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Evaluating the Integration of Critical Thinking Skills in Biology Instruction: A Qualitative Content Analysis of the Grade IX Pakistani Textbook

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This study aimed to evaluate critical thinking in the Grade IX biology textbook. Qualitative content analysis was employed to explore the elements fostering critical thinking skills development in the textbook. Textbooks were selected using a purposive sampling technique. Qualitative content analysis was used for the textbook analysis with the facilitation of NVivo 15. The different strengths include the organization of learning objectives, visual presentation, and contextual application of biological concepts. Moreover, significant limitations were found, including lower-order skills assessment questions, linear scientific methodology, prescriptive real-world application, content-privileged memorization, and minimal epistemological discussion of competing scientific perspectives. This suggests that, as the textbook provides foundational knowledge for biology, there is insufficient scaffolding for critical thinking skills development through evidence-based evaluation, scientific argumentation, and independent enquiry. These findings contribute to curriculum development by highlighting the need for biology educational material to balance content acquisition with authentic opportunities for critical thinking skills development through higher cognitive engagement and enquiry-based learning methods.

1. Introduction

In today's fast-paced world, where everything changes rapidly, it is important now more than ever to ensure that students know how to think critically. These skills have become significant when navigating things academically, professionally, or personally (Dwyer et al., 2014). Therefore, the education system has moved towards making their primary goals (Kivunja, 2015). In science education, developing critical thinking skills has become increasingly important because they are the foundation for scientific enquiry, problem-solving, and innovation (Vieira et al., 2011).

Secondary school science education is a natural place for students to start building these skills, as it is where they will be introduced to everything about the world around them (Siribunnam et al., 2014). During this stage of their lives, they are exposed to a plethora of new concepts, theories and practices that require higher-order thinking. Among all core disciplines within the science curriculum, biology offers some of the greatest opportunities for students to develop and apply critical thinking skills. The study of anything having to do with living organisms' interactions and what makes them all necessitates analytical reasoning, problem-solving, and evidence-based decision-making (Power et al., 2019).

When it comes time for teachers to put their knowledge of teaching into action, textbooks become one of their most crucial tools in secondary school classrooms (Chiappetta & Fillman, 2007). The content structure and pedagogical approaches utilized in these books can either help or hinder students' cognitive development, depending on how well-developed each aspect is (Eskin & Ogan-Bekiroglu, 2013). Thus, understanding a textbook's potential impact on students' cognitive growth is impossible without first analyzing whether it promotes critical thinking (Ennis, 2018).

Science education focuses on the development of critical thinking as an important skill in students. Yacoubian (2020) reflects this as a foundational pillar for developing future citizens with scientific knowledge. Questions related to critical thinking and the capability to frame these questions are vital in science education (Demir, 2015). In this setting, critical thinking is associated with problem-solving, discussion, debate, evaluation, argumentation, and rigorous testing (Osborne, 2014). Moreover, rote memorization is an important problem in the development of knowledgeable, well-rounded, and critical-thinking students. Critical thinking is an important skill of the twenty first century that has been focused on in previous literature (Giri & Paily, 2020; Jamil & Muhammad, 2019; Naseer et al., 2022; Ngozi & Hyacinth, 2021).

1.1 Objectives of the Study

1. To analyze the Grade IX biology textbook regarding the incorporation of elements that promote critical thinking.
2. To identify the strategies used in the Grade IX biology textbook to foster critical thinking.

2. Literature Review

Researchers have investigated how biology textbooks develop essential cognitive abilities among secondary school students, both internationally and in the Pakistani context. Various analytical methods have been used in international research studies to analyze textbooks. Liu (2023) studied how Chinese mathematics instructors think about critical thinking and their work as educators. Liang and Cobern (2013) applied the benchmarks from the American Association for the Advancement of Science (AAAS) to examine Chinese high school biology textbooks and concluded that they met these standards in most areas of evolution. According to Chiappetta and Fillman (2007), five U.S. high school biology textbooks maintained equilibrium when discussing science literacy dimensions.

Zorluoglu et al. (2020) studied Turkey's grade IX chemistry textbook using revised Bloom's taxonomy, which showed a focus on conceptual together with factual content representation. The development of critical thinking in biology has been studied in various studies. Sabri (2019) research at Tufts University demonstrated that enquiry-based learning strategies produced minimal success in teaching biology in UAE classrooms. The combination of project-based learning with self-regulation strategies was evaluated in Nigerian biology education by Ibitoye (2021). Hsu et al. (2024) analyzed problem-solving methods used by undergraduate students in biology education, as Quitadamo et al. (2008) showed that community-based inquiry enhanced critical thinking in general biology programs.

According to Pakistani research, support for higher-order thinking in textbooks is insufficient. Bhatti et al. (2015) established that biology curriculum content adopted mostly lower-order thinking skills, which focused primarily on knowledge acquisition and understanding. According to Tufail et al. (2016), biology textbooks at the higher secondary level fail to provide proper educational support for critical thinking and creativity, among other 21st-century skills. Ali et al. (2017) stated that general science textbooks for grades 6-8 presented insufficient material related to higher-order thinking questions and activities. Several studies in Pakistan have examined how critical thinking progresses in academic subjects. Textbook analyses have been conducted based on biology textbooks with respect to life skills and critical thinking (Jamil, Jabeen, & Moin, 2024; Jamil, Mehmood, & Saleem, 2024) and biology curriculum analysis (Jamil, Bokhari, & Rafiq, 2024). Similarly, a recent study evaluated the 4Cs (critical thinking, communication, collaboration, and creativity) with an emphasis on critical thinking skills development (Jamil et al., 2025). In these studies, critical thinking has been suggested to be focused on keeping in view the 21st century skill.

3. Research Methodology

The current research used qualitative content analysis to evaluate the grade IX Biology textbook (2025) based on the National Curriculum (2023) regarding the development of critical thinking among science students. It was the most suitable method as it systematically examines large text to determine key themes, patterns, and underlying meanings (Kyngäs, 2020) and is used to analyse educational material, such as textbooks, to gather knowledge of content and assess

learning outcomes (Mayring, 2014). A purposive sampling technique was used to select the biology textbook for grade IX, downloaded from https://pctb.punjab.gov.pk/E-Books. This technique was applied based on specific criteria and features (Etkina et al., 2006). Qualitative content analysis was facilitated by NVivo 15 software (Jackson et al., 2019), which helped organise all data and effectively perform analysis concerning textual information (Silver & Woolf, 2018).

4. Findings of the Study

After a comprehensive analysis of the biology textbook for Grade IX (2025-26), several key findings emerged regarding the incorporation of critical thinking elements. The textbook provides fundamental biological knowledge with occasional opportunities for critical thinking development, although these are not consistently implemented throughout the book. The content is predominantly fact-oriented, with a strong emphasis on conceptual understanding and limited emphasis on enquiry-based learning or the evaluation of competing ideas. While the textbook excels at explaining biological concepts and processes, it offers fewer opportunities for students to engage in higher-order thinking tasks such as analysis, evaluation, and creation. The following sections detail the specific findings with supporting evidence from textbooks.

Objective 1: Incorporation of Critical Thinking Elements in the Biology Textbook Grade IX

- ***Content Structure and Organization***

The textbook employs a structured approach that systematically builds biological knowledge but tends to present information rather than guiding discovery. The learning objectives are clearly stated at the beginning of each chapter, and key points are summarized at the end, facilitating review. However, the organization primarily supports content acquisition rather than critical inquiry.

For example, the following statements from the textbook provide this evidence.

"Define Biology.
The Holy Quran instructs to reveal the study of life.
Define major fields of Biology as Botany, Zoology, and Microbiology." (p. 5)

"In this chapter, we will explore the fascinating world of cells, uncovering their intricate structures and vital roles in the living world". (p. 41)

"Biology is the study of life. It deals with the structure of living things and the processes that occur in them." (p. 21)

- ***Questioning Techniques***

The textbook includes various types of questions at the end of each chapter, ranging from multiple-choice questions to short and detailed responses. While some questions promote critical thinking, particularly in the "Inquisitive Questions" section, the majority emphasize recall and comprehension rather than higher-order thinking skills. The following are a few examples from the textbook.

For demonstrations and recall-level questioning, the following is described:

"Which branch of Biology focuses on the study of the structure and function of cells? a) Cytology b) Molecular biology c) Histology d) Ecology" (p. 22)

Higher-order thinking questions are narrated as follows in the Inquisitive Questions section of Chapter 4:

"What role might mistakes in the cell cycle checkpoints play in the emergence of cancer?" (p. 78)

The following example from the text encourages a comparative analysis in the Inquisitive Questions section of Chapter 10.

"How do asexual and sexual reproduction contribute differently to genetic diversity of plant populations?" (p. 166)

- ***Scientific Inquiry and Investigation***

The textbook introduces the scientific method and illustrates its application through examples, such as malaria research. However, it provides limited opportunities for students to apply the scientific method through their own investigations or to critically evaluate scientific claims. The following text provides evidence from Chapter 1 of the 1.6 Scientific Method section.

"Scientists take specific steps while doing scientific work or research. These steps are called the scientific method. For biological research, these steps are called biological method." (p. 14)

The following text from Chapter 1 presents a simplified view of scientific inquiry that does not emphasize the tentative nature of this knowledge:

"In a successful experiment one hypothesis is proved correct and the alternate hypotheses are proved incorrect. Incorrect hypotheses are rejected and the proved one is accepted." (p. 16)

Moreover, it is narrated as follows in the description of the hypothesis in Chapter 1:

"Biologists thought on these observations and discoveries and developed a hypothesis i.e. 'Plasmodium is the cause of malaria'." (p. 18)

- ***Real-World Applications***

The textbook relates biological concepts to real-world contexts, including careers, medical applications and environmental issues. However, these applications are typically presented as information rather than problems for students to solve or evaluate. The following examples from the textbook provide evidence of this aspect. In section 1.3, Careers in Biology, of chapter 1, the following words are narrated.

"The students of Biology get a comprehension of the various phenomena of life. After their FSc with Biology, they can select further studies for diverse careers, for example: 1. Medicine and Surgery..." (p. 9)

The use of enzymes in different industries (Chapter 7) is described as follows:

"Enzymes have extensive applications in various industries. For example; Food industry: Enzymes that break starch into simple sugars are used in production of white bread, buns, and rolls." (p. 111)

The Importance of Biodiversity (Chapter 2) is described as follows:

"Biodiversity provides many essential services for humans and the planet. Here are some key benefits of biodiversity. Ecosystem Stability: Biodiversity helps to maintain the balance of ecosystems." (p. 26)

- ***Conceptual Understanding vs. Rote Learning***

The textbook balances conceptual understanding with factual information, although it sometimes emphasizes memorization over critical analysis. Visual aids and diagrams help illustrate complex concepts, but presentations often focus on what to know rather than how to think about biological phenomena. For example, the following text presents information that must be memorized rather than concepts that must be explored.

"Morphology is the study of the form and structure of organisms. Morphology studies the outward appearance (shape, colour, pattern, etc.) as well as internal structures, like organs." (p. 6)

In the lock and key model, the conceptual explanation is enhanced with a diagram, as in the following text.

" According to it, the active site of enzyme has a fixed structure. The substrate molecule fits precisely into it to form an enzyme-substrate complex." (p. 112)

The explanation of a biological process is described in Chapter 4 (Cell cycle) as follows:

"The cell follows a regular series of events called the 'cell cycle' during its life. This series includes stages of growth, preparation, and cell division." (p. 63)

- ***Multiple Perspectives and Critical Analysis***

The textbook occasionally presents the historical development of scientific ideas or alternative models but rarely encourages students to evaluate competing explanations or understand the tentative nature of scientific knowledge. For example, in the 2.4 History of classification (Chapter 2), it is narrated as follows:

"The history of the classification system can be traced back to ancient times. The Greek philosopher Aristotle (384-322 BC) was the first who classified organisms into two groups i.e., plants and animals." (p. 29)

The historical context for the lock-and-key model is described as follows:

"This model was proposed by a German chemist Emil Fischer in 1894. According to him, active site of enzyme has a fixed structure." (p. 112)

Another alternative model is presented as follows:

"Induced Fit Model: This model was proposed by an American biologist Daniel Koshland in 1958. According to this model, the active site of enzyme is not rigid." (p. 113)

Objectives 2: Identification of strategies used in the Biology Textbook Grade IX to foster critical thinking

Despite its limitations, the textbook employs several strategies that could potentially develop critical thinking skills, including case studies, visual representations, comparative analysis, application questions, and historical context. The following are some examples from the text related to these aspects.

- ***Scientific Reasoning***

An example of scientific reasoning in the malaria case study is narrated as follows.

"When biologists considered these observations, they thought that Plasmodium was not in the marsh water." (p. 18)

- ***Comparative analysis***

The comparative analysis of cell division types is described as follows.

"Mitosis occurs during development, growth, cell replacement, regeneration and asexual reproduction" (p. 76)

Meiosis maintains the chromosome number in next generation by making haploid gametes. Meiosis produces variations in next generations." (p. 76)

- ***Application questions***

The application question requiring deeper analysis is narrated in the following text (Chapter 8, Inquisitive Questions).

"How does the structure of ATP enable it to store and release energy efficiently?" (p. 132)

- ***Historical context***

The historical context for classification systems is narrated as follows:

"In 1866, the German zoologist Ernst Hackel proposed a third kingdom i.e., Protista for Euglena-like organisms." (p. 30)

These findings indicate that while the Grade IX biology textbook includes some elements that support critical thinking development, there remains significant room for improvement in promoting higher-order thinking skills, inquiry-based learning, and scientific argumentation. The textbook establishes a solid foundation of biological knowledge but could better incorporate opportunities for students to analyze evidence, evaluate competing claims, and construct their own scientific explanations in the future.

4.1 Discussion

The current Grade IX biology textbook covers all the biological content or is too comprehensive, but the approach to develop critical thinking is not consistent, and most times, it is limited. The textbook design presents an organizing structure of the book, which has stated learning objectives and summarized key points consistent with the established principles for designing textbooks (Khine, 2013). However, Osborne (2014) calls out the continuing divide science instruction draws between content coverage and the development of scientific thinking as the absolute emphasis on content acquisition instead of inquiry. Similar to the findings of Bhatti et al. (2015), who also revealed a similar inclination towards lower-order thinking skills in Pakistani biology curriculum materials, this content-heavy approach is utilized.

A positive element in terms of questioning techniques is that some of the higher-order questions are present in the "Inquisitive Questions" section. Nevertheless, such questions of predominately recall and comprehension are consistent with Ali et al. (2017) findings regarding the absence of higher-order questions in Pakistani science textbooks. This imbalance mirrors the ‘paradox of recent science training’ as described by Toledo and Dubas (2016), where training and textbooks emphasize the development of critical considerations, whereas assessment focuses on recall.

The examples that the textbook uses to portray scientific inquiry are useful models of

thinking that help to paint a picture of scientific inquiry. However, presenting the scientific method as a linear, systematic process rather than an iterative, creative effort contradicts the contemporary understanding of authentic scientific inquiry. According to Yacoubian (2020), because of the nature of science, teaching the nature of science through a critical thinking approach needs to highlight the tentative character of scientific knowledge as well as the role of creativity in scientific investigation. Chamany et al. (2008) highlight the fact that biological concepts can only be understood if they are connected to real-world contexts, and the textbook does just that.

Nevertheless, these applications tend to be shown to students and not as problems for them to solve. However, this approach restricts the use of Kuhn (2010) terminology of 'authentic problem solving' because students are only applying scientific knowledge to deal with questions. Similar limitations in the application of 21st century skills in Pakistani biology textbooks were found by Tufail et al. (2016). The balance of conceptual understanding and rote learning in the textbook either provides some provision for conceptual development through visual aids and diagrams or is inadequately provided.

However, the textbook presents multiple perspectives and the historical development of scientific ideas, thus providing a foundation for the CT. Nevertheless, as Osborne (2014) maintains, carefully cultivating scientific reasoning necessitates specific opportunities to rate various explanations and comprehend the epistemological basis of such knowledge. The textbook relies on several strategies to develop critical thinking skills, such as case studies, visual representations, and comparisons. These strategies are in line with those suggested by Rizka et al. (2024) as being educationally effective in developing critical thinking. While this is beneficial, implementation in a classroom setting where critical inquiry is encouraged and rewarded to some degree is crucial for their effectiveness (Marin & Halpern, 2011).

However, this study reveals the contradiction between content coverage and critical thinking opportunities, which remains a challenge for the sharing of knowledge with the development of cognitive skills in science education (Zohar & Dori, 2003). Textbook development in Pakistan should focus more on integrating content with more effective authentic opportunities for scientific reasoning and inquiry (Jamil, Jabeen, & Moin, 2024), as Pakistan places the quality of scientific reasoning and inquiry as one of their significant schooling destinations.

5. Conclusion

The study revealed significant discrepancies between comprehensive content coverage and opportunities for fostering critical thinking. Although the textbook is well-organized and features strategic visual aids and contextual applications of biological concepts, it inadequately promotes higher-order cognitive engagement. The predominance of lower-order assessment questions, a straightforward presentation of scientific methods, real-world applications that are more prescriptive than investigative, an emphasis on memorization rather than conceptual understanding, and limited exploration of diverse scientific perspectives collectively impede the development of students' critical thinking skills. This study contributes to curriculum development discussions by identifying specific areas for enhancement, particularly the need for more inquiry-

based learning methods, clear opportunities for scientific argumentation, and discussions on the nature of science. Future biology textbooks should intentionally support critical thinking by incorporating well-crafted questions, investigations, and problem-solving activities that engage students in authentic scientific reasoning while ensuring comprehensive content coverage.

5.1 Recommendations

- Revise assessment questions to incorporate a higher proportion of tasks focused on analysis, evaluation, and creation, thereby engaging students with biological concepts at advanced cognitive levels.
- Modify the presentation of scientific methodology to highlight its iterative and creative nature by including examples that demonstrate how scientific understanding evolves through the repeated testing and refinement of ideas.
- Convert prescriptive real-world applications into investigative case studies that require students to apply biological knowledge to solve authentic problems, particularly those relevant to the Pakistani context.
- Integrate explicit opportunities for scientific argumentation, enabling students to evaluate competing explanations, analyze evidence, and construct reasoned arguments about biological phenomena.
- Enhance content explanations with guided inquiry activities that encourage students to discover concepts through structured investigations rather than passive information reception.

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