

## An Aspect of Science and Non-science Specialist Teachers' Perceptions of Chemistry Diagrams

### Fen Alan ve Fen Alan Dışı Öğretmenlerinin Kimya Görsellerine Bakış Açıkları

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**Abstract.** In the present study, what attracts the attention of science and non-science specialist teachers think in chemistry diagrams are explored. The data were gathered from 50 (25 female, 25 male) teachers of primary and secondary schools in Turkey. Twenty-seven (27) of the participants are science specialists and 23 are non-science specialists. The data were collected in 2012. A qualitative approach was adopted. The data were collected in three steps. Firstly, chemistry diagrams from internet were collected and some chemistry diagrams (12) were chosen by the researchers. In second step, selected diagrams were shown to the teachers. In this step, the participants were asked to think aloud about what they noticed when they looked at these diagrams. In the third step, semi-structured interviews were carried out in order to examine further the thoughts of the teachers on these diagrams. In our study, we found there were no significant differences in responses between the science and non-science specialist teachers. We conclude that it may be helpful to train teachers in the processes of constructing and reading diagrams.

**Keywords:** Teachers, chemistry teaching, chemistry diagrams, science education.

**Öz.** Bu çalışmada fen alan ve fen alan dışı öğretmenlerin kimya görsellerine bakış açıları irdelenmiştir. Çalışmanın örneklemini 50 (25 kadın, 25 erkek) öğretmen oluşturmaktadır. Bu öğretmenlerin 27'si fen bilimleri alanı, 23'ü ise diğer alan uzmanlıklarına sahiptir. Veriler 2012 yılında toplanmıştır. Çalışmada nitel araştırma tekniği kullanılmıştır. Veriler üç aşamada toplanmıştır. Birinci aşamada internet üzerinden kimya ile ilgili görseller toplanmış ve araştırmacılara tarafından çalışma için uygun olan görseller (12) seçilmiştir. İkinci aşamada seçilen görseller öğretmenlere gösterilmiş ve öğretmenlerin sesli düşün tekniği ile görsellerde neler gördükleri tespit edilmeye çalışılmıştır. Üçüncü aşamada öğretmenlerle yarı-yapılandırılmış görüşmeler yapılarak konu hakkında derinlemesine veriler toplanmıştır. Çalışma sonunda fen alan ve alan dışı uzman öğretmenlerin kimya diagramlarına bakış açılarında bir fark bulunmamıştır. Öğretmenlere fen eğitiminde kullanılabilen görselleri oluşturma ve okuma için eğitimler verilmesi önerilmektedir.

**Anahtar Kelimeler:** Öğretmenler, kimya öğretimi, kimya görselleri, fen eğitimi.

**Public Interest Statement.** Aim of this study was examination of what attracts the attention of science and non-science specialist teachers think in chemistry diagrams. It was founded that there were no significant differences in responses between the science and non-science specialist teachers.

**Toplumsal Mesaj.** Bu çalışma fen alanı ve fen alanı dışındaki öğretmenlerin kimya görsellerine bakış açıları irdelenmek amacıyla gerçekleştirilmiştir. Çalışma sonunda fen alanı ve alan dışı uzman öğretmenlerin kimya diagramlarına bakış açılarında bir fark bulunmamıştır.

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## 1. INTRODUCTION

Visuals are very important materials for effective education. There are many studies demonstrate that when science instruction includes visuals such as diagrams, students' learning and achievement about science improved (e.g. Boire, & Vagge, 1999; Davenport, Klahr, & Koedinger, 2007; Mayer, & Anderson, 1992; Mayer, Moreno, Butcher, 2006). However, for effective education the visuals must be used appropriately.

Some science education researches, have been investigated, the effectiveness of diagrams (Heiser, & Tversky 2006; Gobert, 1994). In spite of being effective personal tools for problem solving, diagrams can be seen as a widespread problem in education (Uesaka, & Manalo, 2007). In particular, issues of what observers see, in what order do they see them, do observers give equal priority to different components and interpretations, are there patterns in the way that diagrams are constructed, are animated diagrams observed in a similar way to static diagrams. This paper does not deal with all of these questions but focuses on static chemistry diagrams likely to be used in secondary school settings.

To be able to use visuals effectively in learning, 'visual literacy' is a term frequently used. In the literature, we can find lots of definition for visual literacy (e.g. Branton, 1999; Çam, 2006; Debes, 1969; Sinatra, 1986; Stokes, 2002; Wileman, 1993). Yenawine (1997), defines visual literacy as the ability to find the meaning in imagery.

"Visual literacy is a kind of communication (language) different and independent from the oral expression. Most of the definitions relating to visual literacy include how to interpret a visual image. We would also add that 'reading' a diagram is part of the process of interpretation. That visual literacy involves a specialized language with its own principles and operations reflects the common opinion on which most of the definitions and researches settled. Therefore, when we accept the visual literacy as incorporating a separate language, topics such as reading or seeing the images as the language of the message (visual learning), being aware of visual messages (visual discrimination), learning and teaching how to use it for communication (body language) and the limitations of applying become current issues" (as cited in Özsevgeç, Akbulut & Cerrah Özsevgeç, 2010, p.:30).

Teaching visual literacy requires background knowledge and experiences to formulate new pedagogical strategies in the classroom. Bringing visual literacy into new teaching methods requires teacher training (Begotray, 2002 as cited in McInnish & Wright, 2005, p.: 3).

In chemistry, the situation is compounded by the need to work at three levels of perception, the macroscopic, sub-microscopic and symbolic (Gabel, 1998). Expert chemists often use diagrams as a tool for linking these levels, and for visualizing the invisible (Oversby, 2012). These diagrams are frequently based on implicit conventions. We contend that diagrams would be used more effectively if the conventions were made explicit.

Although the diagrams are effective in science education, teachers must be careful about choosing and reading diagrams. Some recent studies found that some students and teachers lack spontaneity in biology diagram use (Umdu Topsakal & Oversby, 2011a, 2011b; Umdu Topsakal & Oversby, 2012; Umdu Topsakal & Oversby, 2013). Depending on the literature, there is a need to approach the chemistry diagrams as a part of teacher education. In the present study, we aimed to explore the attention of science and non-science specialist teachers to some features of some chemistry diagrams. The research questions are:

1. How teachers explore chemistry diagrams?
2. Are there any differences by exploring chemistry diagrams between science specialist and non-science specialist teachers?

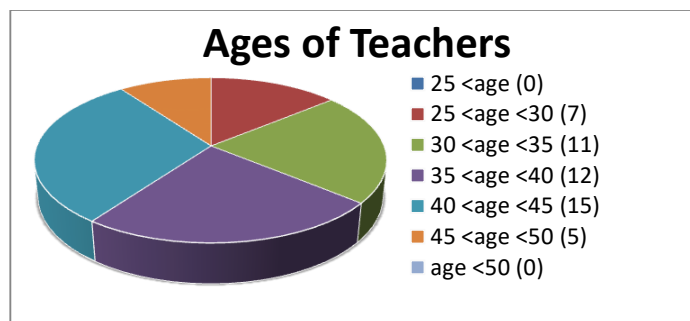
## 2. METHOD

### 2.1 Design of the Research

A qualitative approach was adopted.

### 2.2 Sampling

The research was performed in Turkey. The data were gathered from 50 (25 female, 25 male; 27 science specialists, 23 non-science specialist) teachers of primary and secondary schools. Ages (Chart 1) of these teachers are shown below.



**Chart 1.** Descriptive of Teachers' Ages

Semi-structured interviews were used and 20 (10 female, 10 male/ 10 science specialists, 10 non-science specialist) teachers participated. These teachers were randomly selected from the total sample.

### 2.3 Instrumentation and Analysis

The data were collected in three steps. Firstly, chemistry diagrams from internet were collected and some of these chemistry diagrams (12) were chosen for the investigation. 12 diagrams which are convenient for this research's aim (diagrams which are fundamental chemistry subjects and easy to understand) were selected among the 40 diagrams of 4 topics by the researchers and two other educators in the Science Education Department. These four topics are located in the Science Curriculum. The subjects were: electrochemistry, distillation, chemical structures and the atom model. We have not included the actual diagrams. We have provided sketches which were drawn by researchers, these sketches can serve as a simple reminder for readers. We provided sketches of diagrams for paper as some of the copyright owners would not give permission for the originals to be used, even with appropriate attributions. We took the line, therefore, that we would provide our own sketches for all the diagrams to avoid infringing copyright, yet we were able to provide a good enough idea of what the original diagrams might look like.

In second step, the selected diagrams were shown to the teachers. In this step, the participants were asked to say out loud (Think Aloud Protocol) when they look at these selected chemistry diagrams, focusing on what they noticed. Think Aloud protocol is a method that allows researchers to understand, at least in part, the thought process of a subject as they use a product, device, or manual. The researcher observes while the user attempts to complete a defined task. Ideally, the observer only speaks to remind the user to 'please keep talking' should they lapse into silence' (as cited in Johson, 2016, p.1). In Think Aloud research method participants speak aloud any words in their mind (Charter, 2003). "The Think Aloud Method consists of asking people to think aloud while solving a problem and analyzing the resulting verbal protocols." (as cited in Someren, Barnard & Sandberg 1994, p. xi). There are several investigations that demonstrate the effectiveness of Think Aloud Method (Molich 1994, Smilowitz, Darnell & Benson, 1994). Think Aloud is one way of collecting data in education research studies (Witrock, 1986). In this ethical study, the participants were informed that the researchers were investigating how people read diagrams.

In the third step, semi-structured interviews were carried out to examine the thoughts of the teachers on these diagrams more thoroughly. During the interviews, other questions in parallel with the subject of the chemistry diagrams were asked to reveal more detail. With all the remaining questions, the participants were allowed time to express their ideas freely without being interrupted. If they were reluctant to talk, or at a loss for words, the researcher used further questions to elicit more information. The answers received were recorded by the researcher by taking written notes. Each teacher's interview lasted for approximately 40 minutes.

The data were collected in 2012. The data was collected in Turkish and translated by the Turkish researcher for this study.

#### 2.4 Data analysis

A qualitative approach was adopted. One of the main forms of qualitative data analysis is grounded theory. In grounded theory following steps are as collecting data through several data collecting tools, then coding the data, grouping the codes and create a hypothesis (Allan, 2003). Grounded theory is a research method for creating a theory that is grounded in data systematically collected and analyzed (Strauss & Corbin, 1994, p. 273).

One of the researchers also carried out the Think Aloud Protocol. His noticing compared against the participants. We used the researcher's perceptions because:

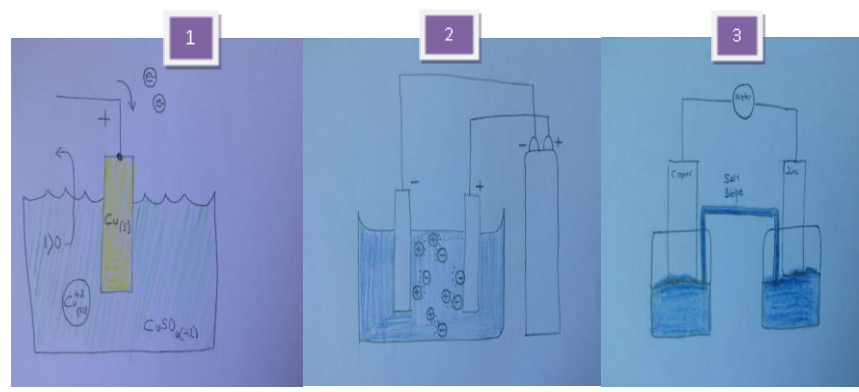
1. The researcher demonstrated a very strong ability to notice many valid components in diagrams of varying content, often many times more than other observers;
2. The researcher, in his published work, has substantial experience in interpreting diagrams, especially in aspects such as location of components, where he is precise.
3. The researcher was able to distinguish, in his perceptions, between simply noticing, and adding a layer of interpretation.

The opinions of the participants who gave the same type of answers and the participants who gave different types of answers were categorized and specified. Some of the participant statements that were different and interesting are also included as displayed quotes in the Results section.

The codes for the data collected in the research process were established by two researchers. Codes generated by researchers were compared and similarity was found as 81%.

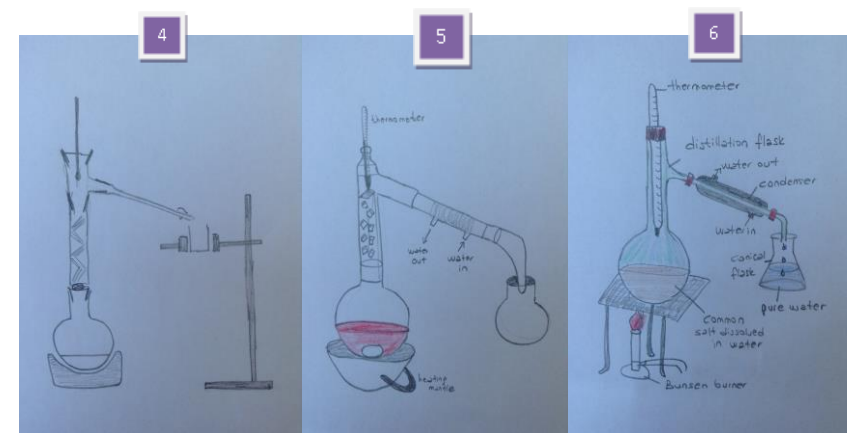
### 3. RESULTS

Most of the participants tried to explain electrochemistry subject, while looking at Figure 1. Although the prior knowledge levels of participants varied, what they noticed did not change. When looking at electrochemistry diagrams (Figure 1), they did not mention 'arrows or shapes'.



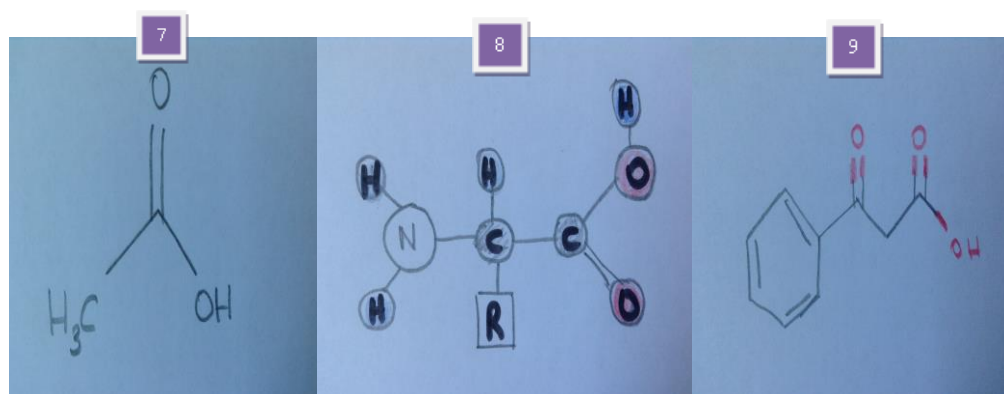
**Figure1.** Electrochemistry Diagrams (Diagram 1, Diagram 2, Diagram 3)

When looking at distillation diagrams (Figure 2), most of the participants tried to explain this chemistry subject and tried to find incorrect aspects of the diagrams. Most of them also explained the names of the chemistry materials they saw. They did not mention details such as colours, labels or arrows.



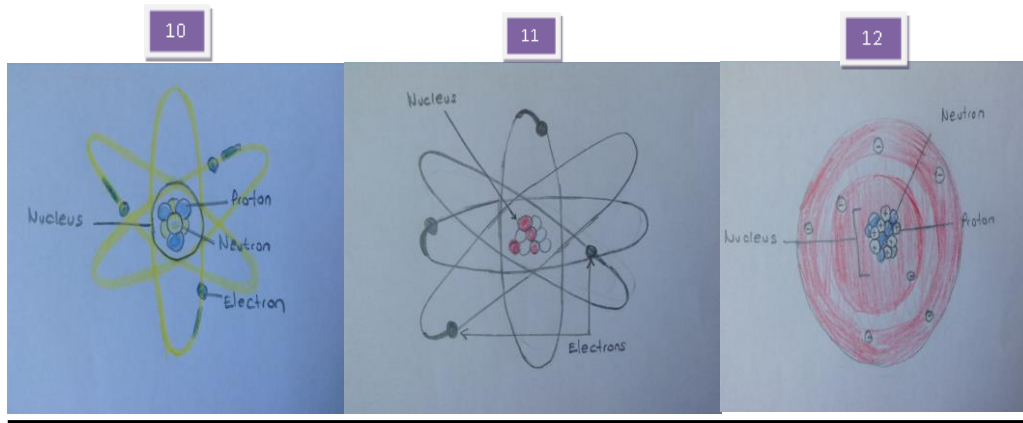
**Figure 2.** Diagrams (Diagram 4, Diagram 5, Diagram 6) of Distillation

Most of the participants tried to recall the names of the chemical structures, while looking at Figure 3. Some names were correct, some were not. They did not mention 'arrows, colours or shapes'. Most of the non-science specialist participants could not give any answer for Figure 3.



**Figure 3.** Diagrams (Diagram 7, Diagram 8, Diagram 9) of Chemical Structures

None of the teachers noticed the colours, shapes or arrows, while looking at Figure 4. All the participants said that Figure 4 is about the atom model. Some of them mentioned only one word such as 'atom', some of them tried to explain what an atom is, or what it contains. Science specialist participants have more knowledge about atom than non-science specialists.



**Figure 4.** Diagrams (Diagram 10, Diagram 11, Diagram 12) of an Atom

All the participants' thoughts when they looked at the science diagrams are categorised as below:

1. They explained the chemistry subjects on the diagrams. Science Teacher, male, 36 (For diagram 6): *'Distillation is a commonly used method for purifying liquids and separating mixtures of liquids into their individual components.'*
2. They tried to find incorrect features. They wanted to see the things that they thought were wrong. Science Teacher, female, 29 (For diagram 10): *'I think this diagram shows us distillation but here must be a heating source.'*
3. They completed the pictures (even gave extra information that was not drawn). Science Teacher, female, 29 (For diagram 10): *'This is an atom model. This is Rutherford's model. His model described the atom as a tiny, dense, positively charged core called a nucleus surrounded by lighter, negatively charged electrons. An atom is the atom was seen to be like a mini solar system where the electrons orbit the nucleus like planets orbiting around the sun.'*
4. They did not notice so many details such as the numbers of protons or electrons.
5. Mostly they did not notice arrows or shapes.
6. Mostly they did not notice colours.
7. Mostly the descriptions were general. Science Teacher, male, 36 (For diagram 2): *'This diagram is about electrochemistry.'* Geography teacher, female, 35: *'Diagram 10 shows atom model.'*

Because of this research we found that, when looking at chemistry diagrams, there are very few differences in responses between the science specialists and non- science specialists. Although the knowledge levels of participants change, what they noticed did not change. For instance; for Figure 2 some science specialist teachers only said that diagrams show distillation. Some of them explained distillation detailed. Non-science specialist teachers said for Figure 2, that these diagrams show a chemistry experiment. These explanations indicate differences of the knowledge level. In addition, because of their professional field, mathematic specialists mentioned mostly mathematical shapes while looking to diagrams. For instance, one of the mathematic teachers noticed rectangles and circles while looking at Diagram 2 and Diagram 3; hexagon while looking at diagram 9. History teachers saw historical events such as war or peace, as kind of analogies. While looking at diagram 10 one said that proton and neutron were like defenders, electrons were like aggressor forces.

Some of the science specialist and non-science specialist participants' statements that were different and interesting are also included as displayed quotes in Table 1.

**Table 1.** Some of the science specialist and non-science specialist participants' statements for some diagrams

Non-science specialist Participants' statements	Science specialist participants' statements
'Diagram 1 shows buoyancy of water.' (Mathematic teacher at the age of 35, Female.)	'Diagram 1 shows electrolysis.' (Science teacher at the age of 36, Female.)
'The diagram 5 shows laboratory.' (Social sciences teacher at the age of 37, Male.)	'The diagram 5 shows distillation.' (Science teacher at the age of 50, Female.)
'The diagram 6 is about warmth.' (Social sciences teacher at the age of 40, Male.)	'Diagram 6 shows distillation.' (Science teacher at the age of 37, Male.)
'The diagram 7 is about substance.' (History teacher at the age of 38, Male.)	'The diagram 7 shows acetic acid.' (Science teacher at the age of 29, Female.)
'Diagram 10 shows atom model.' (Geography teacher at the age of 35, Female.)	'Diagram 10 shows an atom model.' (Science teacher at the age of 36, Male.)

One of the researcher's noticing was put into comparison against the participants. Some descriptions of one of the researcher's noticing about Diagram 1 are below:

The diagram is bounded by a black-lined box. The lower half of the box is coloured uniform light blue, bounded at the top by a wavy horizontal line. The upper half of the box is white. In the middle is a yellow/orange rectangle, short edges horizontal, on the boundary between the upper and lower halves of the box, but the majority in the blue sector. In the upper sector is an L-shaped black line, with a dot where it meets the top of the orange rectangle. There is a black curved arrow (right and downwards directing) at the outside of the L corner, and a large black + sign on the inside. There are two black circles above the curved arrow, block filled yellow and what looks like e-inside, in black. To the left and under the rectangle is a circle, filled in blue (or is it the background showing through?) with what looks like  $\text{Cu}^{+2}(\text{aq})$  although the (aq) is exactly below the +2. There is  $\text{CuSO}_4(\text{aq})$  in the lower right corner. To the left of the rectangle is a long upward curved arrow, starting in the blue and finishing in the white and pointing left. At its bottom end is  $\delta > 0$ . The orange rectangle is shaded yellow towards the middle. The orange rectangle has the text Cu(s) in the middle.

Some descriptions of one of the researcher's noticing about Diagram 7 are below:

This diagram has a single colour. It is arranged almost symmetrically in a kind of pyramid, with the components containing an H at the bottom and the single O at the top. The O at the top has two black lines coming down, to meet an angled line just slightly off-centre. The two components at the bottom have single lines to meet at the middle. One single black line meets at the left a C symbol. The left component has a subscript 3 and an H. The single black line meets an O at the right, next to which, on its right is situated an H.

#### 4. DISCUSSION AND CONCLUSION

We know that science specialist and non-science specialist participants have different knowledge about chemistry topics. This result is inherent. However, despite different knowledge levels, there were no different noticing between the science specialists and non-science specialist participants, while looking at chemistry diagrams. Also, there were no clear differences related to gender and the age.

Because of their background knowledge, participants saw things related to their professional field, while looking to some chemistry diagrams. Sinatra (1986) sees visual literacy as the efficient reconstruction of incoming visual messages with past visual experiences in order to have a



meaning (as cited in Özsevgeç, Akbulut & Cerrah Özsevgeç, 2010, p. 30). Besides, Shepardson and Britsch (2001) have suggested that children contextualize their science experience into three different 'worlds' or mental contexts including imagination, previous experience, and the science investigation itself (as cited in Jones, Gardner, Taylor, Wiebe & Forrester, 2011, p. 358).

As a result of this study our hypothesis is that science specialist teachers are limited in reading or interpreting chemistry diagrams. The teachers should be taught how to 'read' diagrams and how to filter the valuable from the insignificant because of using diagrams effectively in science education.

The theory which we teased out of our observations had the following aspects:

1. Variation in granularity of perception in diagrams was apparent across the participants, and between the participants and the researchers. Within this granularity, the data also raised issues of perception of detail. In fact, the level of detail observed by the participants was often quite limited. Our theory is that such coarseness of grain and overlooking detail is part of the difficulties in using diagrams for explaining that we generally see.

2. Significance of conventions in diagrams may well be only weakly understood, leading to problems in both perceiving and interpreting diagrams.

3. The influence of location of components in diagrams, such as the general rule of including inputs from the left, and outputs from the right, is only weakly appreciated.

This study is part of a collaborative study of wider aspects of the role of diagrams in learning. We have identified diagrams as a widespread problem, and that students and teachers lack spontaneity in diagram use (Umdu Topsakal & Oversby, 2011a, 2011b; Umdu Topsakal & Oversby, 2012; Umdu Topsakal & Oversby, 2013). If visual literacy is regarded as incorporating a different language, then there is a need to know how to communicate using this language, which includes being alert to visual messages and critically reading or viewing images as the language of the messages' (as cited in Stokes, 2002, p. 12). Therefore, as Stokes (2002) concluded a study evaluating the overall impact on student learning is effective for developing tools which measure visual literacy including skills of creating and interpreting visual language.

We have chosen to investigate the simple idea of what is noticed in diagrams as part of a larger investigation of the use of chemistry diagrams in teaching and learning. We have seen that, often, the focus is on interpretation and correction but we feel that, first, we should know what is being noticed by the observers. We have been interested in the level of detail that is discovered by the 'readers' of the diagrams as well as the disposition of elements, such as whether they are grouped, and whether there is a common disposition among diagram creators.

## 5. EDUCATIONAL IMPLICATIONS

This study investigated diagrams in chemistry. We are investigating whether this is the same in other scientific contexts and disciplines. We are expecting to build up a database of how individuals 'read' diagrams. A major outcome of this process will be a better understanding of the role of diagrams in science teaching and learning, and perhaps clearer use by authors of diagrams in their work.

We also recommend that the teachers be taught how to 'read' diagrams, and how to filter the valuable from the insignificant. Resulting from this, we also recommend that explicit teaching of procedural knowledge be a part of the school curriculum. This matter needs to be explored among science educators and policymakers as a development of this research.

We recognised the conflation of noticing with interpretation and plan to carry out further studies to examine this further.



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