Unesa Journal of Chemical Education *ISSN: 2252-9454*
Vol. 6 No. 1, pp. 125-132 January 2017

INTUITIVE THINKING STRATEGY: HEURISTIC REASONING TO RANK BOILING POINT OF CHEMICAL SUBSTANCES

Ia'natsuyarifah, Bambang Sugiarto, and Mitarlis Mitarlis
Chemisty Department, FMIPA, Universitas Negeri Surabaya
email: ianatusyarifah95@gmail.com

Abstract

The characterization of students' reasoning strategy is the most important thing in the development of curriculum and teaching strategies that will support student learning in chemistry. In particular, the identification of shortcut reasoning procedures (heuristic) were used by students to reduce cognitive load can help teacher to devise strategy to foster the development of more analytical ways of thinking. The main goal of this research was to investigate heuristic reasoning that used by vocational student of Light Vehicle Technique (*Teknik Kendaraan Ringan*), focused on their ability to predict the boiling point of chemical compounds represented using explicit composition, chemical structure, and relative molecular mass. Result of this research showed that participant relied heavily on one or more of the following heuristic reasoning to solve the problem: recognition, reduction, lexicographic, and one-reason decision making. Although the use of heuristic allowed participant to simplify some components of ranking task and generate correct responses, it often led them astray.
Keyword: Heuristic, Chemical Bonding, Reasoning

INTRODUCTION

Research on student's idea of natural phenomenon often demand students to explain, predict or making decision under uncertainty. Students' knowledge and reasoning in this case tend to be limited and underdeveloped. They were forced to conclude or making hypothesis without certitude, limited time, and limited source. In this situation, students often rely on any cognitive source which can be used to get plausible answer. Ones can predict that their way of thinking is very affected, directed by their intuition about their saliency and shortcut which can reduce information-processing load. According to Sugiarto (2017), in teaching-learning process teachers have to investigate and explore students' differences in order to adapt the education in accordance with the difference. Students will develop according to their respective capabilities [1].

Learning chemistry requires certain decision making skills about relative value of chemical and physical properties of a wide variety of chemical substances. This process is based on an analysis of the composition and structure of a compound, together with the application of models and chemical principles that allow students to predict about the expected behavior in a different environment. For example, when students compare the melting point of sodium bromide (NaBr) and potassium bromide (KBr), we can begin to recognize that both of these compounds are ionic compounds (model) that the chemical properties are determined by the size and ionic charge on each system (composition / structure). Based on Coulomb's law regarding to the interaction of the charge (principle) we can predict the system with smaller ions and electron charge are more likely to have a higher boiling point because of the energy that required to overcome the force of

Coulomb between charged particles, so knowing that the two compounds has a net charge of the same (+1), and recognizing that the potassium ion (K^+) is greater than the sodium ions (Na^+), students can predict that NaBr will have a greater melting point [2].

The examples above illustrate how the analytical thinking of students who are expected to be applied when analyzing and predicting the behavior of students. Type of thinking like this is the cognitive demands which require the identification of relevant cue to make a decision, recall and store the exact cue, judging manual cue, incorporating information from all possible alternatives, and comparing the alternatives to make a final decision [3]. Unfortunately, research shows that many students do not use or fail to use this type when confronted with various problems in chemistry, of a sort of chemical compounds based on the relative value of the properties is known to predict the stability of the compounds and the products of the reaction different chemicals [2]. Students prefer to use heuristic reasoning to solve this problem.

The purpose of the term 'heuristic' become uncertain in the research literature because researchers use them in different fields, from specific algorithm to complete the task, the general method to find a solution, until the rule of thumbs to resolve the issue. However, the determination and decision-making psychology, heuristics refers to simple reasoning process that reduces the effort associated with the task, especially under conditions of time, knowledge and limited computational power [3]. Limited knowledge led to the students' motivation to settle an issue to be low, especially material that is not directly related to the field they go into, it is more common in vocational students with no chemical subjects they requires. Chemistry in vocational subjects are not tested on the National Exam, only at mid semester and the end of semester. This leads to a lower motivation vocational students against chemical subjects that students do not pay attention to the teacher during the learning process so that the knowledge that they have also limited. In addition, vocational students found difficult chemical subjects and they cannot relate to the field they took.

Heuristics are expected to dominate when the student has the knowledge, capacity, or lack motivation to do the problems well. Although heuristic usually produce a satisfactory answer, the heuristic does not always produce a correct solution and often makes systematic bias [2]. The main goal of this research was to characterize the heuristic reasoning used by vocational students when rangking the boiling point of chemical substance.

METHODOGY

The type of this research is qualitative. The instruments that used are researcher and written question. The prominent of data source in qualitative research are words and action [4], in this research, the data source are written answer document and interview transcript. This research was done ini SMK Negeri Kudu, Jombang with 3 subject reseach from 10th grade student of Light Vehicle Technique *(Teknik Kendaraan Ringan)* vocation. Procedure of this research are asa follows:

1. Subject selection
   Selection of research subject are based on observation to student's communication activity in learning process and teacher recommendation. 3 research subject were obtained to be interviewed.
2. Written test
   Written test was done in the last meeting of chemical bonding matter. Written test was done by presenting the question in projector so the time to complete the task can be controlled. The purpose of constrained time in

this research is to limit the controlling and monitoring mechanism which related to analytical reasoning.

3. Interview
   Interview was done after the written test. The process of interview was done by giving the subject the same problem as the written test then the subject express their answer.

Analysis technique that used in this research is constant non-linear comparation where the general idea and thinking strategy are identified in each question [1]. After the data source is obtained, then data triangulation is done. Data triangulation is an examination of data validity that utilize some other thing [4]. The type of triangulation in this research is method triangulation. The last procedure of this research is to interpret the type of heuristic reasoning that used by subject to complete the task. Identification of the type of heuristic refer to the description of the type of heuristics according to McClary and Talanquer [1]. For reference and privacy purpose, an initial and a label were used in each question. For example, the first question will be labelled as Q1. This labelling system has been used throughout the presentation of the result.

RESULT AND DISCUSSION

Based on research data which have been analyzed and discussed as well as proved the validity, the heuristic reasoning that appears on Light Vehicle Technique (*Teknik Kendaraan Ringan*) vocational group, are as follows:

Table 1. Heuristic reasoning thatused by Light Vehicle Technique (*Teknik Kendaraan Ringan*) vocational group when solving problems in chemical bonding material

Subject	Heuristic reasoning used in question number-		
	1	2	3
R1	*Rec*	*Red*	*ORDM*
R2	*ORDM*	*Lex*	*ORDM*
R3	*ORDM*	*ORDM*	*ORDM*

Information:
Rec = Recognition
Red = Reduction
Lex = Lexicographic
ORDM = One-reason decision making

Based on the Table 1 it can be known that the research subject relies on various types of cognitive resources to solve the problem. For example, some subjects using their prior knowledge about boiling point to make a decision in the rank. However, this research was constrained to the identification and description of heuristic reasoning strategies used by the research subject during the written test and interview.

The analysis which have been done allow researchers to identify heuristics reasoning used by the research subject to rank the physical properties of compounds. Types of heuristic reasoning which used by research subject are as follows: recognition, representativeness, lexicographic, reduction, and one-reason decision making as listed by frequency of usage by research subjects (Table 2), Most of heuristics that identified are public domain rather than a specific domain, but any application based on the composition and structural features of chemical compounds that used in rank.

Table 2. Percentage of heuristic reasoning subject (n = 3) in solving problems in chemical bonding material

Heuristic	Thinking strategy	Average using
Recognition	The decision was made based on the recognition of an object, which is assumed to have the highest value with respect	11,11%

Heuristic	Thinking strategy	Average using
	to the relevant criterion [3]	
Lexicographic	The decision was made by search for cue at a time to differentiate between object, look for corresponding cue, compare the object on their value to the cue, and stop the search when the cue is found that enables a choice between object. [2]	11,11%
Reduction	The decision was made based on the reduction of cue which have similarity between object. [2]	11,11%
One-reason decision making	The decision was made based on the first cue that favors one alternative over others. [5]	66,67%

Naturally, the cue that draw the most attention in distinguishing objects have a strong influence on how the reasoning used. Each subject relied on at least one type of heuristics in the list above in constructing their answers to all the questions with the time constraint. Although this reasoning strategies can be very useful as cognitive tools to compare and rank chemical compounds, some of the subjects in this research failed to use it appropriately. No significant differences were found on the type, frequency, and effectiveness of the heuristics that used by Light Vehicle Technique (*Teknik Kendaraan Ringan*) vocational groups of students.

Here's the type of reasoning heuristic that used by research subjects when completing ranking task of physical properties of the chemical compound as well as a general description of how the heuristic reasoning used by research subjects

Recognition Heuristic

Considering the research subject's response to rank "volatile compounds" in written test and interview. In this case, an array ranking was produced in the selection of alcohol as the most volatile substance. In fact, 30% of the subjects who answered the quiz and interview make this decision. The results of the interview below describes how this type of reasoning was used to justify the subject of their choice, which is alcohol as the most volatile substances:

> *Alcohol is the first because, it related to, um, if spirits and gasoline are similar to it (alcohol), they easy to disappear in this open air, so that will be placed on first. (AP-Q1)*

The subject recognition of alcohol as a volatile substance plays an important role towards making a decision on this task. The results of this research suggest that the selection of alcohol as the most volatile compound is likely based on the recognition heuristic in the form: "if one of the several objects recognizable and others are not, and concluded that the recognized objects have a higher value to a criterion"

[5]. In general, this type of reasoning tend to use heuristics as the recognition of single cue to make decisions, particularly if there is a strong relationship between the recognized objects and criteria (i.e. volatility). These relationships are built and strengthened by the prior knowledge and experience.

Recognition heuristic is often used by the subject as an initial step in the ranks and as a transitional strategy if other efforts failed to distinguish compounds. In this cases, the subject of AP use it to put the compound in the highest position on the rank, which creates a reference to the next option.

Recognition heuristic re-used by the subjects AP in determining the next substance in rangking ‘volatile compound'. It can be seen from the following interview:

> *. . . we often see water while cooking, if the heating is too long, the water will reduce but it will not as fast as alcohol. (AP-Q1)*

The statement above strengthens assumption where the subject AP uses heuristic recognition in solving question number 1, where the subjects stated that they recognize these compounds based on experience and use object recognition in rank.

Lexicographic Heuristic

Another heuristic reasoning that used by the subjects in this research were lexicographic heuristic (Table 2). This type of heuristic are included in the reasoning strategies quickly and simply called 'one-reason decision making' [5]. The strategy of this type rely on prior knowledge of the decision-maker or their belief in the cue that can be used to choose between two or more objects. In particular, lexicography heuristic based on the following rules [6]: (1) search for cues one at a time to differentiate between option, (2) look for the corresponding cue values for each alternative, (3) compare the option on their values for that cue dimension, and (4) to stop the search when a cue is found that enables a choice between option [5]. In general, the final decision based on the selection of objects with highest value to the criteria. In this case, after the differentiate cue is found, the decision is usually made using 'more X then more Y'. For example, upon selecting the compound, KCl, NaCl which has a higher boiling point, the subject stopped looking for cue when the subject is aware that the Mr of KCl is greater than Mr of NaCl, then use those cue for a decision. Subjects were more likely to choose KCl as a compound which has a higher boiling point using the rules of the 'bigger Mr then higher boiling point'.

With an average of 11.11% of all the problem solving using this approach (Table 2). Heuristics of this type generally lead to the correct answer if the appropriate cue found and used appropriately in making the choice. Types of chemical bonds, the structure of the compound, the size of the compounds, intermolecular forces, are some cue which might be considered if ones using lexicographic heuristic reasoning, subjects most likely to notice the size of the compounds in rank. Consider the following interview excerpt:

> *The three of them have ionic bonding, and ionic bonding is between anion and cation (point the structure on the sheet) K^+ and Na^+ are cation, and Cl^- and OH^- are anion. (FN-Q2)*
>
> *KCl, NaCl, NaOH are all ionic bonding, so the boiling point can be seen from their Mr. the bigger Mr the higher boiling point. (FN-Q2)*

This subject identify the value of Mr of compound as relevant cue in boiling point in ranking chemical compounds in question 2. However, the subject does not understand how the value of Mr can affect the boiling point compounds and tend to

use simple heuristics 'the bigger Mr the higher boiling point'.

Reduction Heuristic

In situations where one must choose between multiple objects that look different from each other, a common reasoning strategy is to reduce the cue successively to consider during ranking process [6]. The explicit and implicit cue are known in large quantities that supplied to the matter, some of the research subjects explicitly use heuristic reduction to reduce the cue required to be considered during ranking process. In particular, the subject process by identifying structural features that are common of the three compounds and dismissed it for analysis purposes. Excerpt below illustrates this kind of reasoning:

> *Look, in the question is provided by their ions picture. The three of them are the same, the only difference is their Mr, so yes I ranked based on their Mr. The smallest of all three is NaOH, then NaCl, and the biggest is KCl. (AP-Q1)*

Although 30% of the research subjects using this kind of heuristic, but average use is only 11.11% of all the ranking tasks. The use of this heuristic is generally used when the objects have a common structure (e.g., the same constituent atoms), as what contained in the first and second question.

The excerpt also illustrates how the reduction heuristic is used in combination with other reasoning in making decisions. This is a common pattern among the research subjects who use this type of heuristics to minimize the number of cue to be considered during ranking process with the use of other strategies to make the final decision.

One-Reason Decision Making Heuristic

The analysis of students' answer about substance volatility properties producing final answer: water, alcohol, vinegar. Consider the following excerpts:

> *Because the three of them having covalent bonding. So, the ranking start from the smallest Mr, water, alcohol, and vinegar. (AT-Q1)*

From the excerpt above, the subject makes decisions based on the identification of the distinguishing factors of the three compounds that make them able to predict the behavior differences of the criteria (in this case, the boiling point of compound). For example in excerpt above where the subject noticed some cue (example: the type of chemical bonds and molecular size) during analysis. However, the final decision ultimately decided by the molecular size, compared with the analysis of the individual objects.

The results illustrate the application of the most widely used heuristic reasoning by the subjects (Table 2) to make plausible answer. One-reason decision making, an effort-reduction strategy helps people to choose between objects based on the first cue that considered to be the most supportive than any other cue to the criteria of [5]. This type of heuristics reduces the cue to be considered in making the decision. One-reason decision making heuristics are often used in conjugation with a simple stopping rule which is helpful in determining when to stop and how to make the decision [8]. In this research, the majority of subjects who use this reasoning strategies tend to stop the search when they identified cue that assumed to be related to ranking properties (e.g. boiling point), based on prior knowledge, experience, or intuition.

The research subject using different types of explicit and implicit cue as a single cue in making decisions. Explicit cue that used are as follows: common constituent atoms, the number of constituent atoms, and Mr of the compound. Meanwhile, common implicit

cue that used are the type of chemical bonding and intermolecular forces. If the cue which used only assist them to distinguish two objects in rank, they will start searching other cue, and use them to rank the remaining objects. Consider the following excerpt:

So, in the question there is NH_4OH, it has ionic bonding, so the boiling point will be the highest because the other two is covalent bonding. (FN-Q3)

Then, between methane and methanol, the boiling point of methanol is higher because it has hydrogen bonding. (FN-Q3)

. . . shown in the structure, the three of them have covalent and hydrogen bonding (FN-Q1)

The first is alcohol, because it just have one hydrogen bonding. (FN-Q1)

The second is water, because the Mr of water is smaller than vinegar. (FN-Q1)

In the two cases above, shows how the subject select and use explicit and implicit cue that applied in ranking objects one by one. Based on the excerpt above, the subject using more than one cue in the ranks when they found out that the first cue cannot generate the rankings completely. As can be seen on subject FN where she uses the type of chemical bond as the first cue, then use molecular size as the second cue when the type of chemical bonds cannot resolve the problems, it cannot help subjects FN decide the position of two other compounds in the ranking.

Subjects who use one-reason decision making heuristic are also often use other heuristics such as 'if more X then more Y' [9], to establish the relationship between cue and the p roperties that will be ranked. Subjects tend to relate the value of Mr with boiling point of compounds.

Overall, the results of the analysis of the cue that used in ranking physical properties of compounds using heuristic reasoning subject and the final decision subject can be seen in the following table:

Table 3. Use cue and the results of the final decision

Sub-ject	Result of student reasoning on question-					
	1		2		3	
	Final re-sult	Cue usage	Final result	Cue usage	Final re-sult	cue usa ge
R1	✓	✓	✓	✓	✓	-
R2	✓	✓	✓	✓	✓	✓
R3	-	-	✓	✓	✓	-

Information:
✓ = correct
- = incorrect

Based on the Table 3, we can see 9 relationships that were built by three research subjects, only 88.89% are correct, with 6 (66,67%) proper cue identification, and 3 (33,33)% use of improper cue. Based on the table above, 6 use the correct cue carried out by 2 research subjects. Wrong relationship generally occurs at about the numbers 1 and 3, this is because the initial knowledge of the subject is incomplete, and lack subject familiarity to the compounds that used in the ranking task.

The most common incorrect use of Mr compounds as the cue when ranking the physical properties of the compound without considering other factors, such as the type of bonding of the compounds, intermolecular forces, and symmetrical compound, as was done by subject AT at while completing question number 1 where the subject directly using the Mr of compound as the cue regardless other factors that affect the boiling point.

The students' in comprehension or mistake not only caused fatal in occupied course, but also in other subject. The impact of students' less sharpness in solving problem was not only caused by the learning process activities that took place in classroom, but it was suspected

that there were other causes within students [10].

CLOSURE

Conclusion

Based on the analysis and discussion, we can conclude that student mostly rely on heuristic reasoning when they were encourage to conclude or making hypothesis without certitude, limited time, and limited source. The type of heuristic used by vocational students of Light Vehicle Technique (*Teknik Kendaraan Ringan*) are as follows: recognition, reduction, lexicographic, and one-reason decision making thinking strategy. Although heuristic usually produce a satisfactory answer, the heuristic does not always produce a correct solution and often makes systematic bias.

Suggestion

1. Everyone have different thinking strategy as well as different reasoning in solving problem. Therefore, deeper research is required to explore heuristic reasoning by using more various type of ranking.
2. To know better about heuristic reasoning used by students to make plausible answers as well as the justification, it will be better to increase the quantity of research subject.

REFERENCES

1. Sugiarto, Bambang. 2016. *Delving Students' Metacognition Based on Reflective and Impulsive Cognition Style in Problem Solving about Solubility*. Journal of Science Education Vol. 18, p. 27-30, 2017.

2. McClary, LaKeisha and Vicente Talanquer. 2011 . *Heuristic Reasoning in Chemistry: Making decisions about acid strength*. International Journal of Science Education Vol. 33, No. 10, 1 July 2011, pp. 1433–1454

3. Shah, A. K., & Oppenheimer, D. M. 2008 . *Heuristics made easy: An effort-reduction framework.* Psychological Bulletin

4. Moleong, Lexy J. 2014. *Metodologi Penelitian Kualitatif*. Bandung: Remaja Rosdakarya

5. Goldstein, D. G., & Gigerenzer, G. 2002 . *Models of ecological rationality: The recognition heuristic*. Psychological Review

6. Fishburn, P. C. 1974 . *Lexicographic orders, utilities, and decision rules: A survey*. Management Science

7. Talanquer, V. 2006 . *Common sense chemistry: A model for understanding students' alternative conceptions*. Journal of Chemical Education

8. Todd, P. M., & Gigerenzer, G. 2000 . *Precis of simple heuristics that make us smart.* Behavioral and Brain Sciences

9. Stavy, R., & Tirosh, D. 2000 . *How students (mis-)understand science and mathematics: Intuitive rules*.New York: Teachers College Press.

10. Sugiarto, Bambang, Prabowo, & Suyono. 2014. *Students' Metacognitive Self-Regulation-A Case Study: Molecular Structure Problem Solving*. Chemistry: Bulgarian Journal of Science Education Vol. 23, No. 3, 2014