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PERIODIC TABLE REPRESENTATIONS IN TURKISH UPPER-SECONDARY SCHOOL CHEMISTRY TEXTBOOKS AND THE CHEMISTRY TEACHERS' OPINIONS ON THEM

Sevil Akaygun,
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Abstract. *Periodic table is an important tool of chemistry for understanding the structure, function, and properties of the elements. Periodic table representations given in upper-secondary school chemistry textbooks are critical as they introduce chemical concepts. This study aimed to explore the features of periodic table representations given in Turkish upper-secondary school chemistry textbooks and the opinions of chemistry teachers who were using these textbooks in their classes. This qualitative study was composed of two stages. In the first stage, seven different upper-secondary school chemistry textbooks commonly used in Turkey were selected and analyzed by content analysis based on five criteria; type, content, portrayal, periodic trends, and color, emerged from the data. In the second stage, interviews were conducted by seven chemistry teachers who were actively using these textbooks in their classes. The results showed that generally teachers liked the basic, color-coded, recent, accurate periodic table representations to introduce the concepts. While teaching, they mostly preferred to show a complete periodic table first, and then the segmented ones. For the periodic trends, they agreed to include numerical values on the periodic table for letting students make sense of these values instead of having arrows that may cause memorization.*

Keywords: *Turkish chemistry textbooks, periodic table representations, periodic trend, chemistry education*

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Introduction

Textbooks have been essential materials used at every stage of education. Most probably, chemistry teachers still refer to multiple chemistry textbooks before preparing lesson materials. Similarly, many students still refer to their textbooks when they study for their exams or work on their assignments. Despite the accelerating role of educational technology, textbooks are still the main actors of learning all around the world (Bakken & Andersson-Bakken, 2021; Ferreira & Saraiva, 2021; Lepik et al., 2015; Okan & Kaya, 2022; Vojir & Rusek, 2021). Many students and teachers intensely refer to textbooks as they are found to be durable, reliable, and easily accessible. This situation brings the issue of the importance of being selective and careful while using textbooks for teaching and learning purposes. Not only the content but also the visualizations included in textbooks have been often subject to study as they may be helpful for conceptual understanding, or they may cause misconceptions.

One of these types of content in chemistry is the periodic table representations used in upper-secondary school chemistry textbooks. Representations are defined as specialized symbol systems particularly in chemistry, such as reaction equations, molecular structure diagrams, graphs, and three-dimensional (3D) computer model diagrams, charts, equations, and formulas along with words, photographs and illustrations, educational technologies—video and computers (Kozma & Russel, 1997). The year 2019 was the International Year of the Periodic Table as it was the 150th anniversary of the generation of periodic system by Dimitri Mendeleev, hence it was remembered one more time how important the Periodic Table was in learning chemical concepts. Even though the periodic table seems to be a symbolic representation, it includes abstract concepts that may be difficult for students to visualize, and thus to understand (Avcı & Tasdemir, 2019). Therefore, while teaching periodic table, various tools including visualizations (Avcı & Tasdemir, 2019), games (Alexander et al. 2008; Martí-Centelles & Rubio-Magnieto, 2014), digital applications (Avcı& Tasdemir, 2019; Eymen & Tas, 2017), tasks requiring the implementation of problem-

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solving strategies (Tothova et al., 2021) have been used. Yet, these techniques and tools may not be available for many students and may not have been experienced by many teachers. Therefore, it would be important to take a closer look at the textbooks and how they represent periodic tables as they are accessible by all the students. In addition, the ones published by the Ministry of Education in Turkey are distributed with no charge.

Despite the existence of different tools and techniques that may be included in the instruction, in many countries teachers heavily rely on and plan their classes according to the content of the textbooks (Aldahmash et al., 2016; Lepik et al., 2015; Sánchez & Valcarcel, 1999). Therefore, it is important to determine the views of chemistry teachers on the periodic table representations given in the textbooks since they would be using them actively in their classes.

Literature Review

Within the area of chemistry education, recent research studies investigating chemistry textbooks have focused on several aspects conveyed in textbooks including chemical representations (Akaygun, 2018; Demirdoğan, 2017; Farida et al., 2018; Upahi & Ramnarain, 2019), usage of analogies (Şendur et al., 2011), assessment and evaluation approaches (Gültekin & Nakiboğlu, 2016), the acquisition of content and scientific skills (Koray et al, 2006; Şen & Nakiboğlu, 2012), science textbook tasks (Bakken & Andersson-Bakken, 2021; Vojir & Rusek, 2022), textual and non-textual explanations (Meyer & Pietzner, 2022) and the practical work representations (Chen & Eilks, 2019). It is important for chemistry educators to know how each of these aspects are given in the textbooks for future planning.

Being an important tool for learning, the analysis of chemistry textbooks with respect to various aspects has been conducted in different countries. Ahtineva (2005) analyzed chemistry textbooks used in Finland in terms of activities and context and reported that the quality of textbooks affected the motivation for learning. Chen and Eilks (2019) examined the representations of practical work included in Chinese chemistry textbooks and experimental workbooks and reported that most textbooks were using a structured learning approach with limited suggestions of inquiry-based learning using either guided or open inquiry approaches. Considering the visualizations in chemistry textbooks, Gkitzia et al. (2011) analyzed Greek chemistry textbooks according to five criteria including type of the representation, interpretation of the surface features, their relationship to the text, the existence and the properties of a caption, and the degree of correlation between the components comprising a multiple representation. The same evaluation criteria were used to analyze the visualizations found in the 12 most preferred chemistry textbooks used in the USA (Nyachwaya, & Wood, 2014). As a result, Gkitzia et al. (2011) reported that the majority of the visual representations included in Greek textbooks were macroscopic (23.6%) and symbolic (23.6%), whereas Nyachwaya and Wood (2014) reported that the majority (85%) of the visual representations in the American chemistry textbooks were at the symbolic level.

In the case of Turkish upper-secondary school chemistry textbooks, Demirdoğan (2017) conducted a study to explore the chemical representations included in Turkish upper-secondary school chemistry textbooks. The results of the study conveyed the differences between the textbooks in terms of visual and chemical representations. Also, the author suggested that these representations could be enhanced with the help of chemistry teachers. In a similar study, Akaygun (2018) examined nine textbooks written by Turkish and foreign authors. In this study, Akaygun compared the visualizations in all nine textbooks in terms of type of representation (macroscopic, symbolic, particulate, multiple, hybrid, mixed, integrated or combined), and the attributes of the particulate visualizations (structure or process). The results of the study showed that the macroscopic visualizations were the most common type of representation in eight out of nine textbooks.

In another study, the content analysis of chemistry textbooks was conducted in terms of the usage of analogies. Şendur et al. (2011) found limited and simple analogies included in 9^{th} grade and 10th grade chemistry textbooks. The four analogies determined in the textbooks were classified as inappropriate for cognitive arrangement of students. As conclusion, for effective usage of analogies, the importance of the role of teachers was also highlighted in the study. When the representations of scientific process skills (Koray et al., 2006) and the graphs (Gültekin & Nakiboğlu, 2016) given in chemistry textbooks were examined, it was reported that they were not totally overlapping with the curriculum. Therefore, the results of these studies suggest that the representations given in the textbooks should be carefully examined, and the ways for improvement should be sought.

The opinions of teachers who had been recognized as the loyal followers of textbooks (Aldahmash, et al., 2016), were worth evaluating for a better understanding of effective inclusion of textbooks. Studies including teachers' opinions were also conducted with respect to several aspects. Nakiboğlu (2009) examined expert chemistry teach-

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ers' usage of secondary school chemistry textbooks and reported that these textbooks were regarded as a source of problems by expert teachers, and they were found to be not so effective tools for teaching. In another study considering teachers' opinions, Uyulgan et al. (2010) examined upper-secondary school chemistry teachers' opinions on textbooks regarding various themes including physical properties, cover features, interior cover features, preparatory studies, evaluation studies, content, and method. The results showed that the content of textbooks was very intensive for the secondary school students, the preparatory studies, the number of activities, teaching of concepts, and interdisciplinary connections were found to be insufficient. Teachers emphasized the inconsistency between textbooks and students' levels. Yet, in another study, Ercan and Bilen (2012), explored teachers' opinions on 9th grade and 10th grade chemistry textbooks and reported that the textbooks were found to have problems with the evaluation and assessment part, as well as had inconsistency between the content and the level of students. As can be seen from these previous studies, the opinions of chemistry teachers are very important as they examine the textbooks with a critical lens and do not follow the textbooks unconditionally.

Periodic tables as being important representations used in chemistry, have been examined in rather few studies. In an earlier study, Mishra and Nguyen-Jahiel (1998) studied various representations of periodic tables and categorized them under two main parts: educational and epistemological applications. Considering the features of multiple representations used for periodic systems, the authors designed a hypermedia tool to be used for learning periodic tables. Later, Bensaude-Vincent (2001), examined the graphical representations of periodic systems and pointed out a common belief of impossibility of obtaining a comprehensive periodic table, existed among the chemistry teachers who participated in the study.

Research Aim and Research Questions

For chemistry educators, the periodic table is much more than a symbolic representation; it is a system of relations, structures, and interactions. It is learnt as early as in the 9th grade and extensively covered in the textbooks. Therefore, it can be claimed that it is worthwhile to determine how the periodic tables were conveyed in the textbooks and what the chemistry teachers think about them for developing an understanding of how periodic tables can be used more effectively. Specifically, in this study, it was aimed to seek answers for the following research questions:

1. What are the features of periodic table representations given in Turkish upper-secondary school chemistry textbooks?
2. What are the opinions of chemistry teachers about the periodic table representations given in the 9th grade chemistry textbooks?

Research Methodology

Research Design

This qualitative study adopted the case study design where an in-depth, and detailed examination of a particular case or cases, within a real-world context are examined (Bromley, 1986). The scope of this study covers a particular case of selected chemistry textbooks used in Turkey and the opinions of teachers on them. The study consisted of two consecutive stages carried out in 6 months in 2019. These stages are explained below.

Research Sample

The study was composed of two stages. In Stage 1, first, about 50 chemistry teachers from different cities in Turkey were contacted through the authors' network. The title of the textbook, the authors, and the publication year of the textbooks they were using were asked. These chemistry teachers reported that they had been using ten different chemistry textbooks published between 2014 to 2019. Seven out of ten chemistry textbooks were commonly used in public and private upper-secondary schools in Turkey, therefore they were selected for the analysis and getting teachers' opinions about them. Public schools in Turkey use the textbooks in Turkish, whereas private schools select the textbooks from the ones written in English. In this study, three of the textbooks were written in Turkish. These upper-secondary school chemistry textbooks included a total of 50 periodic table representations. The publication date, language and the publisher of the textbooks are given in Table 1.

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Table 1
The Publication Date, Language, and the Publisher of the Chemistry Textbooks

Upper-secondary School Chemistry Textbook	Date of Publication	Language of the Textbook	Publisher
A	2018	Turkish	National
B	2019	Turkish	National
C	2019	Turkish	National
D	2017	English	National
E	2014	English	International
F	2015	English	International
G	2019	English	Customized

The chemistry teachers working in public schools in Turkey have been obligated to use the chemistry textbook approved and sent by the Ministry of Education (MoNE) to students and teachers as free of charge. Three of these textbooks (named as A, B, C) that were published by different national publishers, were the ones sent by the MoNE. Two of the textbooks (named as E, F) were the ones written by foreign authors and published by international publishers. One of the textbooks (named as D) was written by Turkish authors in English. Yet, one of the textbooks (named as G) was compiled by the chemistry teachers working at a particular school.

Research Procedure

In Turkey, 9th grade (Age 14-15) is the first year of the 4-year upper secondary school. In Turkish 9th grade chemistry curriculum (MoNE, 2018), the topic of periodic table is given as the second unit, so in the national textbooks, it is covered in the 2nd chapter. In the beginning of this unit an introduction to the atom, including the atomic theory and the structure of the atom is made. For the textbooks published by international publishers, the topic of periodic table is given either in the 2nd or the 3rd chapter. Therefore, the periodic table representations given in Chapter 2 or 3 were examined.

In Stage 2, due to the selection of seven chemistry textbooks for inspection, seven teachers who were using each particular textbook were invited for an interview. All the teachers agreed to participate in this study voluntarily. Regarding the demographic information of the teachers, five of them were female, one teacher working at a public school and one working at a private school were male. Three of the teachers who were using upper-secondary school chemistry textbooks written in Turkish were working in public schools. The professional experience of these teachers was between 19 and 24 years. On the other side, four of the teachers who were using upper-secondary school chemistry textbooks written in English were working in private schools. One of these teachers had 3, two of them had 7, and one teacher had 17 years of teaching experience. Five of the teachers had a degree of Bachelor of Science, where one teacher from a public school and one teacher from a private school had a Ph.D. While each of the participants was teaching at the 9th, 10th, and 11th grade levels (Age: 15-17), two of them were additionally teaching at the 12th grade (Age: 18).

Data Analysis

In Stage 1, after the selection of chemistry textbooks, the periodic table representations in each textbook were coded qualitatively and quantitatively. During this process, first, content analysis which is a compiled scientific method where written materials are analyzed systematically, and then, grouped based on specific criteria in order to make information (Cohen et al., 2007) was carried out to obtain meaningful themes and categories from the periodic table representations. As a result, 5 main themes were determined: *type, content, portrayal, periodic trends,* and *color*. The themes and the corresponding categories are shown in Table 2. Finally, the number of periodic table representations that fall under each theme and category were determined.

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Table 2
The Themes and Categories Determined from the Analysis of Periodic Table Representations Given in the Selected Chemistry Textbooks

Themes	Categories
Type	• Complete • Incomplete • Segmented
Content	• Detailed (name, symbol, atomic number, mass number, periods, etc.) • Symbols • Groups • Families of elements • Electron configurations
Portrayal	• Precise • Sketched • Sketched-labelled
Periodic Trends	• Including arrows • Including numerical data • Including both arrows and numerical data
Color	• Use of color for all the elements • Use of color for the families

For the inter-rater reliability agreement, after all the periodic table representations were coded by one of the researchers, the other researcher coded 24% (*N*=12) of all the periodic table representations (*N*=50). After resolving the discrepancies between coders, by discussing particular representations, the inter-rater reliability was obtained to be 96% which was suggested to be a high agreement (Shweta et al., 2015).

In Stage 2, after the selection of textbooks, the teachers who were using each of the textbooks were contacted and asked for their participation in the second stage of the study. Then, amongst the ones who agreed, the participating teachers were determined considering the convenience of their schedule and invited to an interview via video conferencing where the whole interview was video recorded with their permission. The interviews took about 60-70 minutes where they were asked to convey their opinions about each type of periodic table representation included in the textbook, they were using in their classes, by showing particular representation by screen sharing.

Next, the interviews were first open coded, and the content analysis was carried out to determine the themes and categories revealing the opinions of teachers based on the themes and categories that emerged for the periodic table representations. The first coding was performed by the first author, and then 25% of the interviews were coded by the second author reaching to 92% agreement. The discrepancies were resolved through discussion and full agreement was achieved.

Research Results

The results of the analysis for the 1st Stage of the study revealed that there were a total of fifty periodic table representations (PTR) obtained from seven chemistry textbooks. The most PTR (*N*=12) were found in textbook C and the least (*N*=3) in textbook D. As pointed out above, based on the results of the content analysis, the five themes emerged were: *type, content, portrayal, periodic trends,* and *color*. The findings regarding each theme and the corresponding categories are evaluated and described in more detail.

The types of PTR found in textbooks were of three different kinds, which were *complete, incomplete,* and *segmented*. The *complete type* of PTR were the representations of a periodic table without any missing parts. The type of the 15 (30%) of the PTR were found to be complete. Figure 1 (Güntut et al., 2019) shows an example of a complete type of representation. On the other hand, the *incomplete type* of PTR was described as the ones represented without f block, that is to say, block containing the actinides and lactinides. Twenty of the PTR (40%) were represented as an *incomplete type*. Figure 2 (Polat & Eryuva, 2017) displays an example for the incomplete type of PTR. The *segmented type* of these representations were the ones designed according to a particular purpose, such

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as 4A groups of the periodic table. Fifteen of the PTR (30%) were represented as a *segmented type*. Figure 3 (Badur, 2018) shows an example for the segmented type of PTR.

Figure 1
An Example of the Code Showing a "Complete Type" of Periodic Table Representation

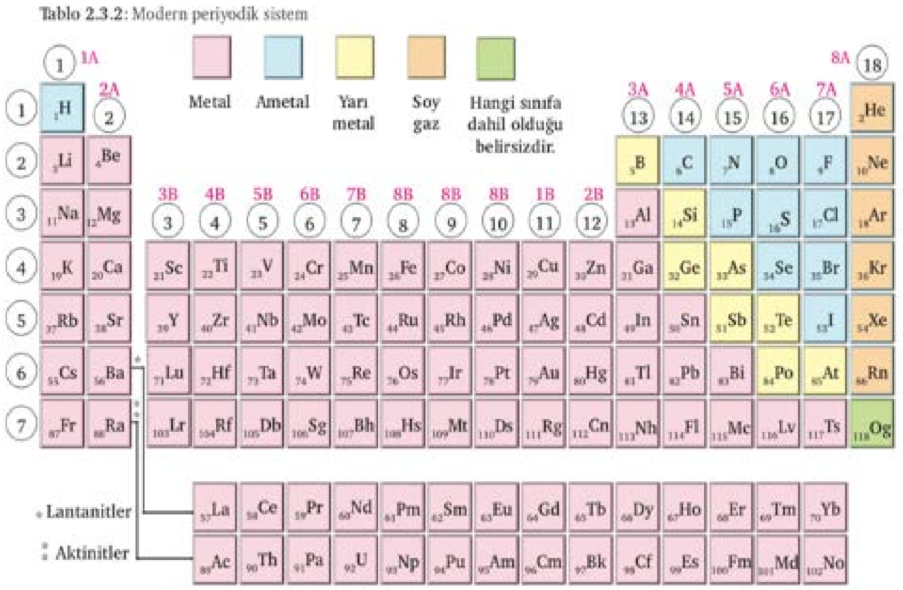

Figure 2
An Example of the Code Showing an "Incomplete Type" of Periodic Table Representation

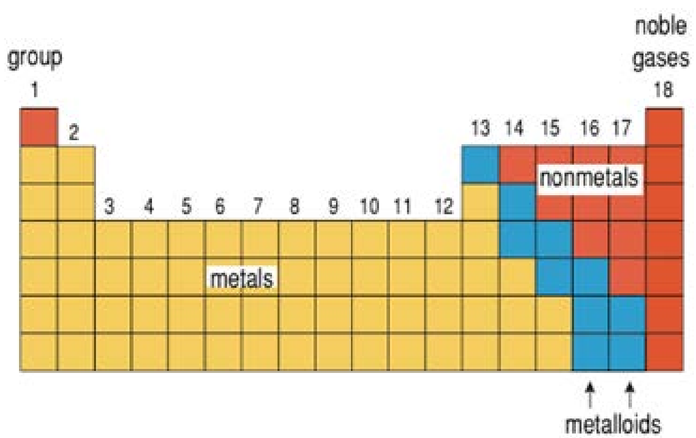

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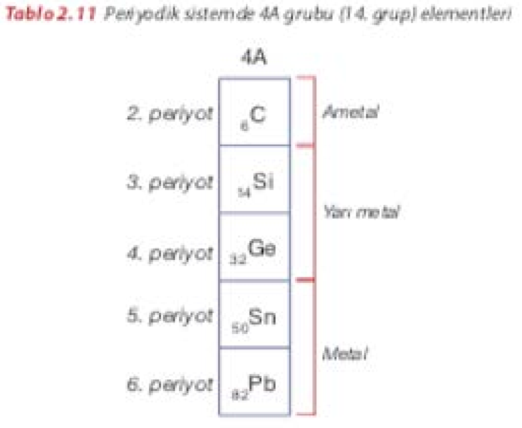
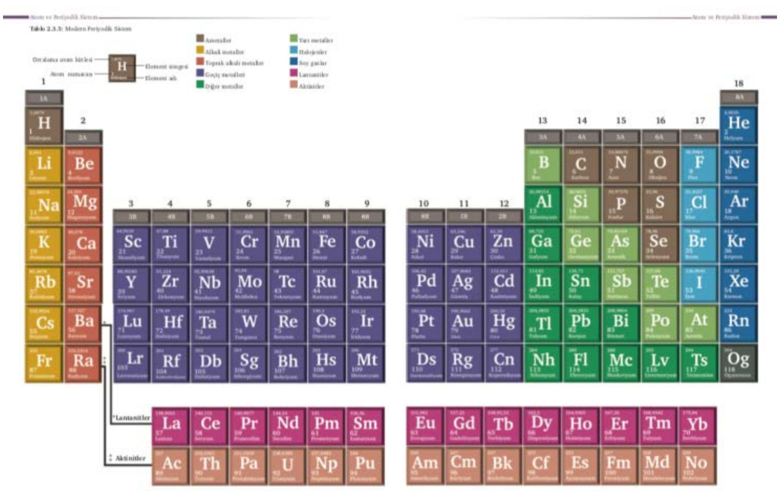
Figure 3
An Example of the Code Showing a "Segmented Type" of Periodic Table Representation



The second theme that emerged from the results of the analysis was the *content* that the periodic table representations included *detailed* content such as, name, symbol, atomic number, mass number, periods, groups, families of elements, and electron configurations, as the one shown in Figure 4 (Güntut et al., 2019). The majority of the sample covered three main contextual properties, which were *symbols* (25%), *groups* (20%), and *families* (15%). There was one periodic table representation including *electron configurations*, even though the concept of electron configurations was not introduced in the 9th grade chemistry curriculum. Nine of the PTR were empty, in other words completely lacking in content.

Figure 4
An Example of the Code Showing a "Detailed Content" of PTR Including the Name, Symbol, Atomic Number, Mass Number, Groups, Families of Elements



The third theme emerging in the analysis was the *portrayal* that included 3 categories; *precise portrayal, sketched portrayal,* and *sketched-labelled portrayal.* The majority of these representations (*N*=28, 56%) were classified as *sketched portrayals.* This kind of representation included deficient content as shown in Figure 5 (Badur, 2018). The other type of representation determined in the textbooks was the *precise portrayal* which had richer content. The results showed that five of the periodic tables (10%) included *precise portrayal* as shown in Figure 4. Lastly, sixteen (32%) of the periodic table representations were classified as *sketched-labelled portrayal* which included a sketched portrayal with some scientific content as shown in Figure 6 (Güntut et al., 2019).

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Figure 5
An Example of the Code Showing a "Sketched Portrayal" of Periodic Table Representation

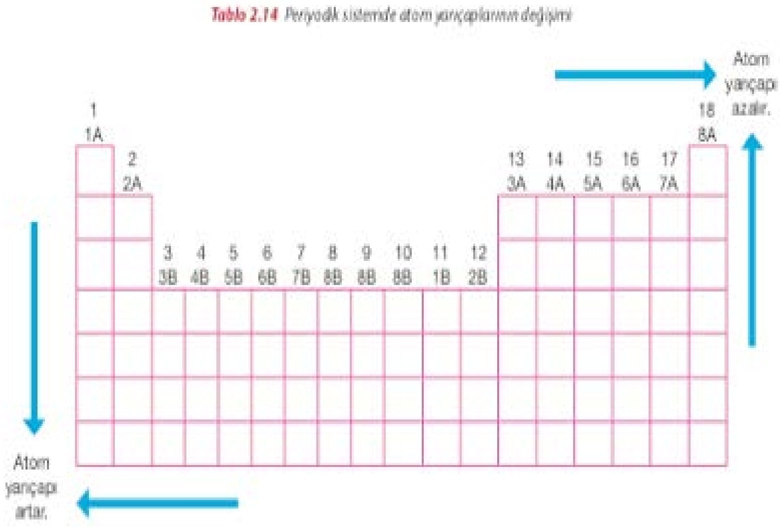
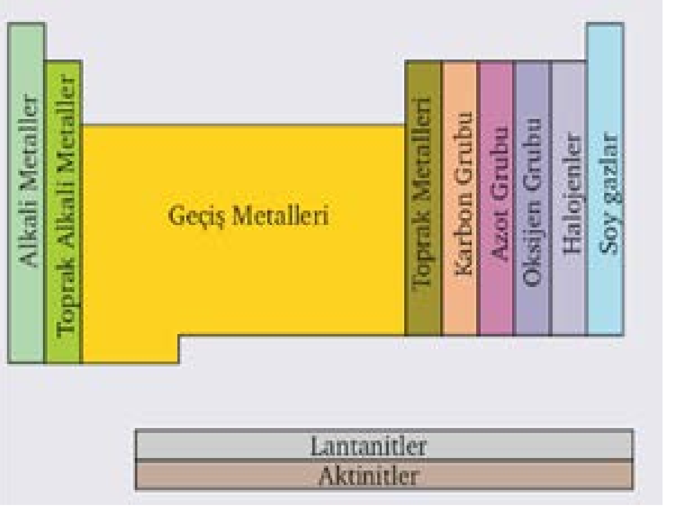


Figure 6
An Example of the Code Showing a "Sketched-labelled Portrayal" of Periodic Table Representation



The fourth theme that emerged in the analysis was the *periodic trends*. The results of the analysis revealed that more than half of the representations (*N*=30, 60%) contained information on the *periodic trends* such as *metallic-nonmetallic property, atomic radius, electron affinity, electronegativity, ionization energy,* and *physical properties*. Among these *periodic trends,* the majority of the representations were designed by involving *atomic radius* (*N*=9, 26%*) metallic-nonmetallic property* (*N*=6, 18%), and *electron affinity* (*N*=6, 18%). In addition, there was only one periodic table representation that included *physical properties* in terms of *periodic trends.* These representations were either given symbolically including *arrows* (*N*=19, 63%) as seen in Figure 7 (a) (Polat & Eryuva, 2017), or *numerical data* (*N*= 9, 30%) as in Figure 7 (b) (Badur, 2018), or *both by arrows and numerical data* (*N*=2, 7%) as shown in Figure 7 (c) (Ertekin et al., 2019).

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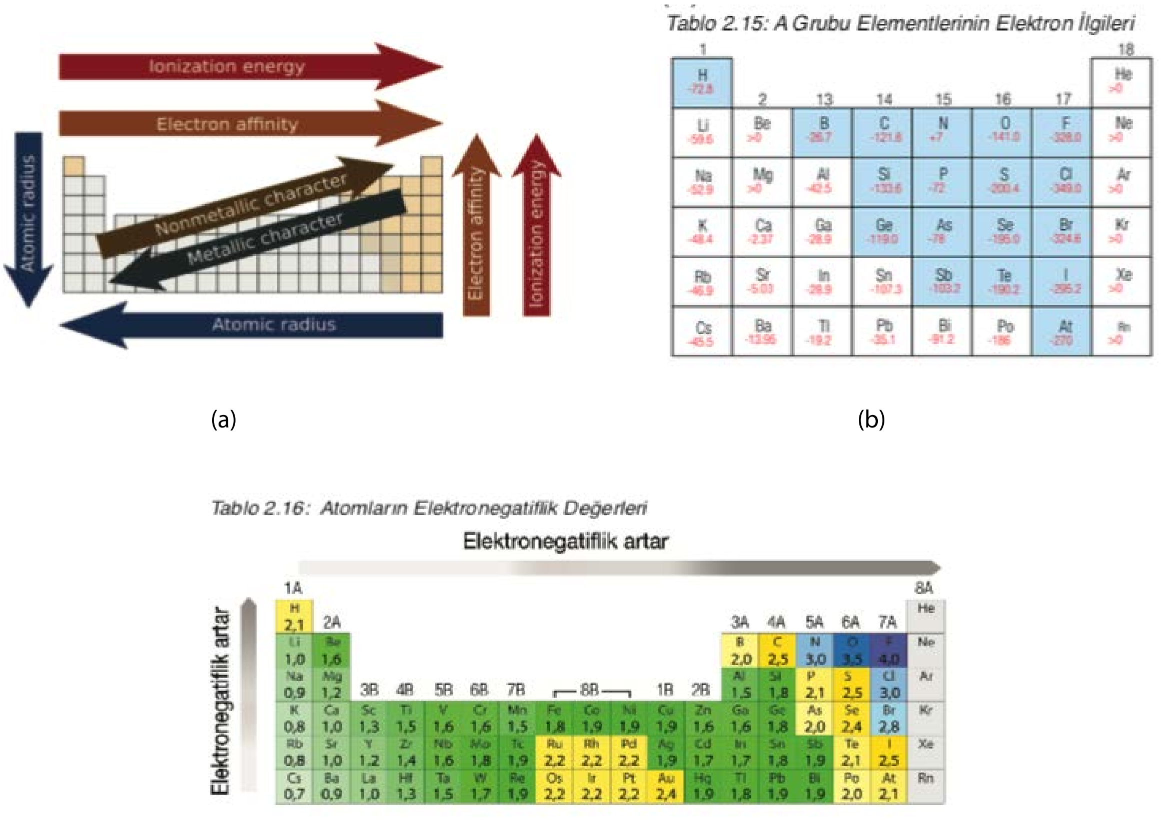
Figure 7

Examples of the Code Showing "Periodic Trends by (a) Using Arrows, (b) Numerical Data, (c) Both by Arrows and Numerical Data" given in the Periodic Table Representations



The fifth theme that emerged in the study was *color*. The results of the study showed that the majority (*N*=36, 72%) of the PTR were designed in color. The rest of them were represented without using color. It was observed that the colored PTR used color for representing elements (*N*= 12, 33%), as seen in Figure 1 or used color-coding for representing families as seen in Figure 4 and Figure 6. (*N*=24, 67%).

For the 2nd Stage of the study, the responses of the teachers were analyzed based on the themes emerged for the periodic table representations; namely, *theme, content, portrayal, periodic trends,* and *color.* When the teachers were shown all three types of the representations; c*omplete, incomplete,* and *segmented*, six of the teachers said they would prefer using the *complete* PTR, e.g., Figure 1, because it was more accurate, whereas the *incomplete* PTR would not be helpful as the students would not see the f-block elements. In addition, they all agreed to show complete PTR first, and then continue with the *segmented* ones, because they would be used for a specific purpose, such as teaching families, e.g., Figure 3. Only one teacher who has the least years of experience said there was no need to show the complete PTR, instead showing a couple of the segmented ones would be more helpful. The teacher who was using the textbook F, specifically said they liked segmented PTR in their textbook as it included everyday life pictures representing connections to the macroscopic level, as seen in Figure 8 (Anonymous author of the customized book, 2019).

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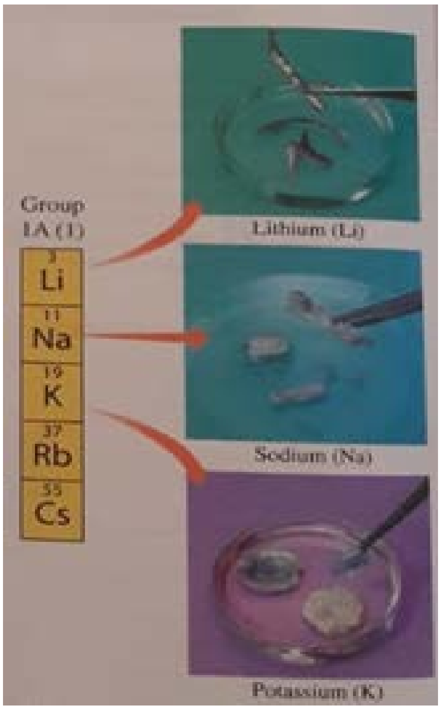
Figure 8
An Example of the Code Showing a "Segmented Type" of PTR Including Connections to the Macroscopic Level



In terms of the *content* given in the PTR, four of the teachers suggested that the PTR should be simple, refined and less crowded such as the one given in Figure 1. which shows the symbols and atomic numbers of the elements as well as the labels of the groups and period. They argued that if the PTR were simple, it would be easier for students to grasp, if they included more information, it would be distracting. On the other hand, two of the teachers claimed that they would like to see more information, such as the mass numbers and the names of the elements on the PTR, such as the one given in Figure 4, as they happened to be more scientific.

Regarding the teachers' opinions about the *precise, sketched* and *sketched-labelled* portrayals of the periodic table representation, four teachers said the PTR included in the textbooks should be precise, revealing the most recent and accurate information available for the day. The teacher who was using the textbook F, specifically said he did not like the complete PTR in their textbook as it did not include the four recently discovered elements, as seen in Figure 9 (Anonymous author of the customized book, 2019).

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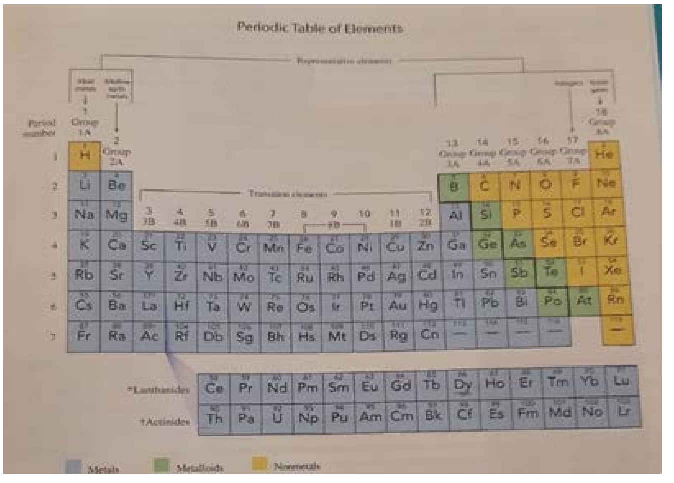
Figure 9

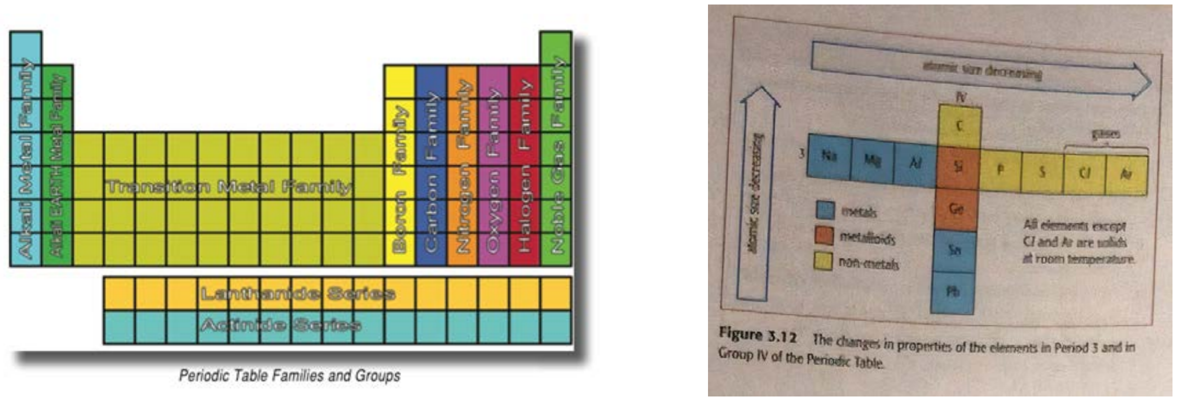
An Example of a PTR missing the Four Recently Discovered Elements



Another important issue raised by three chemistry teachers was that the PTR should not cause any misconceptions or should not include any misinformation. For instance, they said the PTR given in Figure 10 (a) (Polat & Eryuva, 2017) showed Hydrogen as a member of Alkali metals, and Figure 10 (b) (Anonymous author of the customized book, 2019) showed Argon as a nonmetal, which might be considered as problematic and should be corrected in class while teaching.

Figure 10

Example of the PTR Including a Problematic Representation



(a) (b)

In addition, three of the teachers suggested that the PTR given in different portrayals could be used for different objectives or purposes, so they were all important to have in their textbooks. Five of the teachers said they used the *sketched* PTR at last, usually for practice and activities, such as coloring the families.

The fourth theme emerged from the PTR was *periodic trends* which were represented either by using *arrows*, giving *numerical data,* or *both arrows and numerical data*. When the teachers were asked to explain their views on them, five of the teachers said they would definitely prefer the ones including *numerical data* for the periodic trends such as atomic radius, or electronegativity, over the ones having arrows that might cause memorization, as shown in Figure 11 (a) (Ertekin et al., 2019) and (b) (Polat & Eryuva, 2017). One of the teachers, having 20 years of teaching experience, said they did not like the one with the arrows even though it was given in their textbook because it did not show the exceptions. Another teacher with 3 years of experience said it would be better to use the one with the arrows because they did not need to know about the elements to understand periodic trends.

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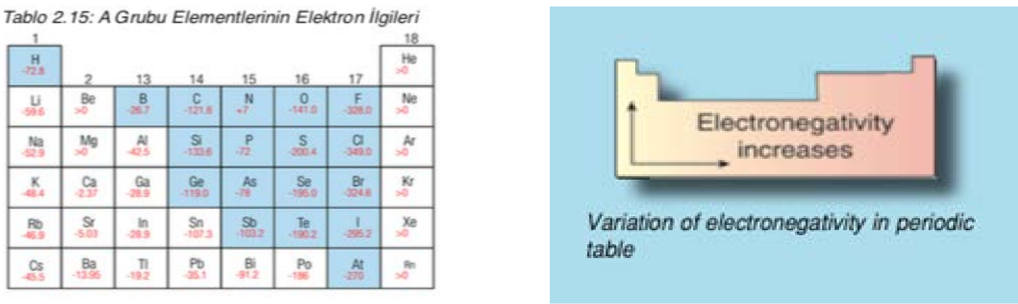
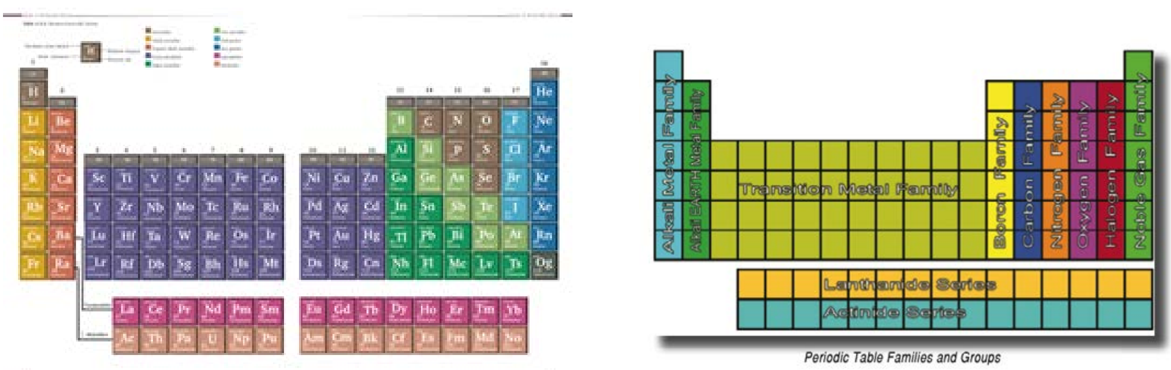
Figure 11
Examples of the PTR Including Periodic Trends Represented by (a) Numerical Data, (b) Arrows



(a) (b)

The last theme that emerged in the analysis of PTR was the *color*. When the opinions of teachers about the use of color in the PTR were asked, all the teachers said that using color was helpful especially for differentiating different groups and elements. Specifically, one of the teachers pointed out that the PTR in their textbook represented families with different colors, including Oganesson (Og, the element with the atomic number of 118) which was a synthetic element and therefore different from all the others, as seen in Figure 12 (a) (Güntut et al., 2019). Another teacher argued that using color was helpful but overusing color might be distracting for students. For instance, the PTR in their textbook used color and colored frames to describe their characteristics as being major or trace elements, as seen in Figure 12 (b) (Polat & Eryuva, 2017).

Figure 12
Examples of the PTR Including Color for (a) Families, (b) Characteristics



(a) (b)

Discussion

Textbooks have been important tools used, especially in K-12 education, as they are easily accessible and reliable sources. Chemistry textbooks include not only textual but also visual representations that are crucial in learning chemistry. Periodic table representations (PTR) are one of those because the topic of periodic table was found to be abstract and hence difficult to understand (Avcı & Tasdemir, 2019). Studies investigating representations in chemistry textbooks used in different countries focused on the types of representations and reported that the macroscopic representations were the most commonly included type (Akaygun, 2018; Demirdoğan, 2017; Gkitzia et al., 2011).

In this study, to the honor of International Year of Periodic Table, 2019, it was aimed to explore the periodic table representations in 9th grade textbooks used in Turkey. First, specifically periodic table representations included in 7

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different commonly used upper-secondary school chemistry textbooks were examined according to 5 criteria that emerged during the analysis; *type, content, portrayal, periodic trends,* and *color*. The first theme, *type* of PTR, had the categories of *complete* (30% of PTR), *incomplete* (40%), and *segmented* (30%). As the findings revealed, the majority of the periodic table representations were showing only a certain section of the periodic table, being either incomplete or segmented. This finding suggests that the textbook authors might have preferred to present a smaller and more focused piece of information as claimed by the *Attention-Guidance Principle* (Van Gog, 2014), arguing that directing students' attention to the certain parts of a material may enhance learning. The second theme that emerged for the periodic table representations was the *content* of the PTR, that included detailed content, symbols, groups, families, and electron configurations. The majority of the PTR were found to include specific information on *symbols* (25%), *groups* (20%), and *families* (15%). This finding is also aligned with the *Attention-Guidance Principle* because novice learners mostly focus on salient or irrelevant features and can easily miss the relevant information (De Koning et al., 2009). Ensuring that the PTR presents specific and relevant information may help students integrate the information provided effectively, not to get lost in details; hence supports understanding. The third theme, *portrayal* of PTR included three categories revealing different ways of portrayal of the PTR as *precise* (10%), *sketched* (56%), and *sketched-labelled* (32%). It was interesting that the majority of the PTR were presented as a sketched drawing with limited information. Even though in the 9th grade, students are learning the concept of periodicity in detail, they may not see the big picture, and lose track if the details are presented (De Koning et al., 2009). Therefore, the reason for including mostly sketched PTR, instead of precise and fully filled periodic tables, might be to scaffold students in perceiving the periodic table as a whole, and this would help students develop representational competence (Kozma & Russel, 1997). The fourth theme of the periodic table representations was the *periodic trends* which was either shown by *arrows* (63%), by giving *numerical data* (30%), or *both arrows and numerical data* (7%). It was interesting to observe that the majority of the PTR were using arrows to depict how the periodic trends change across the group or period. It has been known that arrows are the integral parts of chemistry and commonly used for various purposes including showing direction (Alvarez, 2012; Lakshminarayanan, 2010). In the periodic table representations examined, the arrows which were usually in color, were placed either on or outside the periodic tables to attract students' attention. By using this depiction, it may be easier to display less information, but students may tend to memorize the direction of arrows, not necessarily understanding. In other words, without seeing the numerical data, they may have misconceptions or difficulty in understanding why atomic size, for instance, decreases when moving across a period (Nicoll, 2001). The fifth theme that emerged from the examination of PTR was the *color* as the majority (72%) of the PTR were in color. This theme included two categories; *use of color for all the elements* (33%) and *use of color for the families* (67%). Even though the majority of the PTR were in color, the color was mostly used to depict or highlight a characteristic, such as transition metals. As it was discussed above, it can be claimed that the textbook authors may have decided to avoid the details and to present more specific information by color coding, hence to guide students' attention to a specific part (De Koning et al., 2009).

Secondly, the opinions of chemistry teachers who were using periodic table representations given in the textbooks were evaluated. It was important to uncover their opinions, as it was done previously (Nakiboğlu, 2009; Uyulgan et al., 2010) because they have been regarded as loyal textbook followers (Aldahmash et al., 2016; Vojir & Rusek, 2021). Specifically, their opinions were sought for each of the theme that emerged from the analysis of PTR. For the first theme, the *type* of the PTR, the majority of the teachers (86%) preferred to have a complete periodic table in the textbook because it was the most accurate representation. Yet, while teaching the periodic table, all but one agreed to start with a complete periodic table, and then continue with the segmented ones to show specific sections. By this way, teachers would scaffold their students to proceed from the whole and the parts, and make connection within the periodic table (Belland, 2014; Mayer & Moreno, 1998) because a complete, colorful, fully-filled periodic table may create cognitive load for the novice learners (Sweller & Chandler, 1991). According to Offerdahl et al. (2017), cognitive load can be reduced by helping students to become competent with the parts of visual representations and then integrate these parts with each other to achieve the learning outcomes. This finding is aligned with the idea of helping novice learners by eliminating extra details to decrease extraneous cognitive load by using "from low to high fidelity" strategy (Merrienboer & Sweller, 2010). This idea is also supported by the Coherence Principle of Cognitive Theory of Multimedia Learning that claims the importance of presenting less and basic multimedia rather than more and detailed ones (Mayer & Moreno, 1998). Therefore, it was important to observe how teachers implemented their strategy in helping students understand and effectively use different types of periodic tables given in the textbooks. Regarding the theme of *content* of the PTR, the majority of the teachers (57%) claimed that they would prefer to see less crowded periodic tables, otherwise it would be distracting for

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students, as they may introduce extraneous cognitive load (Sweller, 1994). Regarding the third theme, *portrayal*, of the PTR, four teachers emphasized the importance of having the most recent and scientifically accurate Periodic Tables, that include all the recently discovered elements. Having the *precise* PTR, with the most recent scientific findings presented in the textbooks might help students develop science appreciation (Vinen, 2000) and improve their interest towards learning chemistry (Salta & Koulougliotis, 2012). The other issue the teachers highlighted was not having any problematic PTR that might cause misconceptions; that's probably why they would like to see the *precise* PTR. In addition, five of the teachers suggested that they would use the *sketched* PTR in class activities such as coloring different families. This strategy might be considered as using "worked examples" to reduce cognitive load and support students learning (Merrienboer & Sweller, 2010). Finally, three of the teachers suggested that the PTR portrayed in a different manner could be used for different objectives, so they are all important to have in the textbooks. Being able to use different PTR may improve students' representational competence as they would need to use, interpret, analyze, and transform these representations (Kozma & Russel, 1997). Regarding the fourth theme that emerged in the analysis of PTR, *periodic trends,* the majority of the teachers preferred data-driven numerical values for describing periodic trends instead of including arrows that might cause memorization without understanding the reason behind. As Larson et al. (2012) found an inquiry-based learning activity of periodic trends might help students develop more accurate mental models as they make sense of the data provided, recognize the patterns, and inductively construct the relationships among these data. Finally, for the last theme, *color* of the PTR, the use of color to differentiate families was found to be helpful by all the teachers as it serves as a scaffolding with respect to the attention-guidance principle (De Koning et al., 2009), as discussed above. Yet, it was suggested that overusing colors for all the elements might distract students by creating extraneous cognitive load (Sweller, 1994). In addition, few teachers found including macroscopic representations of the elements helpful as the students are being introduced to the triplet of chemistry and better able to make connections especially among the macroscopic and symbolic representations (Johnstone, 1993).

Conclusion and Implications

The results of this study showed that 9th grade chemistry textbooks used in Turkey include periodic tables with different features including type, content, portrayal, representing periodic trends and using color. The majority of the periodic table representations were found to be adopting the Coherence Principle of Cognitive Theory of Multimedia Learning that suggests using fewer extraneous words and pictures in multimedia environments". It was observed that most of the periodic table representations were presenting less information, highlighting specific content, using simplistic sketch, using color for differentiation to guide learners' attention, and scaffold their learning. This approach was also supported by the teachers as they preferred to use those less detailed and focused representations.

Yet, there was only one feature that the teachers preferred not to use, the simplistic one, the presentation of the periodic trends. Almost all the teachers supported the idea of presenting data-driven numerical values regarding a particular periodic trend rather than showing how the trends alter across the groups or periods by drawing arrows because they claimed that just seeing the arrows without associating it with the numerical data may cause students to memorize instead of making sense of the data and relating it with a particular trend. In other words, the chemistry teachers said they would like their students to drive conclusions instead of remembering the direction of the arrows showing the change in periodic trend.

All in all, the results of this study may guide chemistry teachers while using periodic tables in their classes, textbook authors while selecting periodic table representations in their textbooks, and chemistry education researchers who would explore more effective ways of learning concepts regarding periodic table. More specifically, chemistry teachers may examine the periodic table representations presented in the textbooks they are using and select the best representations that will guide their students' attention for a better understanding. In other words, chemistry teachers can make informed decisions on using the most effective periodic table representations (e.g., color-coded families, numerical shown of periodic trends etc.) for their purpose. Similarly, when textbook authors include periodic table representations in their textbooks, they may adopt Coherence Principle of Cognitive Theory of Multimedia Learning and using fewer detail rather than many extraneous features such as extra colors or information. Finally, chemical education researchers may still evaluate students' interactions with the periodic table representations in different forms and environments to shed light on how to improve students' conceptual understanding.

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Limitations

Despite its relevant findings, this study is limited with the seven 9th grade chemistry textbooks examined and the views of the chemistry teachers interviewed. There were several other 9th chemistry textbooks used in Turkey but not examined in this study. The periodic table representations given in those textbooks may convey different features. Also, if other teachers may have interviewed, they may have brought different opinions and arguments. Therefore, the findings of this case study are limited with this sample.

Future Directions

With the development of technology and inclusion of computers in chemistry classes, dynamic visualizations have been integral parts of teaching and learning chemistry. In this study, only the textbooks as printed materials were examined, but in other studies, how digital periodic tables display the elements through websites or tablet applications may be explored. In addition, eye-tracking technology can be integrated to further explore which parts students focus more or less while working on specific tasks regarding the periodic table. All these attempts will contribute to the understanding of effective use of periodic table representations for conceptual understanding.

Declaration of Interest

The authors declare no competing interest.

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