CURRICULUM & TEACHING STUDIES | RESEARCH ARTICLE

A content analysis of cognitive representations in a ninth-grade science textbook’s chemistry of matter unit: Evidence from Saudi Arabia

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Abstract: This study analyzed cognitive representations of knowledge from the chemistry of matter unit in a ninth-grade science textbook—the only authorized textbook in Saudi Arabia. It examined textual and visual information from two lessons in order to identify the textbook’s introduction of concepts, linguistic context, integration of concepts, and the overall type of knowledge relayed to students. Results showed that Lesson 1 included more analogies than Lesson 2, while Lesson 2 included more relations than Lesson 1. Overall, scientific concepts were more often introduced through historical examples and context in Lesson 1 than in Lesson 2. In both lessons, concepts were integrated explicitly more often than implicitly. Finally, conceptual knowledge was presented more commonly than procedural knowledge in both lessons. I argue that enhancing certain aspects of cognitive representation—such as the use of analogies, linguistic context, relations

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Omar Sozan H., associate professor of science education at College of Education, King Saud University, Riyadh, Saudi Arabia. I am interested in writing to learn and believe that writing and reading are intertwined. Learning is a very complex and constructive process; therefore I believe in active constructivist theory. So, my research interest in science focuses on writing including: expressive, reflective, and argumentative writing. From this approach I also focused on analyzing science textbooks for several aspects: inquiry essential features, critical thinking, and reading comprehension levels. The idea of this study emerges from several studies. It begins with finding reading comprehension levels in science textbooks, students, and science teachers. I want to know if representations included in scientific texts would facilitate learning about scientific concepts. The next project might focus on science teacher awareness of cognitive representation and how they implement them in their teaching. Brian Hand, a Professor of science education at The University of Iowa, in Iowa city, Iowa, USA has published several studies and books in the area of interest regarding multiple modals representations to support learning science in classrooms.

PUBLIC INTEREST STATEMENT

Scientific texts differ in their nature. There is comparative text, text with diagrams, illustrations and graphical text, and explanatory text. Whatever the style of the text, it is necessary to present it in a way that allows the learner to interact with it to reach the meaning by realizing the relationships involved in the text and organizing it in the cognitive structure, so that it is one of the text components instead of memorizing it automatically. Accordingly, the learner needs a number of representation within the text to help him cognitively understand the meaning. Hence, cognitive representations in textbooks play a major role in helping the learner links ideas and concepts with methodological, conceptual, and procedural knowledge. This study analyzes scientific text of two lessons included in the Atomic Structure chapter from 9th grade chemistry textbook to explore the cognitive nature involved in its structure. I argue that enhancing cognitive representation may reduce misconceptions and improve learner’s abilities to learn concepts, especially abstract concepts.
among cognitive representations, and theological evidence in science textbooks—may reduce misconceptions and improve students’ abilities to learn scientific concepts, especially abstract concepts.

**Subjects:** Educational Research; Education Studies; Teaching & Learning; Science Education; Curriculum

**Keywords:** science textbooks; cognitive representation; concept integration; linguistic context; conceptual and procedural knowledge

1. Introduction
Learners can acquire knowledge through teaching or through their personal experiences. Shatil (2013) claimed that cognition reflects the process of acquiring and understanding knowledge through our thoughts, experiences, and senses. Meanwhile, Sgarbi (2012) mentioned that Aristotle stressed that learners acquire knowledge by observing the world around them. Cognitive processing of knowledge involves learning models which reflect the way an individual recognizes, receives, processes, and retrieves new information, data, and skills. Thus, cognitive processing varies from one person to another (Kinsella, 1994), and governs the way in which an individual transforms, integrates, and reconstructs information through experience. For example, some people prefer to learn through mathematical (abstract) information, while others prefer to learn through structural language. These differences in learning patterns are derived from a learner's personal tendencies and characteristics (Vermunt & Donche, 2017).

Multidimensional and complex models essentially combine cognitive (Carolan et al., 2008; Prain & Waldrip, 2006; Yousoof et al., 2007), behavioral, emotional, and psychological elements and take into account the personality traits associated with a learner’s auditory, visual, and sensory perception. Learning patterns can be grouped into four main categories, each of which can in turn be divided into many sub-levels, as shown in Table 1 (Naruse et al., 2008; Vermunt & Donche, 2017). These models provide educational, diagnostic, and therapeutic frameworks that can help teachers design pedagogical approaches and identify tools, methods, and procedures that best fit an individual's learning style.

| Table 1. Definitions of classifications (categories) and examples of basic expressions (Sathayapetch et al., 2013) |
|---------------------------------------------------------------|
| **Classification of Inclusion Type** | **Explanation** |
|----------------------------------|----------------|
| Explicit Text | Concept is directly and clearly written without any reference, connection, or association |
| Implicit, Involved | Concept is neither directly nor clearly written but can be deduced from the text, illustration, or numbers |
| Analogy | Provides the concept metaphorically, via alias, or similarity; compares new concept to a related, common concept |
| Associative Relations | Linking concepts to other physical, chemical, and mathematical concepts according to scientific laws and rules |
| Mental Visual Presumption | Use of the cognitive concept in the linguistic context and cognitive and conceptual text |
| Technical Application Presumption | Vocabulary correlations in a technical system handled by hand or machine |
| Historical Presumption | Text that expresses the date of discovery for a phenomenon or scientific knowledge |
| Theological Representation | Supports concept with evidence from a religious source |
Researchers disagree about whether the process of learning and readiness depends on the level of the learners’ maturity; they agree, however, that learning requires cognitive symbolic representations in order to link verbal and visual materials (Dimopoulos et al., 2003; Evagorou et al., 2015). Learning may be more complex for learners who rely on verbal language and abstraction alone (Zaitoun, 2005). Cognitive representations enable the transformation of textual ideas, concepts, and information into visual forms that facilitate the process of transforming and summarizing such information into forms or structures that are easy to read and comprehend (Strangman & Hall, 2003).

With cognitive representation, as with theories of learning, introductory mechanisms are needed to stimulate and relate a learner’s previous relevant knowledge to the subject at hand (Palis & Quiros, 2014; Taylor & Hamdy, 2013). Therefore, a learner often needs information to be represented visually after reading and studying a text in order to organize and build their own knowledge (Wheatley, 1991). As a result, the cognitive representation of knowledge can be viewed as a process by which an alternative representation replaces knowledge via a mental map comprised of symbols or images (Zaitoun, 2005), or through knowledge schematic symbols (Atherton & Nutbrown, 2016).

Cognitive representations facilitate visual learning by fostering students’ ability to create relationships between symbols and images. This, in turn, expedites students’ retrieval of ideas and information and makes the process of developing and assimilating meanings and concepts easier and more enjoyable (Dimopoulos et al., 2003; Evagorou et al., 2015). In addition, cognitive representations support abstract speech and thus allow information to be assimilated through reading and listening, thereby making education more robust and enduring (Dimopoulos et al., 2003). Cognitive representation also reduces the amount of text required for learning because it helps to rephrase or transform text into a schematic form that highlights key information—thus, it also helps to reduce content overlap and complexity (Winn, 1990). However, erroneous and misleading cognitive representations hinder effective learning (Dixon et al., 2007).

Textbooks that support both procedural knowledge and cognition can help introduce students to cognitive and conceptual knowledge (McCormick, 1997). In this regards, students can attain cognitive and conceptual knowledge, specifically, through reading, writing, speaking, listening, and thinking, as well as by studying science.

Researchers studying cognitive representations in the context of classroom education have stressed the importance of the various ways in which teachers and students negotiate meaning in classroom settings (Tytler et al., 2006; Waldrip et al., 2010). They claim that students benefit from multiple opportunities to explore, engage, elaborate, and re-represent concepts. Greeno and Hall (1997) argued that different forms of representation support contrasting understandings of topics and that students need to explore the advantages and limitations of particular representations. Cox (1999) illustrated several representations, which are considered to be tools for many different forms of reasoning, including initial and speculative thinking, recording observations, showing a sequence or process in time, sorting information, and predicting outcomes. In this light, it is clear that students need to learn how to select representations, which appropriately address their particular needs and must be able to judge these representations’ effectiveness in achieving particular purposes. Ainsworth et al. (2011) claimed that students’ explanatory drawings of phenomena could support their reasoning and help develop their subject-specific scientific literacy.

Cognitive representations in textbooks play a major role in linking ideas and concepts with methodological, conceptual, and procedural knowledge (Mohammad & Kumari, 2007; Vesterinen et al., 2013). These representations—e.g., text, images, drawings, shapes, models, tables, and information maps—are characterized by their reciprocal relationship with the promotion and development of positive feelings and interests toward learning and their role in connecting and applying scientific knowledge and concepts to daily life (Sothayapetch et al., 2013). Therefore, presentation,
interpretation, and/or explanation play important roles in establishing students’ procedural and cognitive knowledge and in developing a student’s mind and mental capacities. Anderson and Krathwohl (2001) divided cognitive concepts into visual and procedural concepts. De Jong and Ferguson-Hessler (1996, p. 107) described these two types as “unchanging static knowledge that includes facts, ideas, rules, and forms”. In addition, Anderson and Krathwohl (2001) suggested that visual and conceptual cognition can be divided into three types of knowledge: knowledge of classifications and categories, knowledge of rules, principles, and generalities, and knowledge of theories, models, and structural forms. According to Spivey (2007), procedural knowledge describes the ability to know how to do things, use research methods, and conduct inquiries and equips students with the necessary foundation from which to develop computational skills, logarithms, and techniques. Tobias and Duffy (2009) argued that procedural knowledge describes the kind of knowledge required to accomplish tasks or apply production rules and systems directly. Anderson and Krathwohl (2001) divide procedural knowledge into three types: knowledge of the use of skills and logarithms, knowledge of the use of methodologies and techniques, and knowledge of criteria for determining when an appropriate procedure should be used. Moreover, learners can associate related concepts in accordance with natural laws via example, similarity, analogy, and metaphor (James & Scharmann, 2007; Sothayapetch et al., 2013).

1.1. Context of the study
Textbooks are one of the most important resources for teaching and learning science in the classroom (Al-Saadani, 2006) because both students and teachers rely on them. Therefore, textbooks greatly affect what will be taught and learned (Eisner, 1987). Omar et al. (2015) illustrated that most of the teachers rely on textbooks as compared to other sources. This implies that textbook publishers should make all efforts to provide excellent and best-quality textbooks in order to provide teachers with model and visions of teaching and learning (Alahmad et al., 2017).

Therefore, Saudi Arabia’s Ministry of Education strives to achieve high-quality education by reviewing and evaluating the inputs, processes, and outputs of the Saudi educational system (Al-Khatib, 2004). Textbooks are vital inputs, as they provide both teachers and students with the necessary resources to help them develop their skills. Previous researchers have found that teachers’ practices are affected by the content of the textbooks they use—especially in the context of science education (Beaton et al., 1996; Yore & Denning, 1989). Furthermore, many development projects have demonstrated a positive relationship between the availability of high-quality textbooks and student achievement (Heyneman et al., 1981). Today’s Saudi science textbooks have been translated from the American McGraw-Hill textbook series and adjusted to suit the Saudi environment. These science textbooks are considered essential sources of information for Saudi students (Alahmad et al., 2017) and include texts, pictures, activities, and illustrations. In short, these textbooks include various cognitive representations which contribute to students’ learning scientific content and concepts at a deeper level.

In Saudi Arabia, the ninth grade is the final grade of middle school and is considered a transitional stage in which students prepare for secondary education. Sciences are taught in three different disciplines (biology, physics, and chemistry). This stage is also when most students tend to specialize their learning. Given the author’s background as a chemist, previous studies’ emphasis on the difficulties students face in understanding the complex concepts in the textbook’s chapter titled “The Atomic Structure” (Aljamaan et al., 2015; Alotaibi, 2019; Nahas, 2006) and this chapter’s importance in paving the way for student understanding of later concepts, this paper analyses the content of “The Atomic Structure.”

1.2. Research problem
Abstract concepts such as those related to atomic theory are relatively difficult for students of all ages to understand. Therefore, related concepts need to be cognitively represented in a way that makes them relatable and more concrete through visuals, analogies, and metaphors. In general,
abstract concepts can be expressed by text, images, and graphs, tables, and other schema (Abd-El-Khalick et al., 2008; Evagorou et al., 2015) in order to help facilitate students' understanding and information retrieval. The linguistic context can be described as the cognitive background associated with the cognitive use of a concept (Bennett, 2005; Bennett et al., 2003; Juuti et al., 2004; Sothayapetch et al., 2013). For instance, when students look at an image, they relate their own ideas to the scientific content of the image's components. Thus, the image is retained in the student's scientific memory and supports their concept of knowledge.

This study analyses the content of two chemistry lessons in a ninth-grade science textbook to determine whether the representations provided in the textbook can help students correctly understand chemistry concepts. It considers the types of cognitive representations employed in the textbook and its linguistic context. It also aims to define how compatibly this textbook formulates, presents, and cognitively represents concepts along the lines of educational methodologies that emphasize the strengthening of new meanings and concepts (i.e. how students receive, recognize, treat, transform, and reconstruct concepts into new experiences).

1.3. Research focus
Few researchers (Abd-El-Khalick et al., 2008; Evagorou et al., 2015; Sothayapetch et al., 2013; Swanepoel, 2010; Wheatley, 1991) have analyzed textbooks' inclusion of cognitive representations in different contexts. However, no such study has been performed on Saudi Arabian science textbooks. This study fills this gap in the literature by examining cognitive representations of chemistry concepts included in two lessons in the textbook's third chapter. Specifically, this study attempts to answer the following questions:

(1) How were the scientific concepts in this unit selected?
(2) To what extent did the unit emphasize conceptual and procedural knowledge?
(3) In which contexts were the concepts introduced?
(4) What kinds of representations did the textbook use to clarify its main concepts?
(5) What type(s) of concept integration did the textbook use in the chapter?
(6) What type(s) of texts and evidence did the textbook use to clarify and interpret concepts?
(7) Which type(s) of representations were used to clarify and interpret concepts?

2. Research methodology
This study used both quantitative and qualitative methods to analyze the contents of the two aforementioned chemistry lessons. The author analyzed these lessons according to the knowledge representations, cognitive concepts, types of knowledge, cognitive representations, and the clues and linguistic context they employed to explain and interpret concepts. The quantitative and qualitative models this study used have also been employed by previous studies (Sothayapetch et al., 2013; Swanepoel, 2010) which analyzed text quality, provided evidence supporting the explanatory power of these models, and explained the conversion of symbols into asymptotic models of analog quantity models.

2.1. The research sample
The sample includes both lessons in chapter 3, “The Atomic Structure,” which is included in unit 2, “The Chemistry of Matter”, found in the Ninth grades Science textbook (2019). The two lessons are “The Atomic Model” and “The Nucleus.”

2.2. Instruments and procedures
This study used the instrument developed by Sothayapetch et al. (2013). As such, the content analysis in this study proceeded according to the following steps and criteria:
(1) Identification of the main terms and concepts which are clearly specified at the beginning of each lesson.

(2) The analysis covered every part of the lesson except the evaluation section. Categories and sub-categories of knowledge elements were determined based on definitions in the literature (cf. Chiappetta & Fillman, 2007; Neuendorf, 2002; Sothayapetch et al., 2013).

(3) Chemical terms were arranged as a list or table so that the concepts could be identified, contained, and interpreted according to the standard variables accompanying them.

(4) The sentences, paragraphs, forms, images, and maps that reflect these concepts were classified based on each element of knowledge associated with those types.

Table 1 shows the classification of a concept's type of introduction or integration in the first column. The second column denotatively illustrates how each concept is presented.

2.3. Reliability of research tools

The analysis was conducted at different times, taking into consideration the rules specified by Keppel (1991). The co-efficient between the two analyses was calculated based on Ott and Longnecker (2008) equation. The two analyses had a concordance of 81%, which indicates that this study’s methodology and instruments are reliable.

3. Results of research

The first lesson, “The Atomic Model,” featured 10 concepts, and they appeared 286 times. The second lesson, “The Nucleus,” featured 10 concepts, and they appeared 321 times. Neither lesson’s inclusion frequency (Table 2) was affected by the nature of inclusion. For example, inclusion might be explicit or implicit, textual or non-textual. For the first lesson, the most frequently included concept was atom, which appeared 90 times (31.47%) of all concepts, followed by electron, (61 times, 21.33%) and nucleus (42 times, 14.69%). The most prevalent concepts in lesson two were radioactive decay (55 times, 17.13%), isotopes (53 times, 16.51%), and half-life (51 times, 15.89%).

Table 3 shows that “analogy” was the most frequently used introduction type in “The Atomic Model”—it appeared 37 times (12.94%) of all concepts. However, it was the least frequent introduction type in “The Nucleus,” where it appeared only 28 times (8.72%). This result might

| Table 2. Prevalence of concept use across the two lessons |
|----------------------------------------------------------|
| Lesson Number  | Lesson 1 (Atomic model) | Lesson 2 (Nucleus) |
|               | Concept     | Frequency | %    | Concept     | Frequency | %    |
| 1             | Element     | 5         | 1.75 | Atomic number | 10        | 3.12 |
| 2             | Atom        | 90        | 31.47 | Isotopes   | 53        | 16.51 |
| 3             | Proton      | 31        | 10.84 | Mass number | 9         | 2.80  |
| 4             | Electron    | 61        | 21.33 | Half-life   | 51        | 15.89 |
| 5             | Neutron     | 21        | 7.34  | Radioactive decay | 55 | 17.13 |
| 6             | Nucleus     | 42        | 14.69 | Beta particles | 17        | 5.30  |
| 7             | Cathode     | 11        | 3.85  | Alpha particles | 21        | 6.54  |
| 8             | Anode       | 8         | 2.80  | Nucleus     | 32        | 9.97  |
| 9             | Cathode ray | 5         | 1.75  | Element     | 39        | 12.15 |
| 10            | Alpha particles | 12 | 4.20 | Atom       | 34        | 10.59 |
| Total         |             | 286       | 100   |             | 321       | 100   |
Table 3. Prevalence of introduction type in the two lessons

| Concept Introduction | Lesson 1 (Atomic model) | Lesson 2 (Nucleus) |
|----------------------|-------------------------|---------------------|
|                      | Frequency (286)         | %                   | Frequency (321) | % |
| Analogy              | 37                      | 12.94               | 28              | 8.72 |
| Relation             | 10                      | 3.50                | 48              | 14.95 |

derive from the nature of the lessons themselves, as concepts related to Lesson 1 lend themselves to analogical representation and concepts related to Lesson 2 are more specific and do not lend themselves to this mode quite as well. It should be noted that analogy could be introduced as images and/or graphical representation. Relationships and practical representations were less frequent in Lesson 1 and more frequent in Lesson 2.

Metaphorical or analogical cognitive representations of knowledge (including figures, images, shapes, or graphics) can be used to compare a new concept with a familiar concept (Sothayapetch et al., 2013). This is demonstrated in the textbook's cognitive representations of the Thomson Model in ninth grade science textbook (Figure 3 on page 90), the Dalton Model (Figure 3 on page 87), and the Rutherford Model (Figure 11 on page 91). Many other cognitive representations, such as manually or machine-drawn forms, are also used (page 102), along with metaphoric shapes (page 100), diagrams (page 101), and tables (page 109).

Atomic model concepts tend to be abstract and thus often require analogical or metaphorical representation to facilitate student comprehension. Indeed, previous studies have shown that a good analogy can improve a student's understanding of scientific concepts (Duit, 1991; Duit et al., 2001; Glynn, 2007; Roth & McGinn, 1998). In order to use analogies effectively, however, it is important to understand the nature of an analogy, what the best kind of analogy is, and how analogies aid learning (James & Scharmann, 2007). An analogy's ability to foster understanding of abstract scientific concepts makes it a crucial tool in science education. However, if analogies are not properly selected, they can produce misconceptions. In this regard, Duit et al. (2001) have stated:

A growing body of research shows that analogies may be powerful tools for guiding students from their pre-instructional conceptions towards science concepts. But it has also become apparent that analogies may deeply mislead students’ learning processes. Conceptual change, to put it into other words, may be both supported and hampered by the same analogy. (p. 283)

Regarding the linguistic context used to represent the concepts, I applied the following contextual classification in the analysis:

- Context of technical application: the concept is applied to a technical situation.
- Context of science and technology in society (STS): the concept is introduced through a reflection on the concept's possible applications in society.
- Historical context: the concept is introduced through an explanation of how and/or who introduced or came up with the concept.
- Theological context: the concept is introduced through scripture, or the discovery of and facts relating to the concept are supported by theological evidence such as Qur’anic verses or “Hadith” (the Prophet’s statements or sayings).

The results presented in Table 4 indicate that historical context was used to introduce the concepts in Lesson 1 more often (148 times, or 51.75%) than any other method. This was followed by STS, with 7% frequency. The most frequently used context in Lesson 2 was STS (99 times,
followed by technical application (48 times, 14.95%). Finally, theological context was barely used to introduce concepts in Lesson 1 and was not used at all in Lesson 2.

Such representations constitute the most important components of cognitive processing because they render complex concepts easier to understand (Winn, 1990). Cognitive representations correspond to the text or linguistic context used to present a given cognitive concept, such as in the Rutherford Model in Figure 1, below.

Electronic cloud models are analogical/metaphorical models which represent the structure of an atom. These models make atomic structures easier to understand, as the structure itself is totally abstract but becomes much clearer when represented as a cloud. Such representations can also present concepts as historical events (Sothayapetch et al., 2013) by expressing the discovery of a phenomenon or evolution of scientific knowledge, such as the one presented in the ninth grade science textbook (pp. 87, 90, 91). They can furthermore represent technical applications of concepts (pp. 93, 88), concepts related to procedural knowledge, and technical concepts (p. 9).

Regarding STS teaching, Yager and Akcay (2008) and Aikenhead (1994) indicated that teaching science via STS tends to improve students’ learning outcomes.

Table 5 shows the types of concept integration used in the two lessons. Results indicate that more than 77.62% of concepts in Lesson 1 and 57.94% of concepts in Lesson 2 were explicitly integrated, while 22.38% of concepts in Lesson 1 and 42.06% of concepts in Lesson 2 were implicitly integrated.

Implicit learning tolerates errors better than explicit learning (Sun et al., 2007, 2005). Regarding the design of curriculum materials, Bybee (2013) argued that integrating components into a lesson...
either as background or foreground explicitly and implicitly could be operationalized as a similarity. Furthermore, Berland and Hammer (2012) found that although implicit conversation supports argumentation in the classroom, it supports students’ learning less than explicit conversation does. Rivet et al. (2016) stressed that focusing more on explicit integration when teaching about watershed concepts throughout a given unit might decrease students’ ability to build their understanding or to independently enhance their own descriptions of phenomena they are learning about. This study also argues that the implicit integration of scientific concepts may develop students’ understanding of crosscutting concepts.

This study analyzed the content of the “Chemistry of Matter” unit in the ninth grade science textbook following Anderson and Krathwohl (2001) classification of the knowledge, cognitive, and procedural concepts expressed by chemical terms. These cognitive concepts have been categorized into 1) conceptual perception, which refers to the knowledge of rules, facts, general principles, theories and ideas and 2) procedural concepts, which refer to the knowledge of how to use skills, logarithms, and calculations, the ability to apply methodologies and techniques, the ability to determine when appropriate procedures should be used, and the knowledge required to accomplish tasks, namely, knowledge of production rules and systems (Tobias & Duffy, 2009). Table 6 summarizes the classification of the cognitive concepts presented in these two lessons.

Results of the analysis showed that conceptual knowledge was emphasized more often in both lessons (92.66% of the time in Lesson 1 and 87.54% in Lesson 2), while procedural knowledge was emphasized less in both lessons (7.34% of the time in Lesson 1 and 21.46% in Lesson 2).

In short, many kinds of cognitive representations are used to express cognitive concepts in a wide variety of fields. Some include visuals, graphs, and other data; others are literal texts expressing ideas and concepts (Zaitoun, 2005). This apparent disparity in the quality of knowledge representations reflects the introduction of concepts and alternative objects to rephrase concepts and to create interconnections between the cognitive concept and connotations, which help students understand concepts and their meanings (Carolan et al., 2008; Evagorou et al., 2015).

### 4. Conclusion
This study conducted a content analysis of concepts contained in two lessons of the ninth-grade Saudi science textbook. The results show that Lesson 1 included more analogies than Lesson 2, and Lesson 2 included more relations than Lesson 1. Science concepts were introduced more often

### Table 5. Prevalence of concept integration type in the two “Chemistry of Matter” unit lessons

| Type of Integration | Lesson 1 (Atomic model) | Lesson 2 (Nucleus) |
|---------------------|-------------------------|--------------------|
|                     | Frequency | %       | Frequency | %       |
| Explicit            | 222       | 77.62   | 186       | 57.94   |
| Implicit            | 64        | 22.38   | 135       | 42.06   |
| Total               | 286       | 100     | 321       | 100     |

### Table 6. Prevalence of type of knowledge from in the two lessons

| Type of Knowledge | Lesson 1 (Atomic model) | Lesson 2 (Nucleus) |
|-------------------|-------------------------|--------------------|
|                   | Frequency | %       | Frequency | %       |
| Conceptual        | 265       | 92.66   | 281       | 87.54   |
| Procedural        | 21        | 7.34    | 40        | 21.46   |
| Total             | 286       | 100     | 321       | 100     |
through historical context in Lesson 1 compared to Lesson 2 because the former included the history of atomic theories. In both lessons, concepts are integrated explicitly more than implicitly. Regarding conceptual types of knowledge, Lesson 2 includes more procedural knowledge than does Lesson 1, which was due to the nature of concepts taught in Lesson 1. Again, most of Lesson 1 includes historical presentations of atomic theories, and thus it does not include more procedural knowledge.

Based on these results, this study argues that enhancing certain aspects of cognitive representation may reduce students’ misconceptions and improve their ability to learn scientific concepts, particularly abstract ones. This study could be beneficial to the design of a science curriculum because it shows that:

- The abstract nature of scientific concepts demands that they be made visual, particularly through analogy, to aid student comprehension.
- Historical contextualization of certain scientific concepts is weak, which might explain the prevalence of misconceptions about such concepts among students.
- Careful representation of abstract concepts would develop students’ understanding of scientific concepts, especially concepts related to atomic structure.
- This research would help curriculum designers to take care of the representations they use in science textbooks for abstract concept so that these representations may not impose misconceptions of scientific concepts among students.
- It may also attract researchers to concentrate on the nature of visualization and cognitive representations of science concepts. Further research is needed to see if improving the historical contextualization of concepts might mitigate students’ misconceptions about atomic theory and, hence, about concepts related to the atom.

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