



PEDAGOGICAL CONSTRUCTIONS OF THE PERIODIC TABLE IN TEXTBOOKS OF ETHIOPIA, TÜRKİYE, AND INDIA

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Abstract. *The periodic table is a foundational framework in science and chemistry education globally; however, its pedagogical presentation varies across educational and cultural contexts. Addressing this variation, the present study compares how the periodic table is represented in secondary-level science and chemistry textbooks from Ethiopia, Türkiye, and India. Using a comparative qualitative textbook analysis, the study examines five dimensions: curricular structure, conceptual depth, nature of science, pedagogical tools, and nature of activities. The findings show that, in all three contexts, the periodic table develops across grade levels rather than appearing as a single isolated unit, though the textbooks differ in how this development is organized. Differences appear in the continuity of topic progression, the timing and density of conceptual abstraction, the visibility of the nature of science, the use of analogies and visual supports, and the cognitive engagement promoted through activities. Ethiopia progresses from observable properties toward explanatory treatment of periodic trends, Türkiye from classificatory logic toward quantum-based interpretation, and India from early atomic-theoretical grounding toward specialized chemistry content. Rather than ranking textbook systems, the study interprets these representations as pedagogical structures that organize abstraction, representation, and learner engagement differently across national contexts.*

Keywords: *chemistry education, comparative textbook analysis, cross-national comparison, pedagogical representation, periodic table*

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Introduction

The periodic table is a cornerstone of chemical literacy because it organizes the elements in ways that support the classification of matter and the explanation of chemical behavior. At the same time, however, its pedagogical translation from a scientific model into a learnable school topic remains a persistent challenge in chemistry education. Beyond memorizing symbols, groups, and periods, meaningful engagement with the periodic table requires students to connect abstract ideas such as atomic structure, periodicity, and model-based explanation. As a result, the topic is widely regarded as conceptually demanding, and students often experience difficulties in understanding its underlying logic and explanatory function (Chowdhury, 2022; Mokiwa, 2017; Scerri, 2020; Suryelita et al., 2019).

Research on the teaching and learning of the periodic table has consistently shown that students' difficulties go beyond unfamiliarity with chemical symbols or element names. Studies have documented that learners frequently struggle to understand the logical basis of periodic classification, the relationship between atomic structure and periodic properties, and the explanatory function of the table as a scientific model rather than a memorization tool (Chowdhury, 2022; Mokiwa, 2017; Suryelita et al., 2019).

These difficulties are not merely a product of student factors but are also shaped by how the topic is introduced and developed in instructional materials. Research has shown that textbook representations of the periodic table vary considerably in the degree to which they foreground conceptual relationships, support model-based reasoning, and connect observable periodic trends to underlying atomic theory (Akaygün & Arkun, 2022; Scerri, 2020). This suggests that the pedagogical construction of the periodic table in textbooks – how it is sequenced, explained, visualized, and connected to broader chemistry content may play an important role in shaping both the accessibility and the depth of students' engagement with the topic.

These difficulties also draw attention to the role of textbooks. In many school systems, textbooks remain one of the main instructional resources through which curriculum expectations are translated into classroom



learning opportunities. They influence the sequencing of concepts, the balance between factual and explanatory knowledge, the forms of representation students encounter, and the kinds of activities through which they are expected to engage with scientific ideas. Research in chemistry education has particularly emphasized the importance of visual and representational supports in helping students connect abstract chemical concepts across symbolic, particulate, and observable levels (Hrast & Ferik Savec, 2017). In this sense, textbooks do not merely deliver content; they structure how a topic is made pedagogically available to learners (Chen et al., 2019; Metwally et al., 2024). Studies on science textbooks have also shown that textbooks may shape the kinds of inquiry and reasoning opportunities made available to students in science learning contexts (Li et al., 2018). Accordingly, the ways in which scientific content is represented in textbooks may influence both students' understanding and their perceptions of what counts as important knowledge (Chen et al., 2019; Ramnarain & Padayachee, 2015). In the case of the periodic table, fragmented, overly dense, or weakly connected representations may further intensify conceptual difficulty and limit meaningful understanding (Akaygün & Arkun, 2022; Nyachwaya & Gillaspie, 2016).

Although the importance of textbook analysis is well established, and the literature has separately documented students' difficulties in learning the periodic table, comparatively fewer studies have examined how this foundational topic is represented across different national textbook contexts. Comparative work on secondary chemistry textbooks has, for example, examined the representation of practical work across different Chinese communities (Chen & Eilks, 2019), yet cross-national analyses focused specifically on the periodic table remain limited. However, such comparison is valuable. A cross-national analysis can reveal how the same scientific content is sequenced, elaborated, visualized, historically framed, and pedagogically supported in different official instructional materials. Rather than treating textbook differences as evidence of simple hierarchy, such an approach can help identify distinct representational patterns and curricular emphases in the teaching of a universal scientific topic. Recent comparative textbook research has also emphasized that textbook analysis should move beyond simple content comparison and examine how educational systems organize knowledge, representation, and learning opportunities across contexts (Huang et al., 2022).

Against this background, the present study compares the representation of the periodic table in selected official secondary-level science and chemistry textbooks from Ethiopia, Türkiye, and India. The analysis focuses on five dimensions: curricular structure, conceptual depth, nature of science (NOS), pedagogical tools, and the nature of activities. The purpose is to examine how the periodic table is introduced, revisited, and developed across grade levels, and to identify similarities and differences in the ways textbooks support students' engagement with this core topic. In doing so, the study aims to contribute to comparative textbook literature by offering a focused analysis of how the periodic table is pedagogically constructed in three national textbook contexts. In addition to identifying cross-national similarities and differences, the study examines textbook representations as pedagogical structures through which scientific abstraction, explanatory relations, and opportunities for learner participation are shaped. In this respect, the study aimed to offer an analytical framework that may support future comparative textbook research in chemistry education. To achieve this aim, the present study addresses the following research questions:

1. How is the periodic table introduced, sequenced, and revisited across grade levels in the selected textbooks?
2. How do the textbooks differ in terms of conceptual depth, representations of the nature of science, pedagogical tools, and the nature of student activities related to the periodic table?
3. What similarities and differences can be identified across the three textbook contexts in the pedagogical construction of the periodic table?

Research Methodology

Design

This study was designed as a comparative qualitative textbook analysis focusing on how the periodic table is represented in selected official secondary-level science and chemistry textbooks from Ethiopia, Türkiye, and India. The study adopted a cross-case comparative perspective, treating each national textbook context as a bounded case while using a shared analytical framework to examine similarities and differences across cases (Stake, 2006; Yin, 2018). Qualitative design was considered appropriate because the study aimed not to measure the frequency of isolated textbook features, but to interpret how the periodic table was pedagogically constructed through sequencing, explanation, representation, and activity design (Creswell & Poth, 2018).



In this sense, the analysis focused on the meanings embedded in the textbooks' treatment of the topic, including how content was organized, how conceptual relationships were developed, and what kinds of learning opportunities were made available to students (Merriam & Tisdell, 2016).

The comparative structure of the study made it possible to analyze a common scientific topic across three official textbook contexts without assuming that the textbooks represented identical curricular traditions or educational priorities. Instead, the goal was to identify observable patterns in the pedagogical representation of the periodic table and to compare how these patterns varied across the three purposively selected national textbook contexts (Ethiopia, Türkiye, and India) (Bowen, 2009; Yin, 2018).

Case and Textbook Selection

In this study, the term 'official textbooks' refers to textbooks issued or formally approved by the relevant national education authority (e.g., a Ministry of Education) for use within the national curriculum, as distinct from supplementary or auxiliary resource materials that are not part of the official curriculum. The three national contexts selected for this study differ in their educational structures, curriculum traditions, and textbook development processes, and a brief overview of each context is provided here to situate the comparative analysis.

In Ethiopia, the national curriculum is developed and approved by the Ministry of Education (MoE), which also oversees the production and distribution of official textbooks used across the country. At the secondary level, English serves as the primary language of instruction for science and mathematics subjects, reflecting both the multilingual nature of the country and the practical need to align with university-level education and international scientific literature. Accordingly, the Ethiopian textbooks analyzed in this study are written in English. Secondary education covers Grades 7 through 12, and science and chemistry are taught as separate subjects in the upper secondary cycle. The textbooks analyzed in this study represent the official instructional materials currently in use at the national level.

In Türkiye, the national curriculum and official textbooks are developed and approved by the Ministry of National Education (MEB). Instruction in Turkish schools is conducted in Turkish, and all MEB-approved textbooks are published in Turkish. The textbooks analyzed in this study are therefore in Turkish, and relevant excerpts have been translated by the authors where necessary for the purposes of this analysis. Secondary education is organized into middle school (Grades 5–8) and high school (Grades 9–12) cycles. Science is taught as an integrated subject in the middle school grades, while chemistry becomes a separate subject at the high school level. The textbooks selected for this study are the most recently approved official editions published in 2023.

In India, the National Council of Educational Research and Training (NCERT) develops the national curriculum framework and produces official textbooks used across the country. NCERT publishes textbooks in both English and Hindi; however, the English-medium versions are widely used across the country, particularly for science subjects, given the prominence of English in higher education and national university entrance examinations. The textbooks analyzed in this study are the English-medium NCERT editions. Secondary education covers Grades 9 through 12, with science taught as an integrated subject in Grades 9 and 10 and as separate discipline-specific subjects, including chemistry, in Grades 11 and 12. The NCERT textbooks analyzed in this study represent the standard official materials used in the central board curriculum.

The cases were selected through criterion-based purposive sampling. Ethiopia, Türkiye, and India were chosen because they provided official and publicly accessible secondary-level science and chemistry textbooks in which the periodic table was addressed across grade levels. Beyond accessibility, however, the selection was guided by several substantive considerations. First, the three countries represent distinct geographical and socioeconomic contexts, which increases the likelihood that the textbook differences identified reflect genuinely different curriculum traditions rather than superficial variation. Second, each country operates a centralized textbook system in which official materials are developed and approved by a national educational authority: the Ministry of Education (MoE) in Ethiopia, the Ministry of National Education (MEB) in Türkiye, and the National Council of Educational Research and Training (NCERT) in India. This structural similarity makes the three contexts comparable as objects of analysis, while their different educational histories, curriculum philosophies, and assessment cultures provide a basis for meaningful cross-national contrast. Third, the periodic table is addressed across multiple grade levels in all three textbook systems, making it possible to trace conceptual progression within each context as well as to compare how this progression is configured differently across countries.

The aim of this selection was not to construct a statistically representative sample of national education systems, but to examine three bounded textbook contexts through comparable official materials. In this respect, the cases

were chosen because they made it possible to analyze how the same foundational chemistry topic was presented in different textbook settings using a shared analytical framework. The combination of structural comparability and substantive diversity across the three contexts is what makes the comparison analytically productive: it allows patterns to be identified that are specific to each context while also revealing shared features in how a universal scientific topic is pedagogically constructed in official instructional materials.

Within each country, textbooks were included on the basis of four criteria: (a) official approval by the relevant educational authority, (b) public accessibility, (c) current or most recently available edition status at the time of data collection, and (d) explicit inclusion of periodic table content at the secondary level. Based on these criteria, the final corpus consisted of eleven science and chemistry textbooks from the three countries - four from Ethiopia, four from Türkiye, and three from India - in which the periodic table was introduced, revisited, or elaborated across secondary grade levels. The full list of selected textbooks is presented in Table 1.

Data Sources

The primary data source for this study consisted of official lower- and upper-secondary science and chemistry textbooks from Ethiopia, Türkiye, and India in which the periodic table or closely related content (e.g., classification of elements, atomic structure, periodic properties, or block structure) was explicitly addressed. The corpus was limited to officially endorsed textbooks because these materials provide the most direct and publicly verifiable representation of how the topic is pedagogically structured within each national textbook context.

Based on the selection criteria described above, the final corpus consisted of 11 textbooks: four from Ethiopia, four from Türkiye, and three from India. In Ethiopia, the analysis included the Grade 7, Grade 9, Grade 10, and Grade 11 chemistry textbooks (Ministry of Education [MoE Ethiopia], 2010, 2013, 2023). In Türkiye, the corpus included the Grade 7 and Grade 8 science textbooks and the Grade 9 and Grade 11 chemistry textbooks (Milli Eğitim Bakanlığı [MEB], 2023). In India, the analysis included the Grade 9 science textbook and the Grade 11 and Grade 12 chemistry textbooks (National Council of Educational Research and Training [NCERT], 2020). Together, these textbooks allowed the study to trace how the periodic table was introduced, revisited, extended, or embedded in related chemistry topics across grade levels.

To support transparency and replicability, all textbooks were obtained in PDF format from official digital platforms: the MoE EMIS Textbook Library for Ethiopia, the Education Informatics Network (EBA) for Türkiye, and the e-Pathshala portal maintained by NCERT for India. The full list of textbooks included in the study is presented in Table 1.

Table 1
Textbook Corpus Included in the Study

Country	Selected Textbooks
Ethiopia	Grade 7 Chemistry Textbook (MoE Ethiopia, 2013) Grade 9 Chemistry Textbook (MoE Ethiopia, 2010) Grade 10 Chemistry Textbook (MoE Ethiopia, 2023) Grade 11 Chemistry Textbook (MoE Ethiopia, 2013)
Türkiye	Grade 7 Science Textbook (MEB, 2023) Grade 8 Science Textbook (MEB, 2023) Grade 9 Chemistry Textbook (MEB, 2023) Grade 11 Chemistry Textbook (MEB, 2023)
India	Grade 9 Science Textbook (NCERT, 2020) Grade 11 Chemistry Textbook (NCERT, 2020) Grade 12 Chemistry Textbook (NCERT, 2020)

Analytical Framework

The analysis was organized around five analytical dimensions: curricular structure, conceptual depth, nature of science, pedagogical tools, and the nature of activities. These dimensions were not treated as fixed categories



imposed in advance without reference to the material. Rather, they were developed through an iterative process that combined three sources: the relevant literature on textbook analysis and chemistry education, the conceptual demands of teaching the periodic table, and repeated close reading of the selected textbook chapters. This approach is consistent with recent comparative textbook research emphasizing multidimensional analytical frameworks for examining how textbooks organize content, representation, and learning expectations across educational contexts (Huang et al., 2022).

These five dimensions were chosen because they made it possible to examine not only what content was included, but also how the topic was pedagogically constructed for learners. More specifically, the framework enabled the study to trace how the periodic table was sequenced across grade levels, how far explanations moved from descriptive classification to theoretical interpretation, how scientific knowledge and model development were represented, which visual and analogical supports were used, and what kinds of student engagement were promoted through textbook activities. Together, these dimensions provided the analytical structure through which the research questions were addressed.

Each of the five dimensions is grounded in established theoretical perspectives in science education and textbook research. Curricular structure draws on the concept of the spiral curriculum, in which topics are revisited across grade levels with increasing depth and complexity, allowing students to build on prior knowledge in a cumulative and progressive manner (Bruner, 1960). Conceptual depth is informed by Johnstone's (1982) three levels of chemical representation: the macro, sub micro, and symbolic levels, which have been widely used to analyze how chemistry textbooks move between observable phenomena, particle-level explanation, and abstract symbolic notation. The nature of science dimension is grounded in the established framework for NOS in science education, which emphasizes the tentative, evidence-based, and historically developed character of scientific knowledge (Lederman et al., 2002). The pedagogical tools dimension draws on research into multiple representations in science learning, which has shown that visuals, analogies, diagrams, and symbolic notations are not neutral aids but active components of explanation that shape how students construct understanding of abstract concepts (Ainsworth, 2006). Finally, the nature of activities dimension is informed by frameworks for cognitive demand in science tasks, which distinguish between lower-order operations such as recognition and recall and higher-order operations such as interpretation, explanation, and argumentation (Anderson & Krathwohl, 2001).

Curricular structure focused on when and how the topic was introduced, revisited, and connected across grade levels. Conceptual depth examined the level of abstraction and the extent to which the textbooks moved from foundational descriptions toward more advanced explanatory content. Nature of science addressed the representation of scientific models, historical development, empirical evidence, and the tentative character of scientific knowledge. Pedagogical tools referred to the representational resources used to support understanding, including visuals, analogies, graphs, tables, and diagrams. Nature of activities focused on the role assigned to students and the kinds of cognitive engagement expected, ranging from recognition and classification to interpretation, explanation, and argumentation.

The purpose of this framework is to support a systematic comparison of how a common scientific topic was pedagogically shaped across three official textbook contexts. The coding framework derived from these dimensions is presented in Table 2.

Table 2*Analytical Dimensions and Guiding Questions*

Analytical Dimension	Indicators for Coding
1. Curricular structure	- At what grade level is the topic first introduced? - At which grade levels is it revisited? - How is the content sequenced across repetitions? (spiral, discrete blocks, or disconnected) - Is learning in lower grades designed as a prerequisite for upper grades?
2. Conceptual depth	- What key concepts are taught at each grade level? - How does the level of abstraction of the concepts increase? - Are advanced-level concepts included? If so, to what extent?
3. NOS	- Is the tentative nature of scientific knowledge emphasized? - How are historical models presented? (As a chronological list, or as competing/evolving models?) Are there examples of the role of experiments and evidence in changing models? - Is science presented as a process of inquiry or as a body of knowledge?
4. Pedagogical tools (analogies, visuals)	- What analogies and metaphors are used to make concrete abstract concepts? - What is the nature of the visuals used (e.g., tables, graphs, diagrams)? Are they simple representations or data-driven analytical tools?
5. Nature of activities	- What types of skills do the suggested or included activities target? - What is the student's role in the learning process? - How does the complexity of activities evolve with grade level? Is there progression from simple procedural tasks to complex problem-solving?

Note. The dimensions were developed iteratively through close reading of the textbook corpus, relevant literature, and alignment with the research questions.

Coding and Analysis Procedure

The unit of analysis was defined as the textbook chapter or section in which the periodic table, classification of elements, atomic structure, periodic properties, or closely related explanatory content was substantially addressed. The analysis began with repeated reading of the selected chapters and their accompanying visuals, tables, diagrams, and activities in order to establish familiarity with both the content and its pedagogical organization.

In the first stage, an initial round of open coding was conducted across the textbook corpus. This process generated 127 preliminary codes that captured recurring patterns related to sequencing, conceptual treatment, NOS representations, pedagogical supports, and student tasks. In the second stage, these initial codes were reviewed comparatively, merged where conceptually overlapping, and refined into a more focused coding structure. This process resulted in 16 analytical codes, which were then organized under the five broader dimensions of the analytical framework.

In the final stage, the full corpus was re-examined through this refined coding structure. The coded material was first analyzed within each country-specific textbook context and then synthesized across cases in order to identify convergences and divergences in the pedagogical representation of the periodic table. This cross-case comparison formed the basis for the findings presented in the subsequent section.

Although the analysis was interpretive in nature, it was guided by a structured coding framework in order to increase transparency and comparability across cases (Schreier, 2012). In this respect, the study combined exploratory engagement with the data and a progressively refined content-analytic framework rather than relying on either fully emergent or fully predetermined categories alone.

Trustworthiness

Several strategies were employed to enhance the trustworthiness of the analysis. First, all included textbooks were obtained from official and publicly accessible repositories, which supports transparency and allows the corpus to be independently verified. Second, the analysis followed an explicitly defined coding framework, making it pos-

sible to trace how interpretations were developed across the five analytical dimensions. Third, the coding structure was subjected to an inter-coder reliability check by both researchers, which yielded substantial agreement (Cohen's $\kappa = .82$). This result supported the internal consistency of the refined coding framework.

In addition, interpretations were grounded in direct textual and visual evidence from the textbooks wherever possible. Rather than making claims about classroom enactment or student learning outcomes, the study remained focused on the pedagogical representation of the periodic table within the selected textbook materials. This boundary was maintained in order to align the claims of the study with the scope of its data.

Research Results

Curricular Structure

Across the three textbook contexts, the periodic table is introduced and revisited through a layered structure rather than as a single isolated topic. However, the point of entry, the degree of continuity across grades, and the instructional role assigned to the topic differ across countries.

In the Ethiopian textbooks, the periodic table appears as a visible topic in Grades 7 and 9 under the title “Periodic Classification of the Elements,” and it is later extended in Grade 11 through its connection to atomic theory and periodic trends. Grade 10 does not revisit the topic as a standalone unit, although related chemical content draws indirectly on periodic ideas. This creates a pattern of recurrence with partial interruption rather than uninterrupted continuity.

In the Turkish textbooks, the progression is more indirect in the lower grades. Grade 7 establishes the conceptual background through the particulate nature of matter and atomic models, while the periodic system is addressed explicitly in Grade 8. The topic then reappears in Grades 9 and 11 with increasing theoretical detail, especially in relation to atomic structure and modern atomic theory. The sequence therefore moves from preparatory foundations to explicit treatment and later elaboration.

In the Indian textbooks, the periodic table is linked to atomic structure from Grade 9 onward and is later developed through Grade 11 and specialized further in Grade 12. In this context, the topic is embedded within a strongly cumulative structure in which earlier atomic concepts support later treatment of periodic law, electron configuration, and block chemistry.

Across the three textbook contexts, the findings indicate recurring treatment across grade levels, although the periodic table differs in how directly it is foregrounded and how tightly successive presentations are linked.

Conceptual Depth

All three textbook contexts show an increase in abstraction across grade levels, but they differ in the timing, density, and degree of specialization with which the periodic table is conceptually developed.

In the Ethiopian textbooks, conceptual progression begins with observable and descriptive aspects of periodicity. In Grade 7, periodic properties are introduced at a relatively accessible level, supported by simple shell-based representations and basic trend illustrations. In Grade 9, the treatment becomes more structurally grounded through modern electron-configuration notation and the classification of elements into s, p, d, and f blocks. By Grade 11, the explanation of periodic trends is extended through concepts such as effective nuclear charge and shielding effect, shifting the emphasis from identifying trends to explaining why they occur.

In the Turkish textbooks, conceptual depth develops through a staged progression from classification to theoretical explanation. In Grades 7 and 8, the emphasis is on foundational concepts such as atom, element, group, period, and the logic of classification, often supported by everyday analogies. In Grade 9, the periodic system is linked to shell structure and valence electrons through the Bohr model, and periodic properties are introduced qualitatively. In Grade 11, the treatment becomes more abstract through quantum numbers, orbitals, Aufbau, Pauli, and Hund principles, and selected deviations in periodic trends are explained by reference to theoretical constructs such as spherical symmetry.

In the Indian textbooks, the topic is developed through an early theoretical grounding followed by advanced extension. Grade 9 introduces atomic structure through shell-based explanations and the $2n^2$ rule, providing a foundation for later treatment of periodic classification. In Grade 11, the textbooks move to a more abstract level through orbitals, quantum numbers, and electron-configuration principles, explicitly linking the modern periodic

law to electronic structure. In Grade 12, the topic is extended further into specialized chemistry through the treatment of d- and f-block elements, lanthanide contraction, variable oxidation states, and related irregularities.

These findings show that conceptual depth increases in all three textbook contexts, but the progression is configured differently. Ethiopia moves from observable properties to structurally grounded explanation, Türkiye from classificatory logic to quantum-based interpretation, and India from early atomic theory to more specialized and advanced treatment of periodic-table-related chemistry.

Nature of Science

The representation of the NOS is visible in all three textbook contexts, although its continuity, explicitness, and degree of integration into the main content narrative vary across countries and grade levels.

In the Ethiopian textbooks, NOS is introduced through historical references, model development, and examples of predictive scientific reasoning. In Grade 7, the development of the periodic table is presented through the historical work of Mendeleev, including the prediction of undiscovered elements and the later confirmation of these predictions. This gives students access to science as a developing body of knowledge rather than a fixed set of facts. In Grade 9, the treatment continues through the shift from early atomic ideas to more modern electronic explanations, although NOS becomes less visible as a distinct focus. In Grade 11, elements of NOS reappear indirectly through discussions of electron arrangement and periodic behavior, but the explicit historical and epistemic framing is less sustained than in the earlier grades.

In the Turkish textbooks, NOS is represented mainly through the evolution of atomic models and the idea that scientific explanations change in light of new evidence. In Grade 7, students encounter a progression from Dalton to modern atomic theory, with attention to the limitations of earlier models. In Grade 8, the periodic system is connected to classification and scientific organization, while Grade 9 links the modern periodic law to atomic structure. In Grade 11, NOS remains visible through the continued use of model-based explanation and through explicit references to the development of scientific ideas. Across these grades, NOS is generally embedded within content explanation rather than developed as a separate historical narrative.

In the Indian textbooks, NOS is presented most explicitly through sequences of model revision, conceptual refinement, and evidence-based change. Grade 9 introduces atomic structure through successive model development, while Grade 11 strengthens this representation by linking the modern periodic law to electronic configuration and by showing why earlier classifications were revised. In Grade 12, NOS is less foregrounded as an independent theme, but it remains implicit in the treatment of irregularities, exceptions, and advanced chemical behavior. The Indian textbooks therefore present NOS most clearly when explaining why scientific models and classificatory systems are modified over time.

These findings indicate that all three textbook contexts include NOS-related elements, especially through historical development, model change, and the relationship between evidence and explanation. However, the visibility and continuity of these elements differ. In Ethiopia, NOS is more visible in early treatment but less sustained across later stages; in Türkiye, it is consistently present but often embedded within broader content explanation; and in India, it is most explicit in the treatment of scientific revision and theoretical development.

Pedagogical Tools

Pedagogical tools are widely used across all three textbook contexts to make the periodic table and related atomic concepts more accessible to students. However, the type, density, and instructional role of these tools vary across countries and grade levels.

In the Ethiopian textbooks, pedagogical tools move from simpler visual supports in the lower grades to more analytical representations in the upper grades. In Grades 7 and 9, color-coded periodic tables, basic diagrams, and familiar analogies are used to organize information and support initial understanding. In Grade 11, visual representation becomes more data-oriented, with graphs and trend-based displays requiring students to interpret patterns and anomalies rather than simply recognize them. The overall pattern suggests a shift from descriptive support toward more analytical visual engagement.

In the Turkish textbooks, pedagogical tools are characterized by the sustained use of analogies and everyday-life representations alongside increasingly formal scientific visuals. In the lower grades, concepts such as atomic structure and classification are frequently supported through concrete analogies that connect unfamiliar scientific ideas to familiar objects or experiences. In the upper grades, these analogical supports continue, but they are



supplemented by more formal diagrams, graphical representations, and model-based explanations. This creates a pattern in which everyday accessibility and formal abstraction coexist across grade levels.

In the Indian textbooks, pedagogical tools increasingly emphasize formal representation and data-rich explanation. Lower-grade materials introduce atomic structure and classification through diagrams and structured explanatory visuals, while the upper grades rely more heavily on tables, orbital representations, symbolic notation, and graphs. Compared with the other two contexts, the Indian textbooks place stronger emphasis on representational precision and analytical reading of visual information, particularly in the treatment of periodic trends and block chemistry.

A particularly clear example of cross-country variation in pedagogical tools can be seen in the representation of the Thomson atomic model (Figure 1). Although the underlying scientific content remains the same, the textbooks draw on different everyday analogies to support students' visualization of an otherwise unobservable model.

Figure 1

Comparative Analogical Representations of the Thomson Atomic Model in Selected Textbooks



Note. Textbook representations from Ethiopia (a), Türkiye (b), and India (c). Across the three contexts, the same scientific model is explained through different everyday analogies, illustrating variation in how abstract atomic structure is made pedagogically accessible to learners. Compiled by the authors from the selected textbooks.

These findings show that pedagogical tools in all three contexts function not only as visual supplements but as integral components of explanation. Across the textbooks, simpler organizational and analogical supports tend to give way to more formal and analytical representations, although the relative emphasis on everyday analogies, descriptive visuals, and data-rich graphics differs across countries.

Nature of Activities

The activities included in the textbooks show progression across grade levels in all three contexts, but they differ in the kinds of student engagement they prioritize and in the degree of analytical demand they place on learners.

In the Ethiopian textbooks, activities in the lower grades are generally structured to support recognition, comparison, and classification. Students are asked to identify periodic patterns, group elements, and relate simple visual information to basic chemical ideas. In the higher grades, the activities become more explanatory and predictive, requiring students to use electron configuration, periodic trends, and related concepts to account for observed behavior. The progression therefore moves from guided identification toward more concept-based explanation.

In the Turkish textbooks, activities also show a graded increase in complexity. In the lower grades, students engage with modelling, basic classification, and concrete representations of atomic structure. In Grade 8, activities linked to the periodic system continue this focus through grouping, matching, and interpretive tasks. In Grades 9 and 11, however, the activities increasingly require students to connect symbolic representations, atomic models, and theoretical explanations. Compared with the lower grades, the upper-grade activities involve more analytical interpretation and less purely descriptive engagement.

In the Indian textbooks, the activity structure places stronger emphasis on interpretation, data use, and theory-linked reasoning, especially in the upper grades. Lower-grade tasks establish familiarity with atomic structure and periodic classification, while Grade 11 and Grade 12 activities require students to interpret graphs, compare trends,

explain irregularities, and relate observed patterns to electron configuration and block structure. As the topic develops, student engagement becomes more tightly connected to abstract explanation and representational analysis. A cross-country reading of the activities suggests that all three textbook contexts include progression in activity design, but they differ in the dominant mode of cognitive engagement they promote. Ethiopia moves from guided recognition to explanatory use of concepts, Türkiye from modelling and classification to analytical interpretation, and India from structured introduction to increasingly data-based and theory-linked reasoning. To synthesize the findings presented across the five analytical dimensions, Table 3 provides a cross-country summary of the main similarities and differences identified in the textbook representations of the periodic table.

Table 3
Cross-Country Comparison of Textbook Representations of the Periodic Table

Analytical Dimension	Ethiopia	Türkiye	India
Curricular structure	Repeated treatment across grades with partial continuity through related chemistry topics	Indirect introduction followed by explicit treatment and later theoretical elaboration	Cumulative structure linked to atomic theory and later specialized chemistry content
Conceptual depth	Progression from observable properties to electron configuration and theoretical explanation of periodic trends	Progression from classificatory logic and qualitative explanation to quantum-based interpretation	Early theoretical grounding followed by advanced quantum treatment and specialized block chemistry
Nature of science	Historical examples and model change, with less sustained visibility in later grades	Model development and evidence-based explanation embedded within content teaching	Stronger emphasis on revision of models and evidence-based theoretical development
Pedagogical tools	Simple visuals and analogies in lower grades; more analytical graphics in upper grades	Sustained use of everyday analogies alongside increasingly formal diagrams and graphs	Greater reliance on structured visual explanation, symbolic notation, and data-rich representations
Nature of activities	Progression from recognition and classification to concept-based explanation	Progression from modelling and classification to analytical interpretation	Increasing emphasis on data interpretation and theory-linked reasoning

Discussion

This study examined how the periodic table is represented in selected official secondary-level textbooks from Ethiopia, Türkiye, and India across five analytical dimensions: curricular structure, conceptual depth, nature of science, pedagogical tools, and the nature of activities. Overall, the findings indicate that the periodic table is treated in all three textbook contexts as a topic that develops across grade levels rather than as a single self-contained unit. At the same time, the comparison revealed meaningful differences in how this development is organized, how conceptual depth is distributed, and how students are supported through representations and activities. These differences are not merely stylistic variations in presentation; rather, they may reflect deeper structural differences in curriculum traditions, educational priorities, and the pedagogical values embedded in each national textbook system. Understanding why these differences exist, and what they might mean for how students encounter scientific knowledge, is therefore as important as documenting that they exist.

One important implication of this finding is that the teaching of the periodic table in textbook contexts appears to depend on staged development rather than one-time presentation. This is consistent with the long-recognized view that the periodic table is conceptually demanding and that meaningful understanding requires more than memorizing symbols, groups, or periods (Chowdhury, 2022; Scerri, 2020; Suryelita et al., 2019). In the textbooks analyzed here, recurring treatment across grade levels appears to function as a way of distributing this complexity over time. However, the form of this recurrence differs. In some cases, the topic reappears as clearly visible unit, whereas in others it is developed more indirectly through related chemistry content. One possible reason for this difference may lie in the underlying curriculum model adopted in each context. A spiral curriculum approach, in which topics are revisited with increasing depth at each cycle, tends to foreground recurrence as an explicit design principle (Bruner, 1960). By contrast, a more linear or modular curriculum structure may treat the periodic table as a self-contained unit at each grade level, with less deliberate scaffolding across years. The variation observed



across the three textbook contexts suggests that these different organizational logics may shape not only when the topic appears, but also how meaningfully later treatment is connected to earlier learning. This suggests that continuity in textbook design is not only a matter of repetition, but also of how later treatment builds on earlier conceptual foundations.

The findings also point to variation in the way conceptual depth is constructed across textbook contexts. In all three countries, the treatment of the periodic table becomes more abstract over time, yet the timing and density of this progression differ. Ethiopia showed a movement from observable periodic properties toward more explanatory treatment based on electron configuration and periodic trends. Türkiye showed a progression from classificatory logic and qualitative explanation toward more explicit quantum-based interpretation in the upper grades. India, by contrast, linked atomic structure to the periodic table relatively early and extended the topic more strongly into specialized chemistry content in later grades. These differences do not necessarily indicate superiority or deficiency; rather, they illustrate alternative ways of distributing abstraction and specialization within textbook sequences.

The differences identified in the representation of the nature of science, pedagogical tools, and activity design further suggest that textbook variation is not limited to content coverage alone but extends to how scientific knowledge is made learnable. In all three textbook contexts, NOS-related elements were present, particularly through model development, scientific revision, and the historical transformation of classificatory systems. Recent textbook studies have similarly shown that representations of the periodic table may reflect broader historical and epistemic perspectives on the development of chemistry as a scientific discipline (Slabin, 2024). However, these elements were not equally visible or equally sustained across the textbook contexts. In some textbooks, NOS was more explicitly foregrounded through historical sequences and examples of theory change, whereas in others it appeared more indirectly within content explanations (Chiappetta & Fillman, 2007). A possible reason for this variation may relate to how explicitly NOS is incorporated as a curriculum goal in each national context. Where NOS is treated as a distinct learning objective rather than as an incidental byproduct of content teaching, it tends to be more consistently represented across grade levels and more deliberately integrated into explanation sequences. The finding that NOS visibility tends to decrease in later grades in some contexts, even as content complexity increases, suggests that content pressure may gradually displace epistemic goals in textbook design. This pattern is consistent with research showing that NOS integration in chemistry textbooks often remains superficial or inconsistent, particularly in upper secondary materials where content coverage demands intensify (Aydin & Tortumlu, 2015).

This is relevant because the periodic table is not only a classificatory chart but also a scientific construct shaped by revision, evidence, and conceptual reorganization over time. The extent to which this developmental character is made visible may influence whether students encounter the topic primarily as fixed information or as part of an evolving scientific enterprise.

A similar pattern can be observed in the use of pedagogical tools. Across all three contexts, the textbooks relied on visuals, analogies, diagrams, symbolic representations, and graphs to mediate understanding of abstract atomic and periodic concepts. Yet the comparative analysis showed that these tools were used with different emphases. In some cases, everyday analogies and accessible visual supports were especially prominent, while in others the representational environment became more formal, data-rich, and analytically demanding in the upper grades. One possible reason for this difference may relate to the pedagogical traditions and curriculum philosophies that shape textbook authorship in each context. The sustained use of everyday analogies in the Turkish textbooks, for instance, may reflect a deliberate instructional strategy rooted in the principle of moving from the concrete to the abstract, which has been emphasized in Turkish science education reform efforts. In contrast, the stronger reliance on formal symbolic notation and data-rich representations in the Indian textbooks may be partly explained by the demands of centralized examinations that reward precise symbolic reasoning and analytical interpretation of quantitative data. In the Ethiopian context, the gradual shift from descriptive visuals toward more analytical graphics across grade levels may reflect an attempt to progressively build representational literacy within a curriculum that must also account for varying levels of prior knowledge and resource availability across diverse school settings.

This finding supports earlier work showing that textbook representations are not neutral carriers of information, but active components of explanation that may shape how students approach scientific content (Mikk, 2000). In the case of the periodic table, such tools appear to play a particularly important role because the topic requires students to coordinate symbolic, structural, visual, and explanatory forms of knowledge at the same time.

The progression observed in activity design also strengthens this interpretation. Across the three textbook contexts, activities generally moved from more guided or descriptive engagement toward more analytical and explanatory forms of participation. However, the dominant mode of engagement differed. Some textbooks placed stronger emphasis on classification, modelling, and scaffolded conceptual transition, whereas others more clearly



foregrounded graph reading, pattern interpretation, and theory-linked explanation. A possible explanation for this difference may relate to the cognitive demands embedded in each national assessment culture. In contexts where examinations emphasize recall, recognition, and structured problem-solving, textbook activities may be designed primarily to rehearse these cognitive operations. Where assessments instead reward analytical reasoning, data interpretation, and theory application, activities may be structured to develop these more demanding forms of engagement progressively across grade levels. The stronger emphasis on data-based and theory-linked reasoning observed in the Indian textbooks, for instance, may partly reflect the cognitive demands of university entrance examinations that require students to apply conceptual knowledge to unfamiliar problems rather than reproduce memorized information. This suggests that activity design in textbooks is not purely a pedagogical decision but may also be shaped by the assessment structures within which textbooks are expected to prepare students. This suggests that the textbooks do not simply vary in how much activity they include, but in the kinds of cognitive work they invite students to do (Andersson-Bakken et al., 2020).

Taken together, the findings suggest that the pedagogical construction of the periodic table in textbooks involves more than the sequencing of chemistry content. Across the three contexts, the topic was organized through distinct patterns of abstraction, sequencing, representation, and activity design. These patterns show how textbooks transform scientific concepts into learnable school knowledge by deciding how much abstraction is introduced, how scientific knowledge is framed, what kinds of representations are used, and what forms of learner participation are expected. Importantly, these decisions do not appear to be arbitrary or purely content-driven. Rather, they seem to be shaped by a combination of curriculum tradition, assessment culture, and the educational priorities of each national context. This implies that textbooks should not be read merely as containers of scientific content, but as culturally and institutionally situated artifacts that reflect particular assumptions about what scientific knowledge is, how it should be organized for learners, and what kinds of engagement with that knowledge are most valued.

Conclusions and Implications

This study compared how the periodic table is represented in selected official secondary-level textbooks from Ethiopia, Türkiye, and India across five analytical dimensions: curricular structure, conceptual depth, nature of science, pedagogical tools, and the nature of activities. The findings showed that, in all three textbook contexts, the periodic table is treated as a topic that develops across grade levels rather than as a single isolated unit. However, the comparison also revealed important differences in how this development is organized, how abstraction is distributed, how scientific knowledge is represented, and how students are invited to engage with the topic.

The main contribution of the study lies in demonstrating that textbook representations of the periodic table vary not only in content coverage but also in the pedagogical logic through which the topic is made learnable. Across the selected textbooks, differences were visible in the continuity of topic progression, the balance between descriptive and explanatory treatment, the visibility of the nature of science, the use of analogies and visual tools, and the kinds of cognitive engagement encouraged through activities. In this respect, the study offers an analytical structure for future comparative textbook research in chemistry education and shows how a common scientific topic may be differently transformed into school knowledge across national contexts.

The findings also suggest several implications for textbook development. First, textbook sequences may be strengthened when conceptual progression across grade levels is made more explicit. Repetition alone may be insufficient unless later treatment clearly builds on earlier foundations and extends them in a recognizable way. Second, pedagogical supports such as analogies, diagrams, graphs, and symbolic representations may be more effective when they are integrated into explanation rather than added as isolated visual or illustrative elements. Third, activities may better support conceptual understanding when they move beyond recognition and routine classification to include interpretation, explanation, data use, and representational reasoning. These implications should not be understood as universal prescriptions, but as comparative insights drawn from the different patterns visible in the selected textbooks.

At the same time, the findings should be interpreted within the scope of the data. The study was limited to selected official textbooks and did not examine classroom enactment, teacher mediation, or student learning outcomes. Therefore, it does not claim that textbook representations directly determine how the periodic table is ultimately taught or learned in practice. Future research could build on these findings by bringing textbook analysis into dialogue with curriculum documents, policy texts, classroom observations, or teacher interviews. Extending the comparative framework to other national contexts or to other conceptually demanding chemistry

topics could also contribute to a more systematic understanding of how scientific knowledge is pedagogically constructed across different educational traditions.

Declaration of Interests

The author(s) declared no conflicts of interests.

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