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Turkish, Indian, and American Chemistry Textbooks Use of Inscriptions to Represent 'Types of Chemical Reactions'

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The purpose of this study was to investigate inscriptions used in 'Types of chemical reactions' topic in Turkish, Indian, and American chemistry textbooks. We investigated both the types of inscriptions and how they were used in textbooks to support learning. A conceptual analysis method was employed to determine how those textbooks use inscriptions to present 'Types of chemical reactions.' Results revealed that textbooks disproportionately used inscriptions at symbolic level and failed to present sub-microscopic level. Moreover, in Turkish and Indian books, explicit connections between all three levels of inscriptions were inadequate whereas American textbook had them sufficiently. Inscriptions including multiple levels were provided simultaneously in American textbook. This research will contribute to growing literature of international studies about use of inscriptions in science textbooks.

Keywords: Inscription, international studies, semiotic analysis, textbook analysis, and types of chemical reactions

INTRODUCTION

People use visual representations such as graphs in daily life to explain phenomena. Because visual representations show in an organized and succinct what we intend to tell, bringing them into play is crucial. Thus, scientists, particularly chemists, use different types of visual representations, because "words alone [are] insufficient to support [scientists'] thinking …" (Kozma, Chin, Russell, & Marx, 2000, p.115).

In this research, we preferred to use "inscription" rather than "representation." The latter term creates misunderstanding due to its dual meaning as visual display and mental content. However, the use of "inscription," suggested by the sociology of scientific knowledge, eliminates that confusion. Whereas mental representations are not communal, inscriptions are shared with other people and groups (Roth & McGinn, 1998). Inscriptions are described as "all forms of visual representations other than text inscribed in some medium" (Han & Roth, 2006, p.173).

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State of the literature

- Both teachers and textbooks play a significant role in students' science learning
- Textbooks are also valuable sources for learners who need to study alone at their own pace, or to remember the topics taught in class.
- Given the importance of science textbooks, Stern and Roseman (2004) posited that high quality textbooks positively affect student learning, which makes analysis of those essential. Moreover, it has been specifically pointed out that even though inscriptions have crucial roles in learners' science learning, the analysis of them has been neglected.

Contribution of this paper to the literature

- Current study by focusing on a chemistry topic within textbooks used in three different countries and cultures aims to illustrate how inscriptions are employed across-countries to aid student learning.
- In this study, although our purpose is not to generalize the results to all textbooks in the countries focused on, we hope that the examination of inscriptions is able to provide useful information to science teachers, textbook writers, and publishers.
- Finally, the new model developed and designated with the acronym ARPSAM will be useful for researchers studying semiotic analysis in science, and help give them a better and more comprehensive lens for analysis.

Not only do scientists use inscriptions, but also science learners, teachers, and textbooks use them as well. For instance, chemistry textbooks include various types of inscriptions (e.g., equations) to explain chemical reactions. For meaningful understanding of what is written in a science textbook, readers should be able to integrate the text and inscription simultaneously (Han & Roth, 2006). However, this is not an easy goal to attain. Although different reasons may be attributed for science learners' difficulties in science learning, one possible reason may be the inadequacy of the inscriptions to tell readers what is intended to be represented by their use (Ainsworth, 2007). Therefore, science teachers and textbooks should not only aim to teach science content, but also to teach how to interpret inscriptions, and how to relate text and inscriptions mutually to provide meaningful science understanding (Pozzer-Ardenghi & Roth, 2005).

The purpose of the study

In this study, we aimed to examine the portrayal of inscriptions used in high school chemistry textbooks to present 'Types of chemical reactions', which is lacking in the research literature. Besides, there is no study that focuses on comparing the use of inscriptions across countries to support students' learning of chemistry. The research questions guiding the study were:

1. Which types of inscriptions are used in Turkish, Indian, and American high school chemistry textbooks?

2. How do Turkish, Indian, and American chemistry textbooks use inscriptions to explain 'Types of chemical reactions'?

Theoretical Framework

Science textbooks are the most commonly available tools for both teachers and learners. Thus, to gain more benefit out of these tools, one needs to understand and interpret them in a comprehensive way how they use various types of inscriptions. Treagust, Chittleborough, and Mamiala (2003) stated that there are three levels of inscriptions in chemistry, namely, macroscopic, sub-microscopic, and symbolic. The phenomena that we can see, such as seeing fire during combustion reaction, are at macroscopic level. Material entities perceivable neither to the naked eye nor through the microscope, such as atoms, are at the sub-microscopic level, which deals with particles and can also be termed as the "particulate level." If we consider the combustion reaction of methane at the particulate level, one methane molecule collides with two oxygen molecules to form one molecule of carbon dioxide and two molecules of water. Finally, if we want to write the equation of the reaction with chemical formulas of reactants and products, this is known as the symbolic description of the reaction.

Semiotics

Han and Roth developed a semiotic model to analyze chemical inscriptions. "Semiotics is concerned with the codes underlying communication" (Han & Roth, 2006, p. 183). Scientific language has semiotic components in addition to verbal ones (Lemke, 1998). The inscriptions and the text in the textbooks are *semiotic resources* and their analysis is known as *semiotic analysis* (Pozzer & Roth, 2003). Such analysis is useful for diagnosing the parts contributing to learners' understanding (Han & Roth, 2006).

The process of learning in general and science learning in particular depends heavily on effective communication. Students' progress in learning depends on their correspondence with inscriptions. Hence, clearer inscriptions lead to better science understanding (Ainsworth, 2006). Now this correspondence depends upon to what extent a learner relates the representative world (i.e., an inscription) with the natural world. In fact, people dealing with chemical phenomena use representational systems in a way to create a linking path between the invisible and visible (Kozma et al., 2000). Because science and particularly chemistry are abstract

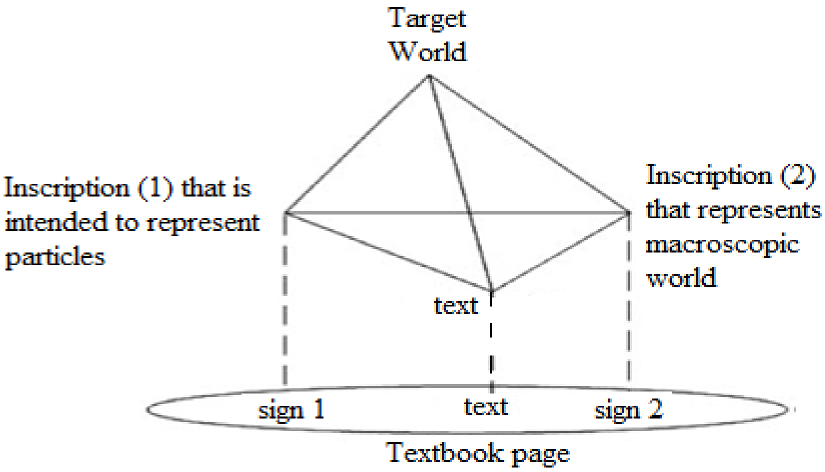

Figure 1. Han and Roth's (2006) triangular pyramid semiotic model (p.183)

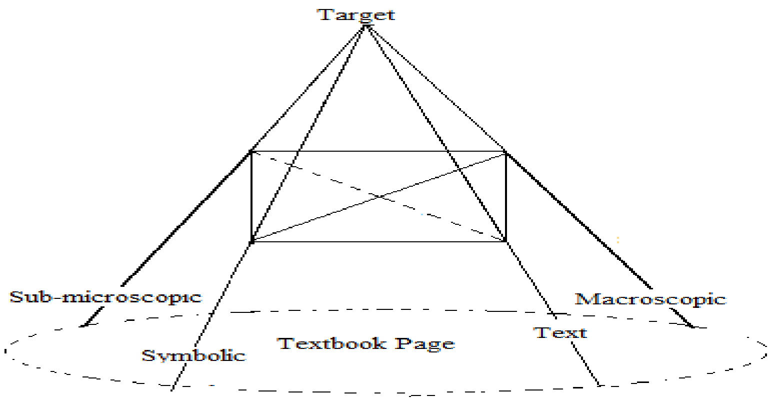

Figure 2. Representation of ARPSAM

in nature, students have to use their imagination to understand the processes in sub-microscopic and symbolic levels (that is, the invisible levels) whose results are experienced overtly on the macroscopic level (the visible level). Now this journey from imagination to comprehension is done by riding on a vehicle where the different extracted meaning of presented inscriptions form its wheels.

Existent Semiotic Model

Han and Roth (2006) developed a semiotic model for analyzing components of textbooks, namely, title, main text, questions, and two levels of inscriptions standing for macroscopic phenomena and the invisible particles (Figure 1).

This triangular pyramidal model has two distinct constituents, the oval base, which is formed by the parts of a chemistry textbook and the top, the targeted world, which the author of a textbook intends the learner to know about. There are three cornerstones that form the base of the pyramid. These are (1) the Text, (2) the Inscriptions showing the macroscopic world (e.g., photograph), and (3) the Inscriptions representing sub-microscopic particles (e.g., depiction of particles reacting). The apical denotes the "the world outside the text" (p.184). It is our natural world of interest in which all related phenomena take place. This model is designed to meticulously interrelate these three cornerstones of the base and the top. Each corner is connected to the others to form four triadic relations among themselves.

In this model, to be able to read an inscription, the reader has to do two types of interpretations, namely, interpretation:

> *…inside an inscription (or text), e.g., structuring [st], and [interpretation] between inscriptions and text, e.g., translating [tl] (or transposing). To get their point, that is, the sense that its author intended, all three elements on the textbook page have to be co-organized. (p. 185, italics are in the original)*

In other words, the former is a "process of analyzing the internal structure of an inscription or text" (p.184) whereas the latter is "the translation process between two worlds" (Han & Roth, 2006, p. 184). Both of the processes are necessary for meaningful understanding of the content represented by the use of inscription in textbooks.

A Rectangular Pyramid Semiotic Analysis Model (ARPSAM)

Treagust et al.'s (2003) three levels of inscription and the prior analysis of the inscriptions used in the chemistry textbooks helped us to realize that although many chemical equations (i.e., inscriptions at the symbolic level) are utilized in textbooks, Han and Roth did not include them in the model. Therefore, we stated that it would be better to add the symbolic level, one of the basic levels of chemical inscriptions into our model. Hence, for semiotic analysis, the new model with a rectangular pyramid is suggested (Figure 2).

The existence of the solid lines from target world to oval base show which levels of inscriptions are used to represent the target phenomenon. For instance, because all lines are solid from the target phenomena to the oval base, in figure 2 target phenomena were represented at all three levels and were explained in the text. If there were a dashed line, it would indicate the lack of a particular level of inscription in the textbook page.

In the ARPSAM, the edges of the rectangle between the oval base and target are used to show whether different levels of inscriptions and the text are connected to each other or not. For instance, the solid line between the symbolic and sub-microscopic levels, the left vertical edge of the rectangle, shows that those levels are linked to each other. The diagonal showed with solid line indicates that the symbolic and macroscopic levels are connected. Finally, if there is a dashed line, such as the one between sub-microscopic level and text, another diagonal of the rectangle, this means that there is no explicit link between levels that are at the text and sub-microscopic level. Not only the connections between inscriptions but also the link between the inscriptions and the text are highly important regarding the comprehension and interpretation of the content (Han & Roth, 2006).

METHODOLOGY

Type of the Study

Conceptual frameworks as guiding principles are the most crucial step to analyze any form of information. Researchers use various conceptual frameworks to analyze textbooks to test their use and representation of some specific content, concept, image, and their epistemological orientation to learning and teaching (Chiappetta & Fillman, 2007). In conceptual analysis, a specific concept or content is chosen for assessment, and the conceptual analysis process looks for quantifying and presence of the specific concept or content.

Selecting the Domain and Countries

Chemistry was selected as the field of interest due to authors' expertise. The topic 'Types of chemical reactions' was determined for analysis because it includes multiple examples of inscriptions at the macroscopic, symbolic, and sub-microscopic levels. The reason why we decided to investigate the Turkish, Indian, and American chemistry textbooks was to capitalize on the authors' language expertise and on cultural background. Additionally, we did a literature review and failed to turn up such research comparing and contrasting those countries' textbooks regarding inscription use.

In response to Han and Roth (2006), we decided to enlarge the sample of textbook analyses of inscriptions by comparing and contrasting inscriptions used to teach 'Types of chemical reactions'. The American (i.e., we mean the US by the use of American) book analyzed was one that is used for general chemistry classes in the school district in Columbia, MO, where all of the researchers study. Therefore, it may not represent the other chemistry textbooks used in other states. The National Council of Educational Research and Training developed the Indian textbook. It is used by public schools in various parts of India. The Turkish textbook examined was published by the Turkish National Ministry of Education in light of the national chemistry curriculum and is used by all public schools. It is also worth mentioning here that because Turkish and Indian textbooks did not have any accompanying CD and lab manual, we decided to analyze the main textbooks only. All textbooks were prepared for learners at 9th grade and used by general chemistry classes. Finally, it is necessary to reveal that our purpose was not to generalize the results gathered in this study to every chemistry textbook used in the countries mentioned. Rather, we aimed to get an idea about which types of inscriptions are utilized and how they are used in different countries.

Data Analysis

We carried out two types of analyses in this research. First, an analysis of frequency, total number of inscriptions, and types of inscriptions for three different countries' textbooks was done. We counted all inscriptions in the types of reactions for all of the textbooks analyzed. After deciding on which aspects of textbooks' inscription would be analyzed and forming the tables used for analysis, researchers conducted the frequency analysis individually. All types of inscriptions were given a number; for instance, all tables, figures, and photos were enumerated. Then, we came together to compare and contrast the results. When differences were faced, we discussed them and reached consensus.

Table 1. Types of Inscriptions Used in Turkish, Indian, and the American Chemistry Textbooks

Various Examples of Types of inscription	Countries		
	TURKEY	INDIA	AMERICAN
Photograph	17	-	-
Drawing	-	1	-
Table	1	-	1
Chart	2	-	-
Equation	23	14	24
Multiple	6	7	6
Total	49	22	31

Table 2. Levels of Inscriptions Used in Turkish, Indian, and the American Chemistry Textbooks

Level of inscription	Countries		
	TURKEY	INDIA	AMERICA
Macroscopic	17	1	-
Sub-microscopic	-	-	-
Symbolic	23	14	25
Multiple	6	7	6
NA	3	-	-
Total	49	22	31

Second, with the help of the aforementioned analysis, we realized that each textbook has its own style and that generally they used similar inscriptions (see Table -1 in the result section). For instance, photographs, equations, and the multiple inscriptions were most common inscriptions used in the Turkish textbook. Therefore, it was reasonable to select a representative inscription used in each textbook. The decision on the representative one was random. Then we conducted a semiotic analysis of representative inscriptions by using the new model, ARPSAM. We analyzed the selected representative inscriptions and drew a semiotic model showing the characteristics of each inscription. Then, we again came together and discussed the differences in our models. Although we had some differences in models that we drew at the beginning, we reached consensus after discussions and sometimes made changes accordingly.

Results were given in two main parts, namely, coarse-grained analysis and fine-grained analysis of inscriptions used in Turkish, Indian, and American chemistry textbooks. In the second part, due to page limitation, analysis conducted for all inscriptions were not provided. Rather, to give an idea of how the textbooks utilize inscriptions, a representative of the inscriptions for each country's textbook was selected. The selection was done in light of the coarse-grained analysis conducted. Then, the fine-grained analyses of the representative ones were carried out by the use of ARPSAM.

RESULTS

Coarse-grained Analysis: Types and Levels of Inscriptions Used in Textbooks

As seen from Table 1, in all analyzed textbooks, chemical equations were the most commonly used ones.

Turkish, Indian, and American textbooks separated 14, 8, and 9 for the 'Types of chemical Reactions' section, respectively. There were a total of 49 inscriptions in the Turkish chemistry textbook with an average of 3.50 inscriptions per page for the unit, 'Types of chemical reactions.' The Indian chemistry textbook had 22 inscriptions. It has 2.75 inscriptions per page for the unit. There were a total of 31 inscriptions in the American textbook with an average of 3.44 inscriptions per page. Therefore, it can be asserted that the Turkish and American chemistry textbooks drew heavily upon inscriptions compared to their Indian counterpart.

'Types of chemical reactions' part was also analyzed in terms of levels of inscriptions used (Table 2). When we started coding, we realized that some of the inscriptions included multiple types and levels, which means that they included at least two types of inscription at the same time (e.g., equations for the symbolic level and photographs for the macroscopic level simultaneously). Therefore, in order to take this into account, we added another category, namely, multiple inscriptions. Finally, for some of the inscriptions (e.g., tables), coding in terms of level was not applicable (NA).

In the Turkish textbook, due to the abundance of photographs and equations, inscriptions were generally

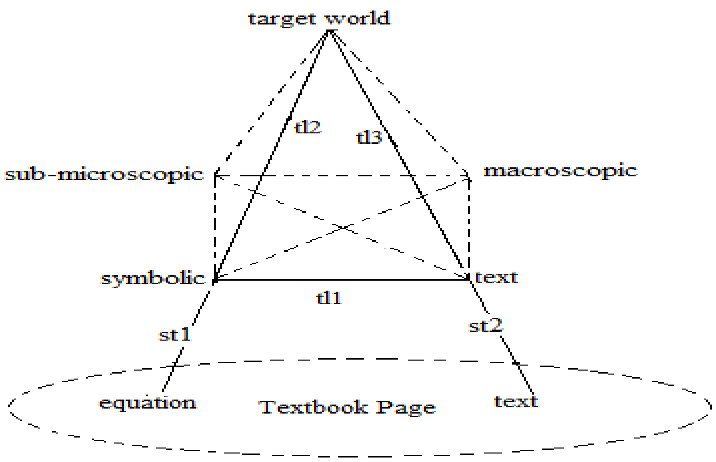

Figure 3. Types of work necessary for reading equations used in all three textbooks

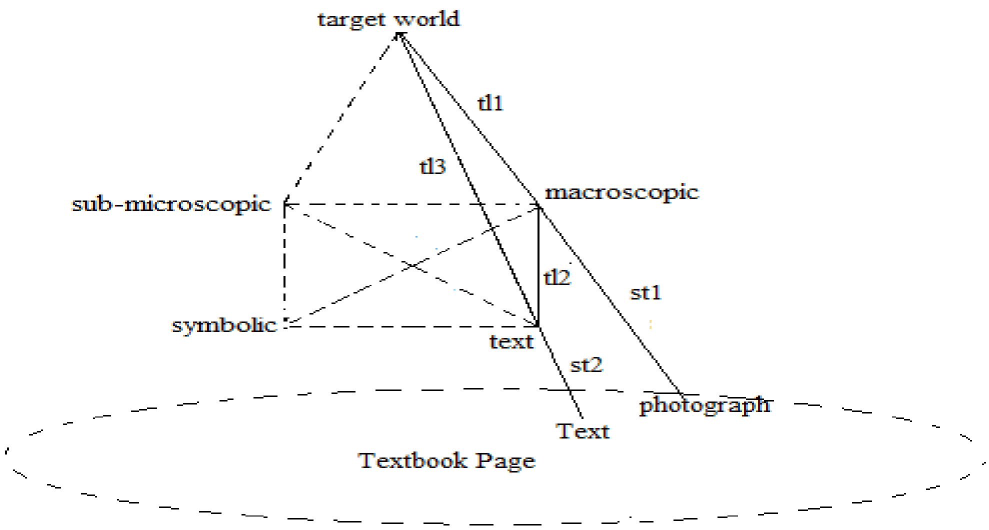

Figure 4. Types of work necessary for reading inscriptions and texts in Turkish textbook

at the macroscopic and symbolic levels. Moreover, four of the multiple inscriptions included macroscopic and symbolic levels together while only one multiple inscription included all of the levels simultaneously. The other one contained macroscopic and sub-microscopic levels jointly. The Indian textbook basically consisted of symbolic level inscriptions. All multiple level of inscriptions comprised macroscopic and symbolic level, which means that the Indian textbook utilized drawings and equations together. Finally, the symbolic level was the most common level used in the American textbook for the 'Types of chemical reactions.' Five of the multiple inscriptions embraced all levels while one of them included the macroscopic and symbolic levels at the same time.

Fine-grained Analysis of the Representative Inscriptions by the use of ARPSAM

Analysis of equation used by Turkish, Indian, and American textbooks

Because the textbooks analyzed drew mostly on equations and used them in the same way, the analysis of an equation was given. In all of them, the equation of a reaction (tl2) was given with a short explanation in the text (tl3) (Figure 3). For example, in Turkish textbook page, for combustion reaction, the equation of the propane's combustion (st1) is provided:

$C_3H_8 + 5O_2 \longrightarrow 3\ CO_2 + 4H_2O + heat$

Then the reaction was explained briefly (st2) and the text and the equation were linked (tl1):

For the combustion reactions, flammable material, air (oxygen), and activation energy are necessary. If there *is no air, the combustion reaction does not occur. Therefore, the gases heavier than air such as CO_2 are used in fire extinguishers… The combustion reactions are generally used for heating. For example, the natural gas, includes propane is used in daily life for cooking and heating purposes. Propane is an organic compound. When it burns, CO_2 and H_2O form (p. 111)*

Because each textbook had its own style for the use of other types of inscriptions, the analyses of representative inscriptions from each textbook are presented in the following part.

Analysis of representative inscription in Turkish textbook

Because photographs, equations, and the multiple inscriptions were the most common inscriptions used in Turkish textbook, we analyzed their representatives deeply. For instance, a photo was provided to explain the precipitation reactions. The geographical shapes (i.e., Pamukkale travertine in Denizli, Turkey) in the photo are a result of precipitation reaction of limestone (target world).

The photo shows the precipitation of limestone as solid (st1). The text asked learners how the geographical shapes occurred. Moreover, it wanted them to compare and contrast the formation of those shapes with the stalactite shapes in some caves (st2) (figure 4). The symbolic equation showing the whole reaction and the chemical formula of limestone was not provided. The representative inscription from the Turkish textbook included a photograph of the result of the precipitation reaction (tl1). The text informed the reader about the macroscopic phenomena (tl2). It also helps learners to understand how they occurred and the chemical reason behind it (e.g., solubility of the salts in water) (tl3). However, the equation of the reaction and the link between the photograph, text, and the symbolic level was missing.

Second, multiple types of inscriptions, especially the ones including both macroscopic and symbolic levels were widespread in the Turkish textbook. In the representative example the photo shows the mixing of two aqueous solutions and the formation of the yellow precipitate (st1). The equation for the reaction is:

$2\ KI_{(aq)} + Pb(NO)_{3(aq)} \longrightarrow PbI_{2\ (s)} + 2\ KNO_{3(aq)}$

The text explains the solubility concept, the ionization of KI and $Pb(NO_3)_2$ ion water, and then the formation of insoluble salt, namely, PbI_2 (st2). Moreover, the chemical equation of the reaction shows the reactants and products (st3) (Figure 5). The purpose of the inscription was to demonstrate the formation of yellow precipite (PbI_2) as a result of double-displacement reaction (target world) (Figure 5). The inscription included a photograph that shows the mixing of KI and $Pb(NO)_3$ aqueous solutions (tl1),

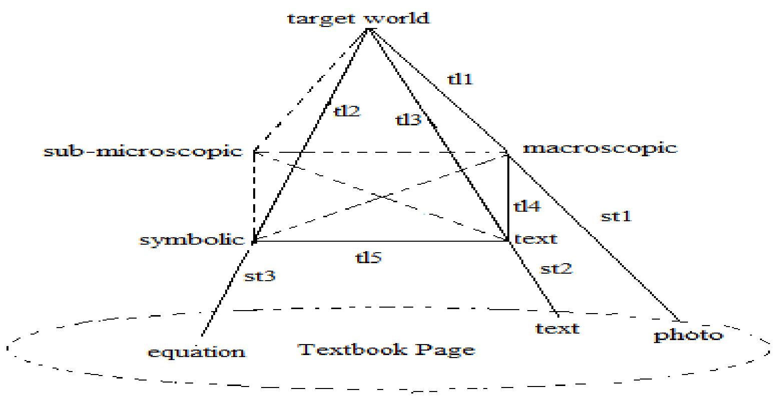

Figure 5. Types of work necessary for reading inscriptions and texts in Turkish textbook

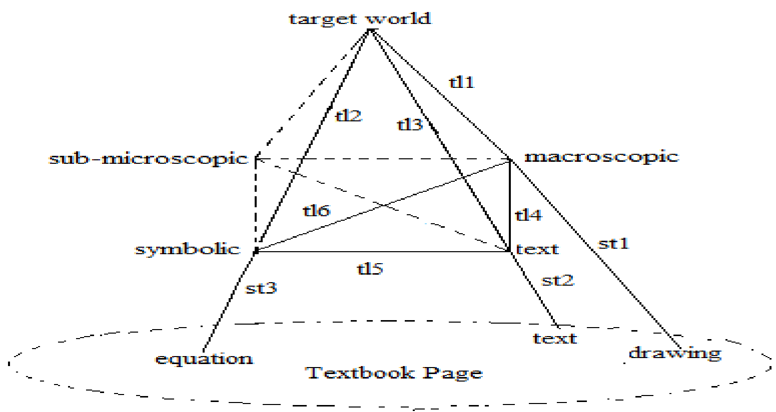

Figure 6. Types of work necessary for reading inscriptions and texts in Indian textbook

equation of the reaction (tl2), and the explanations of the reaction in the text (tl3). The sub-microscopic level was missing in the inscription. In the text, the drawing was linked to the macroscopic level through its caption and the explanation of why the yellow precipitate occurs (tl4). Each of the symbols in the equation was denoted by text and it also explained the formation of potassium iodine by mentioning that the chemical formula that was KI (tl5). The photograph was linked to the equation indirectly. In the photograph, there was no was label for the solutions and the precipitate. Thus, there was no direct link between the equation and the photograph.

Analysis of representative inscriptions in Indian textbook

As mentioned above, an activity with a drawing was the favorite inscription of the Indian textbook that we analyzed. The purpose of the inscription was to show the formation of white precipitate ($BaSO_4$) as a result of double-displacement reaction at the macroscopic level (target world) (Figure 6). The inscription included a drawing that shows the mixing of Na_2SO_4 and $BaCl_2$ aqueous solutions (tl1), equation of the reaction (tl2), and the explanations of the reaction in the text (tl3). As in all other inscriptions in the Indian book, the sub-microscopic level was not provided. The text explained what is happening in the drawing (tl4). Each of the symbols in the equation was denoted by the text and it also explained the formation of barium sulphate by mentioning the chemical formula that was $BaSO_4$ (tl5). The macroscopic drawing was linked to the equation indirectly. The drawing was labeled showing sodium sulphate and barium chloride. Additionally, below the chemical equation, the names of the substances were provided. Therefore, with the help of the text, the equation and the drawing were linked to each other (tl6).

According to the text, if the Na_2SO_4 and $BaCl_2$ aqueous solutions are mixed, a white precipitate insoluble in water is formed. Moreover, the text mentioned that Ba^{2+} and SO_4^{2-} ions form $BaSO_4$ (st2). However, no sub-microscopic inscriptions of the reaction were provided. Similarly, although the text mentioned white precipitate formation, in the drawing there is no precipitate at the bottom of the test tube (st1). Another figure showing the precipitate could have been added to eliminate the inconsistency between text and inscription. Yet another missing relation was between the macroscopic and symbolic level. After explaining the precipitate formation, equation of the reaction was provided (st3).

Analysis of an example of representative inscription in the American textbook

In the American textbook, multiple inscriptions including more than one type of inscription were more common than any other types and thus one of them was analyzed below. The purpose of the inscription was to explain double-displacement reaction with the help of reaction between KI and $Pb(NO_3)_2$ solutions (target world). The two photographs showed both the reactants before the reaction and the formation of the precipitate (i.e. PbI_2 in the form of a yellow precipitate) when one reactant is poured over the other (st1) (Figure 7). The main text below the inscription and the accompanying caption tried to convey the process of the chemical reaction (double-displacement reaction), that is, which ions are replaced and which ones form the products, namely, lead iodide and potassium nitrate (st2). The symbolic equation showed the reactants and products by using their chemical formula (KI, $Pb(NO_3)_2$, PbI_2, and KNO_3) (st3). The drawing that showed round ball-like structures were supposed to be understood as ions of reactants, products, water molecules, and their arrangement (st4).

The inscription included the photographs of the

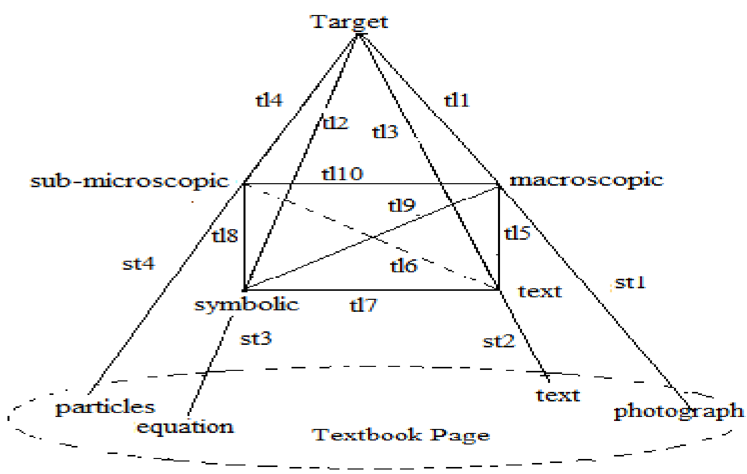

Figure 7. Types of work necessary for reading inscriptions and texts in American textbook

reactants and products (tl1), equation of the reaction (tl2), explanation of the reaction in the text (tl3), and its particulate representation (tl4) (i.e., space filling models of the all substances were provided). Thus, all levels were provided to the readers of the textbooks.

The text explaining double-displacement reaction was linked to the inscription by using its caption. In the text, events occurring during the reaction were also related to both the macroscopic level (tl5) (formation of yellow solid that is PbI_2) and the symbolic level (equation) (tl6). Moreover, in the inscription, the photographs of the solutions before and after the reaction were related to the sub-microscopic level by using arrows from photograph to particulate level from macro level to sub-microscopic level (tl10). However, the macroscopic photograph was not directly linked to the symbolic equation level; instead, it was linked to the equations through the sub-microscopic (particulate) drawing (tl9). Simultaneously, the link between sub-microscopic and symbolic levels was also presented by labeling the particles of the reactants and products (tl8).

CONCLUSION AND DISCUSSION

Textbooks including many types of inscriptions are important source for both learners (Carvalho et al., 2007; Devetak & Vogrinc, 2013; Orgill & Bodner, 2006) and teachers (Carvalho, et al., 2007). In our study, as response to a call from the literature (Good, 1993; Pozzer & Roth, 2003; Roth, et al., 1999), we tried to analyze and compare the 'Types of chemical reaction' part of chemistry textbooks from three different countries, which are different with regard to social, cultural, political, economic and educational issues. We conducted the study to get an idea of which types of inscriptions are utilized and how the different levels of inscriptions are used in chemistry textbooks in Turkey, India, and America. For the fine-grained analysis, we came up with a model, ARPSAM, for analysis of inscriptions. This new model was constructed based on Han and Roth's (2006) semiotic model and Treagust, et al.'s (2003) levels of inscriptions in chemistry (i.e., macroscopic, sub-microscopic, and symbolic levels). In the previous semiotic model symbolic level was missing. Therefore, another important leg, namely symbolic level, that stands for chemical equations, which was deemed as an important level of chemical representation. The new version of the semiotic model will be useful for the future research to investigate use of inscriptions in textbooks and other materials.

The results revealed that the number and the levels of inscriptions were common in the textbooks analyzed. Han and Roth (2006) found that the number of inscription in Korean textbooks was between 1.61 and 2.74. The Turkish, Indian, and American textbooks preferred to employ different types of inscriptions. For instance, the Turkish textbook revealed a predominant use of equations and photographs, as was the case in Korean chemistry textbooks (Han & Roth, 2006) and the American biology textbooks (Bowen & Roth, 2002). However, the Indian and American textbooks frequently draw on equations. Contrary to the previous research findings (Bowen & Roth, 2002; Han & Roth, 2006), equations were commonly employed in all of the cases in our research. However, some of the other types of inscriptions (e.g. graphs) were overlooked. To help learners become familiar with them, textbooks should use different types of inscriptions because unfamiliarity with inscriptions may be the reason why learners have difficulty in understanding them (Devetak & Vogrinc, 2013; Roth & McGinn, 1998). Regarding the comparison of textbooks from three different countries, this research also has important contributions to the science education literature. The literature review that we conducted showed that, to the best of our knowledge, there is any research digging into the use of inscriptions in different contexts. The previous studies were limited to American (Lee, 2010), Brazilian (Pozzer & Roth, 2003), Korean (Han & Roth, 2006), and Portuguese textbooks (Carvalho et al., 2007), particularly in biology topics (Bowen & Roth, 2002). With the help of the analysis conducted in this study, it is possible to have a little sight about the various uses of inscriptions in three different countries. However, it should be taken into account that the analysis was limited only for an example of textbooks from Turkey, India, and America. In other words, the results provided here cannot be generalized to all textbooks in those countries since the countries offer different chemistry textbooks to their students.

Regarding the level of inscriptions, symbolic level inscriptions were frequently used in all the textbooks. Although not very common, multiple inscriptions were also provided in these textbooks. To have better science/chemistry understanding, students need to gain skills with regard to use of different levels of inscription (Olson, 2008). Therefore, textbooks and science courses should highlight the application of the all levels of inscriptions especially at high school level (Kozma et al., 2000).

Based on the analysis conducted in the first part, we came up with representative inscriptions used in Turkish, Indian, and American textbooks randomly. These were examined under our analytical tool revealing both their dark and light sides. Especially in the Turkish and Indian cases, explicit links between different levels of inscriptions were missing. Han and Roth (2006) pointed out that reading the inscriptions used in textbooks is difficult for learners. When the link is not explicit and/or is missing, it is much harder to the idea being explained. Furthermore, it has been stated that it is difficult for learners to make transformations from one level of inscription to another (Gilbert, 2007). If the whole process of understanding the inscription is viewed as a continuum (Olson, 2008), then in the Turkish case there is a large gap between the concrete level and the abstract level without an intermediate step. An inscription showing the particles (sub-microscopic level) and linking these two poles (macroscopic and symbolic levels) would aid the learners to make more sense of what the author intends to accomplish (Treagust et al., 2003). Therefore, more inscriptions linking different levels should be provided in the textbooks in order to represent the target world (Han & Roth, 2006). On the contrary, looking at the American textbook's way of showing particles gives us hope because all levels of inscriptions (i.e. macroscopic, sub-microscopic, and symbolic level) have been utilized, which helps the learners to connect them to explain a chemical reaction (Gilbert, 2007).

Finally, in this study, we responded Han and Roth's call (2006) that was "because of possible contextual factors, more research is therefore required focusing on science textbook inscriptions in different cultures and subject matters" (p. 176). Chemistry has abstract topics that are hard for learners to grasp. "Types of Chemical Reactions" topic is one of the common topics in those three countries' high school chemistry curriculum. Additionally, it is one of the basic topics in learning chemistry. Therefore, studying use of inscriptions in the textbooks other that biology textbook will be informing the literature about how inscriptions were used in teaching chemical reactions, which levels of inscriptions were emphasized and so on.

Implications

In light of the literature reviewed and the results of the study, we provided recommendations for textbook writers, teachers, and researchers. First, for different learners with different learning styles, textbooks should make available diverse types of inscriptions (Olson, 2008). Moreover, all levels of inscription should be brought into play to provide a holistic view of chemistry.

Second, teachers have a vital role in how students learn to interpret inscriptions. Therefore, teachers should be aware of the weaknesses of textbooks' inscriptions and whenever necessary, they should be able to provide additional scaffolding to aid students in interpreting those (Han & Roth, 2006). However, teachers may not have the necessary knowledge to accomplish that goal. Hence, professional development activities should be organized to inform teachers about the importance of the selection and the use of inscriptions in science/chemistry teaching. Moreover, the semiotic model suggested here, ARPSAM, may be shown to teachers Lawson regarding how to examine inscriptions in textbooks and/or in other sources (e.g. internet). With this knowledge, teachers will be supposed to give better decisions regarding the use of inscriptions in science and/chemistry teaching.

Additionally, the inscriptions should be provided from simple to complex and from concrete to abstract order. Starting with macroscopic inscriptions and then supporting them by the use of inscriptions at symbolic and sub-microscopic levels will help learners to better understand the content (Lawson, 2002). Also, Bowen & Roth (2002) pointed out that the inappropriate use of inscriptions is a possible reason of learners' misunderstanding. They suggested revisions in the use of inscriptions for better understanding.

In future research, the ARPSAM model can be brought into play to compare and contrast inscriptions used in different topics and textbooks. For instance, "Atom and its Structure" is one of the abstract topics in chemistry whereas "Metric System and Measurement" is a very concrete one. Therefore, the cognitive processes are different in learning those two units in chemistry, which necessitates the use of different types and levels of inscriptions. However, we know little about the use of inscriptions in textbooks, so semiotic analysis of inscriptions employed in different units seem to provide useful information to related literature. Another comparison can be conducted for inscriptions used at different grade levels. Learners at different grades are at different levels of cognitive development. More concrete inscriptions should be utilized in earlier grades. Then, the level of abstraction should increase throughout the higher grades. Finally, in addition to textbooks' use of inscriptions, teachers' use of them in class should be investigated. How they decide to use inscriptions, which types of inscriptions they use, and the quality of inscriptions used can be analyzed with the use of ARPSAM model.

REFERENCES

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16,* 183-198. doi:10.1016/j.learninstruc.2006.03.001

Ainsworth, S. (2007). The educational value of multiple representations when learning complex scientific concept. In John K. Gilbert, Miriam Reiner & Mary Nakhleh (Eds.), *Visualization: Theory and practice in Science Education* (pp.191-208). Netherlands: Springer.

Bowen, M. G. & Roth, W.-M. (2002). Why students may not learn to interpret scientific inscriptions. *Research in Science Education, 32,* 303 -327. doi: 10.1023/A:1020833231966

Carvalho, G.S., Silva, R., & Clément, P. (2007). Historical analysis of Portuguese primary school textbooks (1920–2005) on the topic of digestion. *International Journal of*

Science Education, 29(2), 173–19. doi: 10.1080/09500690600739340

Clement, P. (2008). Critical analysis of school science textbooks. *Science Education International*, 19, 93–96.

Devetak, I. & Vogrinc, J. (2013). The criteria for evaluating the quality of the science textbooks. In M. S. Khine (Eds.) *Critical analysis of science textbooks (pp.3-15).* Netherlands: Springer.

Gilbert, J. K. (2007). Visualization: An emergent field of practice and enquiry in science Education. In John K. Gilbert, Miriam Reiner & Mary Nakhleh (Eds.), *Visualization: Theory and practice in Science Education* (pp.3-24). Netherlands: Springer.

Good, R. (1993). Editorial: Science textbook analysis. *Journal of Research in Science Teaching, 30,* 619.

Han, J. & Roth, W. M. (2006). Chemical inscriptions in Korean textbooks: Semiotics of macro and microworld. *Science Education, 90,* 173-201. doi: 10.1002/sce.20091

Kozma, R., Chin, E., Russell, J., & Marx, N. (2000). The roles of representations and tools in the chemistry laboratory and their implications for chemistry learning. *The Journal of the Learning Sciences, 9(2),* 105-143.

Lawson, A. (2002). Sound and faulty arguments generated by pre-service biology teacherswhen testing hypotheses involving unobservable entities. *Journal of Research in Science Teaching, 39(3),* 237 – 252.

Lee, V. R. (2010). Adaptations and continuities in the use and design of visual representations in US middle school science textbooks. *International Journal of Science Education, 32(8),* 1099-1126. doi: 10.1080/09500690903253916

Lemke, J. L. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In J. R. Martin & R. Veel (Eds.), *Reading science: Critical and functional perspectives on discourses of science* (pp. 87–113). London: Routledge.

Olson, J.K. (2008). Representing science concepts: The representation continuum. *Science and Children, 46(1),* 52-55.

Orgill, M.K. & Bodner, G. M. (2006). An analysis of the effectiveness of analogy use in college-level biochemistry textbooks. *Journal of Research in Science Teaching, 43(10*), 1040–1060. doi: 10.1002/tea.20129

Pozzer, L. L. & Roth, W. M. (2003). Prevalence, function, and structure of photographs in high school biology textbooks. *Journal of Research in Science Teaching, 40(10),* 1089–1114. Doi: 10.1002/tea.10122

Pozzer-Ardenghi, L., & Roth, W. M. (2005). Making sense of photographs. *Science Education, 89,* 219-241. doi: 10.1002/sce.20045

Roth, W.M. & McGinn, M. K. (1998). Inscriptions: Toward a theory of representing as social practice. *Review of Educational Research, 68(1),* 35-59.

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from Project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching, 41*(6), 538-568. doi: 10.1002/tea.20019

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education, 25(11),* 1353–1368. doi: 10.1080/0950069032000070306

Vinisha, K. & Ramadas, J. (2013). Visual representations of the water cycle in science textbooks. *Contemporary Education Dialogue, 10*(1), 7-36. doi: 10.1177/0973184912465157

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