of these processes (Maeyer, 2013; Talanquer, 2014). There are scientific studies available in the literature, which proved that, when we encounter new problems or situations, Type 1 processes are triggered rapidly with a little effort (Evans, 2008; Evans & Stanovich, 2013; Talanquer, 2014). Especially when we have limited time and our knowledge or motivation is lacking, Type 1 processes are considered as a faulty response by our cognitive system (Talanquer, 2014). In daily life, Type 1 reasoning processes enable us to make reasonable decisions or find satisfactory responses without a need for a cognitive path. However, Type 1 processes are also found responsible for the occurrence of several biases during the reasoning process of individuals. These biases could cause us to make mistakes in our intuitive decisions. In certain cases, it is required that mistaken intuitions should be prevented to conduct a solid reasoning and to make correct decisions and effective analytical reasoning, in other words Type 2 processes, should be utilized instead of these mistaken intuitions. With the intervention of Type 2 processes, inappropriate responses caused by Type 1 processes could be prevented or corrected. If an individual is extremely knowledgeable on a subject, or has high cognitive abilities, or a tendency to be reflective, under these circumstances, most probably Type 2 processes would intervene. If an individual has limited knowledge, with limited capacity, or lacks sufficient motivation to accomplish a task, it is possible that Type 1 processes would dominate (Morewedge & Kahneman, 2010; Shah & Oppenheimer, 2008; Stanovich & West, 2000; Talanquer, 2014; Tasdelen, 2002).

Most Type 1 processes are considered as shortcut reasoning strategies and called heuristics (Gilovich, Griffin & Kahneman, 2002; Morewedge & Kahneman, 2010; Shah & Oppenheimer, 2008; Talanquer, 2014). Heuristics shorten the information processing path and thus, help the individual to decide in a shorter than expected period of time. Heuristics usually facilitate reasoning by decreasing the number of cues used in decision making or creating implicit rules on where and how to search for information, when to terminate the search and what to do with the outcomes (Shah, 2008; Todd & Gigerenzer, 2000). Since heuristics effectively utilize the easily available information, they are considered as rational. Especially when there is limited information, short time and limited availability of computer technologies, heuristics could assist us in making the right decisions. However, heuristics are also responsible for the systematic mistakes in judgment (cognitive bias) (Talanquer, 2000; Todd & Gigerenzer, 2000).

Problem of Research

As a result of cognitive psychology studies and studies in other fields, several heuristic strategies are specified and defined. Price heuristic could be given as an example; if an individual has no information about the quality of an expensive product, she or he could conceive it as a quality product only because of its price (Graulich, 2014; Kahneman, 2011; Mitra, 1995). Specified and defined heuristic strategy types increase by the day and these strategy definitions meddle with each other. Most of the studies conducted on heuristic strategies are in fact presentations of field-specific examples of general principles. Heuristics identified as a result of such studies generally named after the content of the studied field. These heuristics with different names in fact use similar cognitive processes (Graulich, 2014; Shah, 2008). Thus, recent studies increasingly aim to categorize the heuristic strategies and collect them under general nominations. For instance, Morewedge and Kehneman (2010) grouped the most frequently used heuristics under three headings. These heuristics were recognition, availability and representativeness (Goldstein & Gigerenzer, 2002; Kahneman & Frederick, 2002; Morewedge & Kahneman, 2010).

Literature review revealed studies that were conducted to investigate the effects of intuitive thinking on decision making processes on matters of chemistry. In these studies, it was determined that intuitive thinking had different effects on learning and decision making processes of chemistry students, the students utilized various heuristics in reasoning processes, and vast majority of the students relied on Type 1 processes in decision making (Becker & Cooper, 2014; Cooper, Corley & Underwood, 2013; Maeyer & Talanquer, 2010; Maeyer & Talanquer, 2013;

McClary & Talanquer, 2011; Taber, 2009; Talanquer, 2006). This could be explained by the fact that certain traditional heuristic principles taught in class could diminish the cognitive paths in students, and memorization habits of the students. As a result, students could comprehend the concepts in a wrong or oversimplified manner.

As a result of the studies conducted on intuitive strategies of chemistry students, it was observed that students had various cognitive biases related to certain subjects such as degree of acidity of the molecules, organic chemistry reactions, solving chemical problems, molecular structure-property relations and classification of chemicals (Arellano & Towns, 2014; Becker & Cooper, 2014; Cooper, Corley & Underwood, 2013; Graulich, 2014; Kraft, Strickland & Bhattacharyya, 2010; Maeyer & Talanquer, 2013; McClary & Talanquer, 2011). These biases were the results of various heuristics utilized in reasoning and with these type of heuristic strategies, and students were able to provide correct answers without using the principal and important chemical knowledge. Furthermore, they gave incorrect answers using heuristic strategies as well.

All studies provided as examples above related to the effects of intuitive thinking on the decision making processes on chemical subjects focused on identification of heuristic strategies used by students and classification of these strategies. For instance, McClary & Talanquer (2011) identified that students frequently utilized three main heuristics while solving problems on the degree of acidity. These three heuristics were reduction, representativeness and lexicographic (McClary & Talanquer, 2011). Maeyer & Talanquer (2010) in a research conducted on ordering chemical compounds relatively based on physical or chemical properties and ordering different types of chemical reactions based on realization trend, determined that students utilized at least one or more of the recognition, representativeness, one-reason decision making and arbitrary trend heuristics (Maeyer & Talanquer, 2010). Provided examples reflected that several heuristics were identified and defined as a result of studies conducted on reasoning of the students in subjects of chemistry.

It is rather important to identify and define the heuristics utilized by students in chemistry subjects. However, it is also significant to explain how heuristics cause biases in students' intuitive judgment and decision making processes while solving problems of chemistry. Morewedge and Kahneman (2010) stated that even the scientists who proposed the dual-process model could not explain how the model actually worked and they proposed a new model (Morewedge & Kahneman, 2010). In the model proposed in an article they published in 2010, they mentioned three properties of associative memory to explain how heuristics could cause biases in intuitive judgment and decision making processes. These three properties are attribute substitution, fluency process and associative coherence (Morewedge & Kahneman, 2010). They stressed that each of these three properties could work with each other, and especially noted that these three properties could support and fortify each other in judgment and decision making processes. These three associative properties are summarized below (Graulich, 2014; Morewedge & Kahneman, 2010; Talanquer, 2014).

Attribute substitution: Commencing the evaluation of a special attribute of a stimulus automatically activates the evaluation of other dimensions and attributes of the same stimulus. In certain times, a target attribute could be less accessible than other attributes that the target attribute is associated with. In such cases, an easily accessible attribute could substitute the target attribute. In most cases, decision makers are not aware of such substitutions. For instance, consideration of whether an individual is generous or not. This consideration automatically makes it possible to remember other traits of the same individual (being sympathetic, friendly, virtuous or honest). Although there are no examples of the individual's generosity, an effect towards the perception of the individual as generous would be created.

Fluency process: All data given in a problem are not processed by the brain with the same level of difficulty. For an individual who is new in a field, examination of the properties given explicitly is easier than examination of properties given implicitly. During making judgments and decisions, individuals tend to use information achieved more easily. Fluency process predicates subjective ease and difficulty experiences related to accomplishment of a cognitive task. For instance, if there is more than one solution for a particular problem, the differences in solution paths could increase or decrease the perception of difficulty about the problem independent of the content of the problem. Unconscious selection of the cues that would be used in making a decision about a subject promotes a rapid decision. In this manner, correct or incorrect decisions could be made.

Associative coherence: Human memory is based on association of objects, properties and well-experienced events with each other. Cognitive structures existing in human memory associated with certain objects or events could automatically appear when an individual perceives certain things that could remind the individual these objects or events. Past knowledge could be remembered again. When an individual encounters a similar situation, this past knowledge could be reutilized for the new situation. However, incorrect decisions could be made as a

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

result of using this information in situations that are not related to those occurred in the past or in new situations superficially similar to those remained in the past.

Morewedge and Kahneman's (2010) model revealed the effects of associative memory and is focused on the types and properties of the associations that became effective in decision making process (Graulich, 2014). Thus, the Morewedge and Kahneman (2010) model would be beneficial for the objective of identification and explanation of reasoning resources of the students with intuitive associations, not for determination and classification of the heuristics (Graulich, 2014). Literature review revealed only one research that focused on explaining intuitive judgment processes in chemistry-related subjects using the theoretical model published by Morewedge and Kahneman in 2010. Mentioned research was published by Graulich in 2014 (Graulich, 2014). In this research, Graulich first mentioned the findings of the research by McClary & Talanquer on students ordering the molecules by the degree of acidity (McClary & Talanquer, 2011) and explained that three associative properties proposed by Morewedge and Kahneman could be used in explaining these findings using an example. This example is as follows: Students tend to compare the degrees of acidity of two different molecules by calculating the number of hydrogens in these two different molecules (attribute substitution). Hydrogens are responsible for the acidity of a solution (associative coherence, activated association). Determination of the number of hydrogens in a molecule is easily accessible information (fluency process). Using of such shortcut strategies leads to a perception and a generalization that diprotic acids are stronger than monoprotic acids. For example, H_2S molecule could be assessed as a more strong acid than HCl. In fact, HCl molecule is a stronger acid than H_2S molecule. Use of such shortcut strategies in comparison of acidity strengths would prevent the assessment of several variables such as electronegativity, bond strength and polarity, and thus, the problem would be solved using a shortcut, but incorrectly (Graulich, 2014). In the research published by Graulich (2014), the data obtained in the empirical research conducted by Graulich (2014) were presented and interpreted as well. For this purpose, the author explained intuitive judgments that affect response models used by the students in answering multiple choice questions on addition reactions, which is an organic chemistry subject, based on the three properties of associative memory (associative coherence, attribute substitution and fluency process) proposed by Morewedge and Kahneman (2010). Graulich (2014) identified that most (95%) of the decision making processes used by the students in answering the multiple choice questions were dependent on one or more of these three associative memory processes (Graulich, 2014). Graulich (2014) reported that this dependency resulted in correct answers as well as incorrect ones and presented the research findings based on how these three intuitive effects influenced the response models of the participants under three different headings. This innovation which was related to addition reactions, an organic chemistry subject, brought to the scientific world and its contributions are obvious. However, similar studies in other subjects in chemistry, especially in general chemistry are needed. The authors of the present article, to contribute to the scientific world in the related field, conducted a research on "chemical bonding theories and molecular structures." In this present research, to explain how heuristics utilized by students in a multiple choice examination related to the subject of "chemical bonding theories and molecular structures" caused biases in intuitive judgment and decision making processes, similar to Graulich's research, we utilized the model proposed by Morewedge & Kahneman (2010). The results of the present research and similar studies would contribute to better understanding of students' reasoning by educators in chemistry education.

Methodology of Research

General Background

The aim of the present research is to examine the impact of associative memory processes on the decision making processes of the students in a multiple choice examination on the subject of "chemical bonding theories and molecular structures." The subject of "chemical bonding theories and molecular structures" is one of the main subjects of general chemistry and could be accepted as an appropriate case for assessment of reasoning processes of students in general chemistry. In general chemistry courses, students are instructed on Lewis dot structures, valence-bond theory (VBT), valence shell electron pair repulsion theory (VSEPR), molecular orbital theory (MOT) and identification of molecular structures and molecular stability based on these theories in detail under the above mentioned subject matter. Determination of whether a molecule has a dipole moment utilizing molecular structures is also instructed under this subject matter. The subject is quite appropriate to research how students associate their superficial information with deep chemical knowledge. Students might consider that two compounds with similar chemical formula would have the same molecular geometry and the central atoms in these two different compounds have gone through the same type of hybridization. For instance, there are 3 chlorine atoms around the central atom of both BCl_3 and NCl_3 molecules. Superficially thinking, these two compounds are similar with respect to chemical notation. Thus, it could be conceived that these two compounds have the same molecular geometry and central atoms of boron and nitrogen have performed the same type of hybridization. In reality, the molecular structures and hybridization types performed by the central atoms in these two compounds are quite different. The above example demonstrates that the subject of "chemical bonding theories and molecular structures" is rather appropriate for use in investigating how the students associate their surface knowledge with deep chemical information.

The research question guiding this research is: In the subject of "chemical bonding theories and molecular structures", how the effects of heuristics on intuitive judgment and decision making processes can be explained by using the three characteristics of associative memory (attribute substitution, fluency process and associative coherence)? To answer this question, a mixed-methods approach, both qualitative and quantitative research methods, were used in this research. Detailed information about sample of research, time, methods, instruments and procedures is given below.

Sample

The present research is conducted in Firat University during the 2015-2016 academic year fall semester in Turkey. The number of students enrolled in the department of Science Teaching is 210. A total of fifteen first-year students enrolled in Science Teaching department participated in this research (8 males and 7 females) on a volunteer basis. There are four basic chemistry courses called as General Chemistry I, General Chemistry II, Analytical Chemistry and Organic Chemistry in the Education Faculties, Science Teaching Programs in Turkey. Various subjects such as properties of the matter, atomic structure, atoms and molecules, stoichiometry, periodic trend, chemical bonding theories and molecular structures, gases, liquids and solids are taught to students in General chemistry I courses. All the students who participated in this research had already joined the General Chemistry I course and were successful. All participants are domestic and from a variety of cities in Turkey. All participants involved in this research were given pseudonyms to protect their identity.

Research Methods, Instruments and Procedures

A mixed-methods approach, both qualitative and quantitative research methods, was used in this research. In the mixed-methods approach, quantitative and qualitative methods are combined in the context of one research. This approach takes advantage of using multiple ways to explore a research problem. In this research, both questionnaire and individual interview were utilized. There are several reasons for choosing this approach in which both qualitative and quantitative research tools were used. This approach is often used in science education research and offers some advantages that may be useful for this research. The use of the approach increases the interpretability and meaningfulness of the findings. At the same time, it enhances the validity of the research by removing prejudices and limitations associated with each research method (Greene et al., 1989; McClary & Talanquer, 2011).

The questionnaire was prepared by the researcher. The researcher is a specialist in science education. In addition to this, the views of a chemistry expert and assessment and evaluation expert were also obtained. The questionnaire took its final form after a pilot study was carried out at a different university. A total of 120 undergraduate students enrolled in Dicle University Education Faculty, Science Teaching program participated in the pilot study. The first form of questionnaire was containing six questions. The pilot study results showed that almost all of the participants marked the same options in the sixth question. So, the sixth question of the questionnaire was cancelled. The final status of the questionnaire contains five multiple choice questions related to the subject of "Chemical Bonding Theories and Molecular Structures". The questions in the questionnaire are shown in Table 1. The subject of "Chemical Bonding Theories and Molecular Structures" was instructed to these students in General Chemistry I course that they have taken previously. Attention was paid to choose superficially intimidating molecules for the questions, since the reasoning of the students was exceedingly associated with surface traits and the students extremely rely on memorization (Cooper, Corley & Underwood, 2013; Maeyer & Talanquer, 2010; Maeyer & Talanquer, 2013). Superficial similarity or distinction of the molecules could trigger certain associations. For instance, in the 1st question, molecular structure of SF4 was asked. Participants could only notice the number 4

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

in the formula. When only this number is considered, in other words when only the fact that the central atom has 4 bonds is considered, the participants could make an association that "if 4 atoms are bonded to the central atom, the structure could be tetrahedral or square planar." And thus, the participants could answer the question incorrectly.

Participants were given 10 minutes to answer the questions and to mark the correct option. It was reported in the literature that the effect of intuitional judgment and decision making increases when there is a time limit (Gillard et al., 2009b; Kelemen & Rosset, 2009; Talanquer, 2014). Thus, a time limit was implemented.

After the completion of the questionnaires, interviews were held with the students for approximately 45 minutes. The participants were asked their reasons to pick the answer they selected and to eliminate the other choices. Each interview was audio-recorded and transcribed.

Data Analysis

Data from interviews conducted immediately after the completion of the questionnaires were analysed using a pre-coding scheme based on the Morewedge-Kahneman model, similar to the research by Graulich (2014). For this purpose, the interviews given by the participants were reviewed several times based on the following particulars: 1) Strategies used by the participants to select an answer, 2) Fluency effects, 3) Associations used to identify the differences between the multiple choice answers. Other studies available in the literature on heuristic reasoning of students in chemistry were perused in designing the coding diagram (Maeyer & Talanquer, 2010; McClary & Talanquer, 2011).

Results of Research

The questionnaire questions related to the subject of "chemical bonding theories and molecular structures" and the number of participant responses on each choice that was available for these questions are presented in Table 1. Greyed figures reflect the number of students who marked the correct answer. This table demonstrates that the ratios of the correct answers marked by the students for each question were the following: 40.0% (for question 1), 33.3% (for question 2), 26.6% (for question 3), 46.6 % (for question 4), and 33.3% (for question 5). These ratios only reflect the ratios of participants that selected the correct answer and do not reflect the ratios of the participants that utilized their chemical knowledge accurately.

Table 1. The questionnaire questions that used in this research.

Q.1) What is the molecular form (structure) of SF4?			
A (5)	B (1)	C (6)	D (3)
Tetrahedral	Square planar	Seesaw	Triangular bipyramid
Q.2) The bond angles for BF3, PF3 and NF3 molecules are a, b and c, respectively. Which answer below reflects the correct descending order for a, b, and c?			
A (5)	B (5)	C (2)	D (3)
a > c > b	b > a > c	c > b > a	b > c > a
Q.3) Formal charge values of the central atoms of CO32-, SO3 and NH41+ molecules are a, b, and c, respectively. Which answer below reflects the correct descending order for a, b, and c?			
A (2)	B (4)	C (4)	D (5)
c > b > a	b > c > a	a > b > c	a > c > b
Q.4) Which option below reflects the correct order for the stability of O2, O21+ ve O22- molecules?			
A (2)	B (2)	C (4)	D (7)
O2>O21+= O22-	O22->O2>O21+	O2>O21+>O22-	O21+>O2> O22-
Q.5) Dipole moment values for BeH2, CCl4 and H2O molecules are a, b, and c, respectively. Which answer below reflects the correct descending order for a, b, and c?			
A (3)	B (5)	C (4)	D (3)
b > a > c	c > a = b	c > b > a	a > b > c

Note: The figures in parentheses given next to the multiple choice answers are the number of students who marked that answer. Greyed figures reflect the number of participants who gave the correct answer for the question.

All 15 students who participated in the research marked an option that was correct for them for all 5 questions in the questionnaire. In the interviews, students were asked to elaborate on the reasons for marking these options. The students explained in detail the reasons for the preferences they made for each question in the questionnaire during the interviews. Since each of the 15 students explained how to answer five questions, a total of 75 questions-solving methods have been obtained from the interviews. These 75 question-solving methods were examined in consideration of the general strategies that the students used to solve the questions. The same or similar strategies are grouped together under one heading. Thus, four different strategies were obtained. Since the students decided to mark an option after solving the questions, each of these strategies can be considered as a decision making strategy. Decision making strategies determined by this research are: Effort to remember previously learned information, use of surface traits, processes related to the use of chemistry knowledge and random answering. These decision making strategies were also presented in Table 2 with the number of students using these strategies and their percentages.

Table 2. Decision making strategies that the students used to solve the questions.

Decision making strategy	n	%
Effort to remember previously learned information	11	14.66
Use of surface traits	37	49.43
Processes related to the use of chemistry knowledge	12	16.00
Random answering	15	20.00
Total	75	100

n = Number of answers given using the related decision making strategy

In the questionnaire questions designed for the present research, it was requested to identify molecular structures, compare bond angles, formal charges, molecular stabilities, and dipole moments using chemical bond theories (VBT, VSEPR, MOT, and Lewis dot structure). This was the intended target attribute. Table 2 demonstrates that the participants did not utilize chemical bond theories in 63 decision making strategies (84%) and thus, did not assess the intended target attribute. The analysis of collected data furthermore showed that most of the decision making processes of the students were dependent on one or more of these three associative memory processes (associative coherence, attribute substitution and fluency process). This dependency resulted in both correct and incorrect answers. Findings of the research were organized and interpreted to explain how these three associative effects (associative coherence, attribute substitution and fluency process) affected the question answering models of the participants.

The first task while answering multiple choice questions is to determine what was demanded in the question. This could be seen as a very simple process. However, the initial approaches of the participants to the questions revealed that attribute substitution affected the initial interpretation of the questions by the participants and there were differences between the intended target attributes in the questions and the interpretations of the students as explained by them. It was determined that, in 62 problem solving methods (82.66%), the participants substituted the given question with another initially after reading the question and inclined to remember what they were instructed in class or what they learned from another source. Furthermore, it was identified that, in 51 out of these 62 problem solving methods, the participants were not able to remember the answer and gave up this strategy. The number of problem solving methods where the last decision was made with this strategy was 11 (14.66%). Attribute substitution caused differences between the intended target attribute and the interpretations expressed by the students. For instance, question 1, which was "what is the molecular structure of SF_4?" originally, was reduced to "Previously our teacher explained the structure of SF_4 molecule in the class as an example, what was the structure of the SF_4 finally" or "What was the molecular structure of SF_4 as I learned in the book." This was the result of the effect of attribute substitution. The participants attempted to remember what they were instructed in the class or when they read in any book using such a strategy. This strategy could be evidenced in the problem solving method of Kemal used to respond to the 1st question:

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Kemal: I picked the option C for the answer of the 1st question.
Interviewer: Could you please explain the strategy you used to arrive at this answer?
Kemal: First, I tried to remember whether I came across the molecule in the class or not. After thinking a while, I remembered that the instructor explained the molecule in the class previously and after making some calculations, the instructor mentioned the molecular structure as "seesaw".

A similar example was the method of Tulin used in question 4. Tulin answered the question incorrectly using a similar strategy:

Tulin: I picked the option C as the correct answer.
Interviewer: Could you please explain the strategy you used to arrive at this answer?
Tulin: I have a general habit. When I learn about a subject at school, I study the same subject again during the same day or as soon as possible using a textbook. When I learned "chemical bonding theories and molecular structures" subject, I have studied the same subject using a textbook. At that book I saw the MOT diagram for O_2 molecule. In the textbook, the stabilities of anions and cations of the O_2 molecule were explained and sorted based on the MOT diagram. I thought, if I remembered their order, I would be able to answer the question correctly. After thinking a while, I remembered the descending order was similar to the option C and I picked the option C.

The effect of attribute substitution was not observed only in the participants' initial approach to the question, but also in the proceeding stages of the solution. For instance, question 4 requires the students to order the stabilities of O_2, O_2^{1+} and O_2^{2-} molecules. It was determined that, in seven out of fifteen problem solving methods examined, participants compared the stabilities of these molecules by assessing the charges of the molecules. Assessment of molecular charges was the result of attribute substitution. The method used by Caner on question 4 could be given as an answer. While Caner attempted to solve this problem, he did not draw the MOT diagram for O_2 and interpreted it, instead he chose a simpler method:

Caner: I picked the option C as the correct answer.
Interviewer: Could you please explain the strategy you used to arrive at this answer?
Caner: First, I tried to remember whether I saw the order of these three molecules' stabilities in the class. But I could not remember. Then, I thought about a way to solve the problem. I was not sure if the method I thought about was right or not, but I decided to try my luck. I examined the three molecules up close. The only difference between these molecules was their charges. Negative charges on the molecule decrease the stability, positive charges increase it. Thus, the molecule with the highest stability should be O_2^{1+}, while the one with the lowest stability should be O_2^{1-}. I thought that way. My method could be correct or not. I am not sure.
Interviewer: You have said negative charges on the molecule decreased the stability of the molecule and positive charges increased the stability. Why and how the molecular charges change the stability? How did you reach such a judgment?
Caner: I thought when the molecule receives an electron; this electron could harm the structure. Therefore, the stability would decrease. I do not know exactly why, but I think this method is reasonable.

In the present research, it was identified that the participants were not aware of the effects of attribute substitution. Furthermore, it was determined that attribute substitution, fluency effect and associative coherence reinforce each other. It is difficult to find an example where one of these three associative effects occurred without the other two. As a result of this research, this fact has been encountered. For example, as explained above, attribute substitution observed during the initial approaches of the participants during problem solving was reinforced by their attempts to remember what they have learned before (fluency effect). It was also observed that these associative effects supported and reinforced each other during the further steps of problem solving. For example, Tulin's method of solving the question 4 above: Identification of molecular charges to determine the molecular stabilities (attribute substitution); molecular charges are responsible for the stability of a molecule (associative coherence), determination of molecular charge is an easy way to obtain information (fluency). These three associative effects triggered and reinforced each other. A careful analysis of interview data showed that the participants utilized surface traits frequently similar to the example given above. Solving the problem with the use of surface traits is a result of the fluency effect. Fluency effect manipulated the strategies or cues utilized for a task. Thus, fluency effect is the most dominant among these three associative processes that occur during individuals' decision making processes and reinforces attribute substitution. The tendency of the students to prefer easy-access information is considered as a result of the fluency effect. In 37 of 75 problem-solving methods examined (49.33%), it was identified that the participants utilized surface traits. Table 3 summarizes how the participants utilized surface traits for each question. Associative processes effective in this process are presented in Table 4.

Table 3. The ways participants utilized surface traits.

Question*	Use of surface traits	n
Q.1	There is the number 4 below the fluorine atom in SF4. This means that the central atom has 4 bonds. If there are 4 atoms around the central atom, then the structure is tetrahedral.	4
Q.2	Larger the radius of the central atom, larger the degree of its bond angles.	3
Q.2	As the electro-negativity of the central atom increases, the degree of bond angles increases as well.	2
Q.2	Higher the number of electrons in the molecule, larger the degree of the angle.	2
Q.3	Higher the positive charge on the molecule, higher the formal charge on the central atom. Negative charges on the molecule decrease the formal charge value of the central atom.	2
Q.3	Higher the negative charge on the molecule, higher the formal charge on the central atom. Positive charges on the molecule decrease the formal charge value of the central atom.	3
Q.3	Whether it is positive or negative, higher the charge on the molecule, higher the formal charge on the central atom.	5
Q.4	As the value of the positive charge on the molecule increases, stability of the molecule increases as well.	2
Q.4	As the value of the negative charge on the molecule increases, stability of the molecule increases as well.	2
Q.4	The most stable state is the neutral state. As the value of the charge on the molecule increases (positive or negative), stability of the molecule decreases.	2
Q.4	The most stable state is the neutral state. Molecular charge decreases stability. The charge value is insignificant.	1
Q.5	As the number of atoms around the central atom increases, dipole moment value of the molecule increases as well.	3
Q.5	As the electro-negativity of the central atom increases, dipole moment value of the molecule increases as well.	4
Q.5	As the radius of the central atom increases, dipole moment value of the molecule increases as well.	2

n: Number of decisions made using the related method
**: Questions 1-5 were presented in Table 1.*

Use of such surface traits caused the participants to change the original tasks asked from them. Change of the intended task is a result of attribute substitution effect. Attribute substitution reduces complexity by unconsciously ignoring the information required to solve the problems. For instance, the task intended for the participants was to determine the molecular structure using Lewis dot structure model and then finding the formal charge of the central atom for each molecule and rank their findings. In 10 out of 15 problem solving methods, it was determined that the participants assessed the molecular weights instead of accomplishing the above mentioned task. Surface traits such as molecular charges, central atom coordination numbers, central atom radii, central atom electro-negativities, and total number of electrons for each molecule were frequently used by the participants. A detailed analysis of Tables 3 and 4 could assist in understanding how the use of above mentioned surface traits unconsciously resulted in biases.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 4. Associative processes effective on the process of the participants using surface traits and related explanations.

Question*	Identified associative effects and explanations
Q.1	Determination of the coordination number of the central atom, in other words number of atoms bound on the central atom to identify the molecular geometry (attribute substitution). Coordination number of the central atom determined the geometry. Each coordination number expresses a geometrical form (associative coherence). To determine the number of atoms around the central atom is easily accessible information (fluency effect).
Q.2	Comparison of the radii of central atoms to compare the bond angles (attribute substitution). Radius of the central atom is responsible for the bond angles. As the radius of the central atom increases, degrees of bond angles increase (associative coherence). Comparison of the radii of central atoms is easily available information (fluency effect). Associative effects revealed in methods where electro-negativity of the central atom or total number of electrons in the molecule are assessed could be explained similarly.
Q.3	Determination of molecular charges to compare the formal charges of central atoms (attribute substitution). Higher the positive charge on the molecule, higher the formal charge value of the central atom (associative coherence). Determination of molecular charges is easily available information (fluency effect). Associative effects revealed in methods where negative charge on the central atom is considered to compare formal charges could be explained similarly.
Q.4	Identification of molecular charges to compare molecular stabilities (attribute substitution). As the positive charge value on the molecule increases, stability of the molecule increases as well (associative coherence). Determination of molecular charges is easily available information (fluency effect). Associative effects revealed in methods where negative charge on the central atom is considered to compare molecular stabilities could be explained similarly.
Q.5	Comparison of coordination numbers of central atoms to compare the dipole moments of molecules (attribute substitution). As the coordination number of central atom increases, molecular dipole moment value increases as well (associative coherence). To determine how many atoms there are around the central atom (coordination number) is easily available information (fluency effect). Associative effects revealed in methods where electro-negativity or the radiuses of the central atoms of the molecules are considered to compare molecular dipole moments could be explained similarly.

** Questions 1-5 were presented in Table 1.*

Participants who used surface traits created certain generalizations of their own while utilizing these traits. Thus, they thought that they have solved the problem rationally. In other words, via these generalizations, they have accepted their assumptions as valid and reliable. This type of behaviour has been known as "extreme self-confidence in judgment". The effect of associative coherence caused the formation of extreme self-confidence. For example, when the participants were solving the 1st question, they made a generalization that "each coordination number represents a geometrical figure." They considered this generalization as coherent. This situation was the result of associative coherence. The students' solution processes in question 2 could be given as another example. The participants made a generalization that "the radius of the central atom is responsible for the bond angles and as the radius of the central atom increases, the degree of bond angles increase as well" while solving this problem (the effect of associative coherence). These generalizations made by the participants were as a result of their mono-causal thinking. However, when evaluating chemical events, all factors affecting the event should be considered, not only one single factor.

In explaining certain properties of molecules such as boiling point, melting point, acidity and hardness, generally concepts such as electro-negativity, radius and charge are utilized. Students, who are accustomed to using these concepts or properties frequently, preferred to continue to use those to compare molecular bond angles, stabilities, formal charges or dipole moments, in a way that seemed logical to them. Use of these types of properties are easier to utilize bond theories. Use of these types of easier strategies instead of complex methods such as molecular orbital theory activated various associations. The present research conducted revealed in detail how these associations occurred and how these associations triggered each other within the context of "chemical bonding theories and molecular structures." Disclosure of the students' intuitive judgment processes with these types of studies would contribute significantly to studies on chemistry education and better understanding of students by the educators.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Discussion

The research revealed that the interviewed pre-service science teachers relied extremely on heuristic reasoning, rather than analytical thinking to make decisions when they faced with questions related to the topic of "chemical bonding theories and molecular structures". These heuristics let them decrease cognitive endeavour and create answers in the absence of necessary knowledge; unhappily, these cognitive constraints frequently led students astray. The total accuracy rate of the answers given by the students in this research is 36%. This rate is very low. Similar to the results of this research, it has been stated that total accuracy rates of the answers in different chemistry topics were detected as low in other studies in literature. For example, the total accuracy rates of the answers were determined as 27% and 31% in the Hydrogen Bonding and Addition Reactions topics, respectively (Graulich, Hopf & Schreiner, 2011; Miller & Kim, 2017). However, it has been also stated that in a research related to the Acid Strengths topic, this rate was determined as 77%, but unfortunately, less than 8% of participants marked correct answers used non-scientific ways (McClary & Talanquer, 2011). The main purpose of the researches in literature related to intuitive reasoning of students in chemistry courses is generally to identify and describe the heuristics which are usually used by students. One of the most reported and described heuristic in researches related to intuitive reasoning of students in the different areas of science is *recognition* (Gigerenzer, 2008; Leron & Hazzan, 2006; McClary & Talanquer, 2011, Pohl, 2004) *Recognition* heuristic is related to effort to remember previously learned information. In relation to this heuristic, Oppenheimer (2003) identified the recognition heuristic as follows: "According to the recognition heuristic, when an individual only recognizes one of two items, the individual will judge the recognized item to be greater in whatever dimensions are positively correlated with recognition." The results of the current research demonstrated that the participants used 4 different decision making strategies. One of these decision making strategies is "Effort to remember previously learned information". This strategy corresponds to *recognition* heuristic. As a result of this research, it was found that this strategy was used by the student with the rate of 14%. *Recognition* heuristic is a kind of heuristic that is almost completely encountered in studies on intuitive judgments related to chemistry concepts such as six-electron case, acid strength and addition reactions, with the similar rates detected in this research (Graulich, Hopf & Schreiner, 2011; Graulich, Tiemann & Schreiner, 2012; McClary & Talanquer, 2011). Another strategy named "use of surface traits" was also used by pre-service science teachers in response to the questions with the rate of 37% in this research. In each of the questions in the questionnaire, students were looking for visual cues such as type of the central atom, the number of other atoms connected to the central atom and charge of atoms or molecules. This quest generally caused them to use surface traits. In general, students relied on heuristic reasoning to find a way to fill in their knowledge gaps related to the topic of "chemical bonding theories and molecular structures". They used the heuristics especially, to make up for their lack of understanding about how to determine molecular structures, bond angles, stability, dipole moment values and formal charge. For example, to rank the dipole moment values of molecules in question 5, they used reasoning such as "as the number of atoms around the central atom increases, the dipole moment value of the molecule increases as well". Students should have determined the geometry of the molecules firstly, and then they should have created vectors for each bond in the structure. The sum of the vectors in structure expresses the net dipole moment as a vector. Students preferred not to follow this path. Students preferred the heuristic use, which is an easier way.

The main aim of the present research is to explain how the heuristics utilized by the students caused biases on intuitive judgment and decision making processes, using the three characteristics of associative memory. These characteristics have been named as "attribute substitution", "fluency process" and "associative coherence". So, this research focused on how heuristics cause biases in intuitive judgment rather than identify and describe the heuristics. It was determined by this research that the Processes related to the use of chemistry knowledge were used by students with the rate of only 16%. However, the total utilization rate of effort to remember previously learned information and the use of surface traits strategies are %64. The heuristics involved in the use of these two strategies have led to various prejudices. These strategies that students used for each question on the questionnaire were carefully examined to explain how the heuristics utilized by the students caused biases on intuitive judgment and decision making processes. The analysis of collected data showed that these decision making processes of the students were dependent on one or more of these three associative memory processes (associative coherence, attribute substitution and fluency process). These processes have begun to show their effects from the first moments when the students begin to solve the question. The students substituted the given question with another initially after reading the question and inclined to remember what they were instructed in class or what they learned from

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

another source. This is a consequence of *attribute substitution*. Attribute substitution caused differences between the intended target attribute and the interpretations expressed by the students. The effect of attribute substitution was observed not only in the participants' initial approach to the question, but also in the proceeding stages of the solution. Furthermore, it was determined that attribute substitution, fluency effect and associative coherence reinforced each other. How these effects reinforced each other can be understood by carefully examining Table 4. For example, as explained above, attribute substitution observed during the initial approaches of the participants during problem solving was reinforced by their attempts to remember what they have learned before. In this way, the tendency of the students to prefer easy-access information is also considered as a result of the *fluency* effect. Similar to these results, the literature stated that it is difficult to find an example where one of these three associative effects occurred without the other two (Talanquer, 2014). The participants utilized surface traits frequently. Solving the problem with the use of surface traits is a result of the *fluency* effect. Fluency effect manipulated the strategies or cues utilized for a task. Thus, fluency effect is the most dominant among these three associative processes that occur during the individuals' decision making processes and reinforces attribute substitution. Participants who used surface traits created certain generalizations of their own while utilizing these traits. Thus, they thought that they have solved the problem rationally. In other words, via these generalizations, they have accepted their assumptions as valid and reliable. This event is a consequence of the effects of *associative coherence*. The effect of associative coherence caused the formation of extreme self-confidence. For example, when the participants were solving the third question, they made a generalization that "Higher the positive charge on the molecule, higher the formal charge value of the central atom". In a research that conducted by Graulich (2014), the effects of these associative processes have also been explained in a similar way. In their research that related to organic chemistry reactions, Graulich (2014) stated that more than half of the participants replaced the question "What reagent is responsible for this reaction to occur?" with a simpler question "Where do I see the reagent for this reaction that I learned in class?". Graulich explained this event as a consequence of effect of *attribute substitution*. Graulich (2014) also stated that most of the participants used the functional groups such as OH, Cl, H_2O in the reaction medium, or on the molecule, as a clue. Graulich (2014) explained this event as a consequence of the effect of *fluency*. Graulich (2014) lastly stated that most of the participants did some generalizations such as "X_2 makes two halogens" and "HX makes one halogen". Graulich (2014) explained this event as a consequence of effect of *associative coherence*. It has been understood from the results of researches related to intuitive judgments and chemistry topics, the effects of these associative processes have been seen differently for each topic in chemistry concepts. For this reason, it will be useful to carry out similar studies in different chemistry topics.

Conclusions

Cognitive science theories have been used in researches related to forethought or intuitive reasoning of students in the different areas of science for years. However, researches related to the role of heuristics that are emphasized in the dual-process model in chemistry concepts have started very soon. Furthermore, researches on the use of the three characteristics of associative memory to explain how heuristics cause biases in intuitive judgments in chemistry concepts are very limited. To close the gap in the literature, this research in which cognitive psychology and science/chemistry education were evaluated together will make an important contribution to the literature. The strategies used by the participants to answer multiple choice questions posed in relation to the subject of "chemical bonding theories and molecular structures" were firstly determined by this research. Identification of the strategies of the participants raised the question that what is really measured with these types of examinations. Although the task required from the participants was to answer the question using chemical processes, majority of the participants used shortcuts and especially the surface traits. It was found that specific tasks required from the participants triggered heuristic reasoning strategies. During the interviews, participants stated that they have preferred the strategy that would cost them the minimum time. The participants answered the questions correctly or incorrectly using these types of strategies. The only responsible for the selection of these type shortcut strategies is not the students themselves. It is possible that shortcut problem solving strategies instructed to the students during all their academic life diminished the cognitive path in the students and thus, they could have developed a habit of solving the problems using shortcuts. Intuitive thinking is a normal human behaviour; that type of reasoning should not be prevented. As educators and teachers, our task is to determine how intuitive thinking affects the comprehension of the students, and after carefully analysing these determinations, to create field-specific successful ways of thinking. It could be beneficial to explain to students the incorrect ways of thinking that could be encountered during implementation of the shortcut strategies, which are frequently utilized on a subject matter, while instructing that particular subject matter in General Chemistry courses. It has been proposed to pose comparison questions to motivate the students to answer the questions using the chemical processes. The questions used in the present research were generally comparison questions. However, the results demonstrated that students frequently preferred shortcut methods despite the comparative questions that were posed. Therefore, we recommend that studies should be conducted to determine which type of questions would force the students to use chemical processes. Especially in multiple choice examinations where surface traits are used frequently, formats that would motivate students towards thinking in terms of chemistry are needed to be developed. We also consider that there is an extreme need for further studies on how to make Type 2 processes more active to correct the biases caused by Type 1 processes on chemistry subjects.

Finally, it should be stated that in the context of this research, no study has been conducted on whether some training methods can remove the effects of heuristics. This situation can be considered as an incomplete aspect of this research. For this reason, it is recommended to conduct researches on the use of specially designed different training strategies in order to remove the influence of heuristics on intuitive judgment.

References

Arellano, D. C. R., & Towns, M. (2014). Students understanding of alkyl halide reactions in undergraduate organic chemistry. *Chemistry Education Research and Practice, 15*, 501−515.

Becker, N. M., & Cooper, M. M. (2014). College chemistry students' understanding of potential energy in the context of atomic–molecular interactions. *Journal of Research in Science Teaching*, *51* (6), 789–808.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice, 8* (3), 293–307.

Connor P. E., & B. W. Becker. (2003). Personal value system sand decision-making styles of public managers. *Public Personnel Management, 32* (1), 155-180.

Cooper, M. M., Corley, L. M., & Underwood, S. M. (2013). An investigation of college chemistry students' understanding of structure-property relationships. *Journal of Research in Science Teaching, 50* (6), 699–721.

Driver, M. J., Brousseau, K., & Hunsaker, P.L. (1990). *The dynamic decision maker five decision styles for executive and business success*. Harper & Row: New York.

Evans, J. S. B. T. (2008). Dual-processing accounts of reasoning, judgment and social cognition. *Annual Review of Psychology*, *59*, 255–278.

Evans, J. S. B. T., & Stanovich, K. E. (2013). Dual-process theories of higher cognition: advancing the debate. *Perspectives on Psychological Science*, *8* (3), 223–241.

Ferrari, J. R. & Dovidio, J. F. (2000). Examining behavioral processes indecision: decisional procrastination and decision-making style. *Journal of Research in Personality, 34* (1), 127–137.

Gigerenzer, G. (2008). Why heuristics work. *Perspectives on Psychological Science*, *3* (1), 20-29.

Gigerenzer, G., & Goldstein, D. G. (1996). Reasoning the fast and frugal way: models of bounded rationality. *Psychological Review*, *103* (4), 650–669.

Gillard, E., Van Dooren, W., Schaeken, W., & Verschaffel, L. (2009b). Proportional reasoning as a heuristic-based process: time constraint and dual task considerations. *Experimental Psychology, 56* (2), 92–99.

Gilovich, T., Griffin, D., & Kahneman, D. (2002). *Heuristics and biases: the psychology of intuitive judgment,* edited by Gilovich, T., Griffin, D., and Kahneman, D. Cambridge University Press: Cambridge, U.K.

Goldstein, D. G., & Gigerenzer, G. (2002). Models of ecological rationality: the recognition heuristic. *Psychological Review*, *109* (1), 75–90.

Graulich, N. (2014). Intuitive judgments govern students' answering patterns in multiple-choice exercises in organic chemistry. *Journal of Chemical Education, 92* (2), 205-211.

Graulich, N., Hopf, H & Schreiner, P.R. (2011). Heuristic chemistry—addition reactions. *Chemistry - A European Journal*, *17*, 30 – 40.

Graulich, N., Tiemann, N., & Schreiner, P.R. (2012). Heuristic chemistry—a qualitative research on teaching domain-specific, strategies for the six-electron case. *Chemistry Education, Research and Practice*, *13*, 337–347.

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed method evaluation designs. *Educational Evaluation and Policy Analysis, 11* (3), 255–274.

Harris, R. (1998). *Introduction to decision making*. Vanguard University of Southern California: California.

Kahneman, D., Tversky, A., & Slovic, P. (1982). *Judgment under uncertainty: heuristics and biases.* Cambridge University Press: New York.

Kahneman, D., Gilovich, T., & Griffin, D. (2002). *Heuristics and biases: the psychology of intuitive judgment.* Cambridge University Press, New York.

Kahneman, D. (2011). *Thinking, fast and slow.* New York; Farrar, Straus and Giroux.

Kelemen, D., & Rosset, E. (2009). The human function compunction: teleological explanations in adults. *Cognition, 111* (1), 138–143.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Kraft, A., Strickland, A. M., & Bhattacharyya, G. (2010). Reasonable reasoning: multi-variate problem-solving in organic chemistry. *Chemistry Education Research and Practice*, *11*, 281–292.

Leron, U., & Hazzan, O. (2006). The rationality debate: application of cognitive psychology to mathematics education. *Educational Studies in Mathematics*, *62* (2), 105-126

Maeyer, J., & Talanquer, V. (2010). The Role of Intuitive Heuristics in Students' Thinking: Ranking Chemical Substances. *Science Education*, *94* (6), 963–984.

Maeyer, J. R. (2013). Common-sense chemistry: the use of assumptions and heuristics in problem solving. *Published Doctoral Dissertation*, The University of Arizona.

Maeyer, J., & Talanquer, V. (2013). Making predictions about chemical reactivity: assumptions and heuristics. *Journal of Research in Science Teaching*, *50* (6), 748–767.

McClary, L. K., & Talanquer, V. (2011). Heuristic reasoning in chemistry: making decisions about acid strength. *International Journal of Science Education, 33* (10), 1433-1454.

Miller, K., & Kim, T. (2017). Examining student heuristic usage in a hydrogen bonding assessment. *Biochemistry and Molecular Biology Education, 45* (5), 411–416.

Mitra, A. (1995). Price cue utilization in product evaluations: The moderating role of motivation and attribute information. *Journal of Business Research*, *33* (3), 187–195.

Morewedge, C. K., & Kahneman, D. (2010). Associative processes in intuitive judgment. *Trends in Cognitive Sciences,* 14 (10), 435–440.

Oppenheimer, D. M. (2003). Not so fast! (and not so frugal!): Rethinking the recognition heuristic. *Cognition*, 90, 1-9.

Pohl, R. F. (2006). Empirical tests of the recognition heuristic. *Journal of Behavioral Decision Making*, *19*, 251-271.

Scott, S., G., & Bruce, R. A. (1995). Decision making style, the development and of a new measure. *Educational and Psychological Measurement, 55* (5), 818-831.

Shah, A. K., & Oppenheimer, D. M. (2008). Heuristics made easy: an effort-reduction framework. *Psychological Bulletin*, *134* (2), 207-222.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: implications for the rationality debate. *Behavioral and Brain Sciences*, *23* (5), 645-726.

Stanovich, K. E., & West, R. F. (2003). *Evolutionary Versus Instrumental Goals: How Evolutionary Psychology Misconceives Human Rationality.* Hove East Sussex, UK: Psychology Press.

Stanovich, K. E. (2004). *The robot's rebellion: finding meaning in the age of Darwin*. Chicago: University of Chicago Press.

Taber, K. S. (2009). College students' conceptions of chemical stability: the widespread adoption of a heuristic rule out of context and beyond its range of application. *International Journal of Science Education, 31* (10), 1333–1358.

Talanquer, V. (2006). Common sense chemistry: a model for understanding students' alternative conceptions. *Chemical Education Research*, *83* (5), 811-816.

Talanquer, V. (2014). Chemistry education: ten heuristics to tame. *Journal of Chemical Education, 91*, 1091-1097.

Tasdelen, A. (2001). Decision making styles of pre-service teachers in relation to some psychosocial variables. *Journal of Pamukkale University Education Faculty, 10*, 40-52.

Tasdelen, A. (2002). Decision making styles of student teachers in relation to different psychosocial variables, *Published Doctoral Dissertation*, Dokuz Eylul University, İzmir.

Todd, P. M., & Gigerenzer, G. (2000). Pre-cis of simple heuristics that make us smart. *Behavioral and Brain Sciences*, *23* (5), 727–741.

Received: *January 08, 2018* Accepted: *April 10, 2018*

Mustafa Uğraş	PhD, Assistant Professor, Firat University, Education Faculty, Department of Elementary Education, 23119, Elazig, Turkey. E-mail: mugras@firat.edu.tr