Critical Thinking Skills Development for 21st Century: An Analysis of Biology Curriculum (2006)

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Abstract

Critical thinking has become an important skill of the 21st century to cater for complex challenges. The current study aimed to analyze the curriculum of biology (2006) to explore the critical thinking skills addressed in the document. The curriculum document was selected through purposive sampling technique. To do the document analysis, thematic analysis was used with the facilitation of NVivo 12 software that examined the curriculum's aims and objectives, importance of critical thinking in the document, pedagogy, and assessment techniques suggested for the development of critical thinking. According to the findings of the study, the document explicitly addresses critical thinking in aims and objectives section. It also focuses on evidence, rational thinking, and intellectual honesty. Moreover, the suggested pedagogy is open ended questions, inquiry-based learning, concept mapping, and dialogue for the development of critical thinking skills among students. For the development of higher order thinking skills, a substantial weightage is allocated to alignment of the curriculum's goals. However, the study also identifies potential areas for improvement, such as providing more explicit guidance on integrating critical thinking across the curriculum and offering specific examples of activities and assessments that promote critical thinking. The findings suggest that while the curriculum lays a strong foundation for critical thinking skills development, its effective implementation relies on teachers' capacity to translate these intentions into classroom practice.

Keywords: *critical thinking, Biology curriculum, 21st-century skills, qualitative content analysis, NVivo 12*

Introduction

In today's rapidly changing world, critical thinking skills are essential for success in personal, academic, and professional life. The ability to analyze, evaluate, and make informed decisions is crucial for navigating the complexities of the 21st century (Higgins, 2015). Education plays a vital role in developing these skills, and curricula should be designed to foster critical thinking among students. The exponential growth of information in the digital age necessitates the ability to critically discern and process information effectively (Zhang, 2018).

Critical thinking is defined by different authors. Mendelman (2007)) defines it as the skills of inference, analysis, evaluation, and decision-making. According to Cottrell (2017), it is a cognitive activity involving attention, judgment, and selection. In the view of Paul and Elder (2019), it is a vehicle that educates the human mind. Similarly, Facione et al. (2020) describe it as inference, interpretation, evaluation, explanation, and self-regulation. In the previous literature, the most used definition is the art of analyzing and evaluating (Paul & Elder, 2019) and reflective and reasonable thinking focused on determining what to believe or do.

Critical thinking has been considered an essential skill of 21st-century skills, critical thinking is considered essential (Bialik et al., 2015). For the teaching-learning process it should be integrated due to its significance in both academic and overall life (Dwyer et al., 2014). Critical thinking can guide learners in finding solutions to social problems by acquiring and critically evaluating information (Dwyer et al., 2014). In an information-rich society, learners need the ability to compare and evaluate knowledge critically considering their understanding.
Science education places particular emphasis on critical thinking as a fundamental skill. Yacoubian (2020) considers it a foundational pillar for fostering scientific knowledge and developing future citizens. Critical questioning and the ability to formulate questions are crucial aspects of science education (Demir, 2015). In this context, critical thinking is linked to problem-solving, debate, discussion, argumentation evaluation, and rigorous testing (Osborne, 2014). However, rote memorization poses a significant obstacle to the development of knowledgeable, well-rounded, and critically thinking students.

Various techniques for developing critical thinking skills have been suggested in the literature, including questioning, problem-solving, inquiry-based teaching (Orlich et al., 2012),

cooperative/collaborative learning, conversation, group discussion, and debate (Fung, 2014; Stanley, 2017).

Biology, as a discipline, plays a vital role in understanding the complexities of life and the natural world. It encompasses a wide range of topics, from the study of molecules and cells to ecosystems and global environmental issues (Reiss, 2022). In the 21st century, the field of Biology has become increasingly interdisciplinary, with connections to other sciences, technology, and society. So, the education of Biology should not provide only a foundation of knowledge, but critical thinking skills are also necessary for this subject.

Objective of the study

The following was the objective of the current study:

1. To analyze the curriculum of Biology for grades IX-X about the critical thinking skills development at the secondary level.

Review of the Literature

Critical thinking is a topic of interest for researchers and teachers with a focus on its importance as an important skill for the twenty-first century. For the subject of Biology, CT is an essential skill for decision-making and application of knowledge in real-life contexts. Several studies highlight the importance of critical thinking in the subject of Biology. In the view of Vieira et al. (2011) CT is an essential skill for the students to be engaged in scientific knowledge. In the same way, Yacoubian (2020) also focuses on the role of critical thinking in the development of scientific literacy and the preparation of students for the challenges of the 21st century. In this fast-changing world, where scientific knowledge is constantly growing, CT skills enable students to adapt and apply their knowledge to new situations (Dwyer et al., 2014).

Critical thinking has been focused on in Biology by different scholars as in the view of Chowdhury (2016), through critical thinking interest is developed among the students in other subjects such as physics, chemistry, and technology. CT in Biology has become more important in the 21st century. Exploring critical thinking in curriculum development is an important aspect of Biology focusing on different aspects of critical thinking. Yacoubian (2020) analyzed the Lebanese Biology curriculum with findings that incorporation of CT elements like problem solving and inquiry-based learning, students learn more explicitly through instructions as well as critical thinking.

Some findings are of the view that the curriculum of Biology always may not used for the development of critical thinking development as in the view of Marthaliakirana et al. (2022), more explicit integration is needed of critical thinking skills in Biology. There should be a clear alignment between assessment and learning outcomes of the curriculum. Moreover, different instructional strategies have been seen as effective for the development of critical thinking in Biology. According to the meta-analysis conducted by Abrami et al. (2015), about instructional interventional designs for the development of critical thinking skills. It was revealed that explicit instructions like collaborative learning, practice, and feedback were seen to be the most effective for the development of critical thinking skills. In the same way, Vieira et al. (2011) highlighted the importance of problem solving and inquiry-based learning to foster critical thinking in the Biology classroom.

There have been explored other instructional strategies for the promotion of CT in Biology like case-based learning, argumentation (Heng & Sol, 2021), and technological usage to enhance learning environments. All these strategies are used for students' engagement, to make them active learners, for their meaningful learning experiences, for analyzing the information, making judgments, and evaluating evidence. The effectiveness of these instructional strategies depends on the ability of teachers for a supportive learning environment and provide suitable scaffolding and feedback. Teachers can play an important role in developing CT skills as well as opportunities for the students to practice these skills as well (Fernández-Arias et al., 2022).

In the Pakistani context, different current studies explore critical thinking development in the Pakistani education system, especially in science and social studies curriculum and teaching practices (Jamil, 2021; Jamil et al., 2023; Jamil & Muhammad, 2019; Jamil et al., 2021a, 2021b; Naseer et al., 2022). The main objectives of these studies involved evaluating teachers' perceptions and observed practices associated with critical thinking teaching (Jamil et al., 2023; Jamil et al., 2021b); analysing the existence of critical thinking thoughts in educational policies and curriculum (Jamil & Muhammad, 2019); and assessing critical thinking skill development opportunities in textbooks. Major findings revealed that while teachers and policies espoused critical thinking as an important instructional goal, actual teaching practices and curricular content did not effectively promote critical thinking skills. For example, science lessons emphasized rote memorization over higher-order analysis (Jamil et al., 2021b), and social studies

textbooks presented more factual information than conceptual analysis or evaluative tasks (Naseer et al., 2022).

The recent study aimed to explore critical thinking skills development incorporated in the Biology curriculum (2006). Through analysing the aims and objectives, pedagogy, and assessment practices for fostering CT through described importance in the document. The study findings will provide significant insight for different stakeholders like teachers, policymakers, curriculum developers and researchers to enhance CT skills development in the subject of Biology and to make the critical thinkers for the twenty-first century.

Research Methodology

This study employed a qualitative content analysis approach (Kyngäs, 2020) to examine the Biology curriculum (2006) in depth. Purposive sampling was utilized to select the curriculum document, as the research aimed to analyze its potential for developing critical thinking skills (Patton, 2014). This sapling technique was used in the current study as it provides a complete understanding of the curriculum document (Zikmund et al., 2013). For the data analysis, NVivo 12 software was adopted being a facilitator, which is the most suitable software for data management of large text documents (Bazeley & Jackson, 2019). In the view of Bazeley and Jackson (2019), this software is the most appropriate one due to its different tools that address the research objectives from several sources. For the data analysis through NVivo, there were four steps, that are data importing, data coding, framework matrices creation, and findings reporting (Bazeley & Jackson, 2019). So, the Biology curriculum was imported into NVivo in the format of PDF. The relevant sections are then coded as nodes and child nodes (Miles, 2020). Moreover, these coding units were then condensed and summarized to get further deeper understanding of the meaning of the text (Bazeley & Jackson, 2019).

Findings of the Study

1. Critical Thinking in Aims and Objectives

Critical thinking has been discussed in the aims and objectives section highlighting the rationality, evidence, and intellectual honesty for the development of scientific learners depending on logical reasoning with evidence and decision-making skills. The capability to apply biological understanding to real-life problems and approach them rationally is a key critical thinking skill that the curriculum seeks to cultivate.

In the curriculum, developing *"respect for evidence, rationality, and intellectual honesty" as one of the aims* (page 8). It also indicates developing students' *"ability to apply biological understanding to appropriate problems (including those of everyday life) and to approach those problems in rational ways"* (page 8).

In the Standards section, Standard 2a states *"Students will be able to display a sense of curiosity and wonder about the natural world and demonstrate an increasing awareness that this has led to new developments in science and technology."* The related benchmarks include *"Generate scientific questions about the living world based on observation" and "Evaluate the strengths and weaknesses of claims, arguments or data" (pg. 12-13).* Generating questions and evaluating claims and arguments are key critical thinking skills.

In the Glossary, higher-order terms that relate to critical thinking are defined, such as:
- *Discuss: "requires the candidate to give a critical account of the points involved in the topic."*
- *Predict: "implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information."*
- *Deduce: "implies that some supporting statement is required (e.g. reference to a law/principle, or the necessary reasoning is to be included in the answer)." (pg. 93-94)*

2. Importance of critical thinking

The curriculum's emphasis on reasoning and conceptual grasp highlights the significance it places on critical thinking. By stating that the process of acquiring knowledge is more important than the facts themselves, the curriculum shifts focus from rote memorization to the development of analytical and evaluative skills. This approach recognizes that in the rapidly evolving field of Biology, the ability to think critically and adapt to new information is more valuable than simply accumulating a large body of static knowledge.

The curriculum emphasizes *"reasoning and conceptual grasp at every stage"* (page 5). It states that *"The process by which factual knowledge can be acquired is more important than the facts themselves"* (page 92). This highlights the importance placed on developing students' critical thinking and reasoning skills.

3. Pedagogy/teaching methods suggested for critical thinking development

The suggested pedagogies and teaching methods aim to create a learning environment that fosters critical thinking. Inquiry-based teaching strategies encourage students to ask questions,

formulate hypotheses, and seek evidence to support their conclusions. This approach mirrors the scientific process and helps students develop critical thinking skills through active engagement with the subject matter. Encouraging dialogue and discussion among students allows them to articulate their ideas, consider alternative perspectives, and refine their thinking. The use of open-ended questions in textbook exercises challenges students to think beyond simple recall and apply their knowledge to novel situations. Concept mapping helps students organize information, identify relationships between ideas, and integrate new knowledge with existing understanding, promoting deeper learning and critical thinking.

The curriculum suggests inquiry-based teaching strategies where possible (page 90). It recommends providing opportunities to *"refine ideas through dialogue with others"* (page 90). Open-ended questions that *"encourage students to think critically and creatively"* are recommended in textbook exercises *(page 87).* Concept mapping is suggested to relate new information to existing knowledge (page 87).

4. Assessment for critical thinking

The evaluation strategy's high weightage for higher-order thinking skills (analysis, evaluation, synthesis, application) indicates the curriculum's commitment to assessing critical thinking. By moving beyond mere recall of facts and emphasizing the application of knowledge and reasoning skills, the assessment strategy aligns with the curriculum's goals of developing critical thinkers. The recommendation for open-ended questions in assessments provides opportunities for students to demonstrate their ability to analyze, evaluate, and synthesize information. The focus on assessing scientific understanding and reasoning over factual knowledge reinforces the importance of critical thinking in the study of Biology.

In the Assessment and Evaluation section, more emphasis is recommended on *"Assessing scientific understanding and reasoning" rather than just scientific knowledge (pg. 84).* Understanding and reasoning require critical thinking.

The evaluation strategy allocates 85% weightage to *"Knowledge, Comprehension, Analysis, Evaluation, Synthesis, Application"* (page 83). Open-ended questions are recommended in textbook exercises to develop critical thinking (page 87). More emphasis is recommended on *"Assessing scientific understanding and reasoning"* compared to just scientific knowledge (page 84).

Discussion and Conclusion

Discussion

The current study findings highlight the significance of CT skills development incorporated into the Biology curriculum IX-X (2006). As per the findings of the study, there are significant highlights of critical thinking regarding aims, pedagogy and suggested assessment mechanisms. These findings are linked with the development of cognitive significance for 21st-century skills specifically critical thinking (Bill et al., 2020; Boa et al., 2018). Furthermore, the curriculum focused on conceptual understanding and reasoning instead of only rote memorization since reasoning and conceptual understanding focus on CT skills development (Saavedra & Opfer, 2012). To acquire the knowledge of facts, the curriculum aims to develop an ability for the analysis, evaluation, and application of information in new situations (Geisinger, 2016). Moreover, the pedagogy discussed and suggested is dialogue, open-ended questions, inquiry-based learning, and concept maps that are aligned with curriculum objectives to foster critical thinking skills (Abrami et al., 2015). The usage of these approaches is significant for the engagement of the students in an active way for the scientific process that encourages them to question, formulate hypotheses, seek evidence, and draw conclusions (Pedaste et al., 2015; Zion & Mendelovici, 2012). Through the development of discussion and dialogue practices, the curriculum document fosters the ability of the students to the ideas, make alternative perceptions, and refine their thinking (Alexander, 2018; Murphy et al., 2014). The focus of the evaluation strategy is to assess the analysis, synthesis, and evaluation aspects of higher-order thinking skills that are effective for assessment practices related to critical thinking (Brookhart, 2010; Ennis, 2018). Open-ended questions recommended in assessment practice provide an opportunity for the students to enhance higher-order thinking abilities through the application of knowledge and reasoning skills in new situations (Brookhart, 2010; Ennis, 2018). Scientific understanding and reasoning with factual knowledge also reinforce the significance of critical thinking in Biology subject (Auerbach & Schussler, 2017). Yet, the current study has also identified different areas to improve like explicit guidance for critical thinking development and provision of different activities related to assessment for the development of critical thinking. The findings of the current study are also consistent with previous literature that focuses on explicit instruction for the teachers and use the relevant pedagogy for the promotion of critical thinking skills among students (Abrami et al., 2015; Janssen et al., 2019). For the teachers, provision of essential resources and professional development opportunities may enhance their classroom practices as

suggested by the curriculum (Darling-Hammond et al., 2017). Moreover, the current study findings contribute to the growing body of literature in Biology (science education) specifically in the context of Pakistan. The findings of the current study may inform curriculum developers, teacher training institutes, and policy makers aimed at enhancing critical thinking skills in science education (Darling-Hammond et al., 2017).

Conclusions

The analysis of the Biology curriculum IX-X (2006) in Pakistan reveals that the curriculum document has a great emphasis on critical thinking skills development among students. The inclusion of critical thinking in the aims and objectives, the focus on reasoning and conceptual understanding, the suggested pedagogical approaches, and the alignment of assessment strategies with critical thinking goals demonstrate the curriculum's intent to foster these essential skills. Moreover, the curriculum clearly states the importance of critical thinking by highlighting respect for evidence, rationality, and intellectual honesty. It fosters a scientific mindset that depends on logical reasoning and evidence-based decision-making, encouraging students to apply their biological understanding to real-life problems and approach them rationally. There is also a focus on CT which is the priority of acquiring knowledge over the facts, shifting rote memorization to higher-order thinking skills. Furthermore, the pedagogy that is suggested in the curriculum document is inquiry-based learning, dialogue, open-ended questions, and concept maps to make the learning environment conducive to the development of CT. For the assessment, specific weightage has been suggested for the development of critical thinking skills through questioning related to analysis, synthesis, and evaluation.

Recommendations

Based on the above findings and conclusions, the following are the recommendations of the study:

- Explicit guidance and support for teachers is needed to integrate critical thinking skills development among the students of Biology.
- Specific examples of activities, assessments, and teaching methods should be used in the Biology curriculum for the promotion of critical thinking skills.
- The use of inquiry-based learning, dialogue, open-ended questions, and concept mapping should be encouraged as key pedagogical approaches for the development of critical thinking skills in Biology.

- There should be alignment between assessment practices with the critical thinking goals of the curriculum through the incorporation of problem-solving tasks, open-ended questions, and performance-based assessments to apply the students' knowledge and reasoning skills to new situations.

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