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Critical Thinking Development for 21st Century: Analysis of Physics Curriculum

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Critical thinking has been focused on 21st-century skills. The current study analyzed the national curriculum for Physics (2006) to determine the importance and elaboration of critical thinking skills essential for 21st-century learners. The document was analyzed through qualitative content analysis by facilitating NVivo 12. The curriculum emphasizes critical thinking through learning outcomes requiring students to explain phenomena, solve problems, analyze data, and draw conclusions. Assessment objectives also evaluate these skills. Interactive teaching methods like inquiry, discussions, and concept mapping are suggested to promote critical thinking. The analysis found that critical thinking abilities are highlighted as important in the preamble, with aims to improve process skills, problem-solving, and application of concepts. Specific standards call for developing reasoning and explanation abilities. Teaching strategies provide guidelines for student-centered methods that nurture critical thinking. Assessment methods test skills in explaining unfamiliar situations, solving new problems, interpreting data, and conducting valid inquiries. Overall, this Physics curriculum comprehensively integrates opportunities for developing and accessing critical thinking abilities across all aspects - learning outcomes, teaching methods, and assessments. Recommendations include ensuring guidelines on interactive methods are implemented by teachers and assessments evaluate higher-order skills rather than just recall. Implementation fidelity would determine the development of critical thinking through this curriculum.

1. Introduction

Critical thinking is the ability to analyze information objectively and make reasoned judgments that allow one to decide what to believe and how to act (Cottrell, 2017). It involves interpreting, analyzing, evaluating, explaining, sequencing, questioning, and deciding (Duron et al., 2006; Tuzlukova & Usha, 2018). With the exponential growth of information in the digital age, critical thinking has become essential to make sense of complex ideas across disciplines and apply knowledge to solve real-world problems. Therefore, cultivating critical thinking is crucial in modern education for the 21st century.

The importance of critical thinking has been widely recognized as we prepare students for future careers, citizenship, and lifelong learning (Elder & Paul, 2020). As technologies rapidly evolve and impact our lives and work, students need adaptable cognitive skills rather than just content knowledge. Students have access to more information than ever but need critical discernment to filter accurate information from misinformation. Critical thinking empowers students to assess diverse perspectives, challenge assumptions, avoid bias, and consider context before accepting or formulating an argument (Elder & Paul, 2020). These meta-cognitive skills nurture more nuanced reasoning to navigate an increasingly interconnected world. Researchers have identified critical thinking as one of the most important skills for the 21st century, along with creativity, collaboration, and communication (Albanese & Paturas, 2018; Saavedra & Opfer, 2012). Developing critical thinking has become a key objective across school curricula over the past decade. International assessments like PISA and national reforms in countries such as the United States, Australia, the UK, and Singapore focus on evaluating and cultivating critical thinking across subjects (Grey & Morris, 2022). Science education, in particular, is well-aligned to foster critical thinking as students ask questions, hypothesize explanations, collect and analyze data, challenge claims based on evidence, and draw conclusions through inquiry (Underwood, 2018). Science inherently involves higher-order cognitive skills in critical thinking - identifying a problem, researching existing knowledge, producing and interpreting experimental data, developing solutions using logical reasoning, and communicating evidence-based arguments. At the university level, critical thinking has been an important factor for the students (Bezanilla et al., 2021)

Recent research proves that science courses designed with inquiry-based methods, open-ended investigations, collaborative problem-solving, and explicit critical thinking instruction help enhance the quality of student thinking and reasoning (Abrami et al., 2015; Onsee & Nuangchalerm, 2019; W. Suastra et al., 2019). Physics, as a foundational science, is ideally positioned to strengthen critical thinking abilities, which can also transfer to other domains. Studying real-world physical phenomena through scientific practices trains disciplined thinking that relies on gathering empirical evidence, quantitative analysis, logical argumentation, and critical evaluation of claims (Recker, 2021). Research has specifically shown that active learning in Physics correlated with gains in generic critical thinking skills measured by standardized tests.

Hence, educational reforms and policy documents emphasize integrating instructional strategies and assessments that systematically cultivate critical thinking in science education, particularly Physics, to meet the demands of the 21st century (Kivunja, 2015b; Reimers & Chung, 2019). It includes framing the Physics curriculum around the real-life application of concepts through inquiry, designing authentic assessments that evaluate higher-order abilities beyond factual recall, and leveraging digital technologies as learning tools that mirror workplace settings requiring critical thinking (Kivunja, 2015b). As Physics provides an ideal platform to develop analytical and quantitative reasoning ability, curriculum analysis is warranted to determine attention to critical thinking skills. Investigating national Physics curriculum documents and implementation challenges can help strengthen critical thinking outcomes to better prepare students for higher education and professional scenarios. Being an important aspect for the students' learning the current study analyzed the Physics curriculum in its specific perspective.

1.1 Objective of the study

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

2. Review of the Literature

Several educational reports and studies highlight critical thinking as among the most crucial skills required today, alongside creativity, problem-solving, and collaboration (Saavedra & Opfer, 2012). Rapid technological and societal changes have increased the need for critical discernment amidst the proliferation of access to information, perspectives, and claims. Students must develop analytical abilities grounded in rationale, objectivity, and empirical evidence as part of 'learning how to learn' to adapt to evolving landscapes. Hence, curriculum reforms and instructional priorities emphasize constructing knowledge through inquiry, evaluating arguments, and decision-making aligned with critical thinking frameworks.

Science education is naturally positioned to nurture critical and creative thinking habits of mind entailed in experimentation, evidence-based explanations, and peers. Therefore, science process skills overlap with components of critical thinking like making hypotheses, systematically testing variables, analyzing results, reviewing existing knowledge, resolving misconceptions through data interpretation, and articulating inferences to reach logically coherent claims (Quitadamo et al., 2008). Recent science curricula now explicitly prioritize critical thinking as learning outcomes, framing lessons around real-world application of scientific concepts, which fosters problem-solving and metacognitive evaluation skills (Kivunja, 2015b).

The National Curriculum for Pakistan outlines thinking skills under its curriculum, which aims to empower students' logical reasoning, argumentation, and investigation capacities. Constructivist, inquiry-based teaching methods are suggested across subjects as essential for developing analytical abilities and higher-order cognition rather than rote learning. Science and Physics curricula particularly call for conceptual understanding applied through experiments and creative, open-ended tasks, with assessments testing analysis, synthesis, and evaluation grounded in Anderson and Krathwohl's framework bridging thinking skills to learning domains.

Conceptual grasp and application of Physics rely on cognitively challenging skills - interpreting phenomena, developing mechanism-based explanations by integrating mathematical models and laws, analyzing quantitative data, constructing coherent lines of argumentation, and scrutinizing the reasoning, limitations, or assumptions underlying claims (Ivanitskaya et al., 2002). As Physics inherently involves precise, logical procedures and causal evidence-based inferences, practicing it builds critical competencies regardless of explicit instruction (Etkina et al., 2006). Therefore, Physics has been empirically demonstrated to nurture transferable critical thinking skills better than most other disciplines, achieving 21st-century education priorities.

The Pakistan Secondary School Certificate Physics curriculum asserts that Physics enables «systematic and logical thinking, which is central to the scientific method that cultivates analytical mindsets (Saiful et al., 2020). From the school level onwards, the policy outlines embedding critical thinking in Physics through inquiry tasks and concept mapping exercises, with summative assessments evaluating comprehension, application, and logical coherence in scientific problem-solving. University Physics courses also adopt similar learning outcomes, prioritizing evidence-based reasoning and open-ended assessments for developing intellectual independence, objectivity, and careful evaluation of multifaceted phenomena - the foundation of critical thinking (Kazmi & Naaranoja, 2015).

While curriculum documents signal goals for enhancing critical competencies through science and Physics foundations, research evidence regarding translated outcomes remains limited (Shaheen, 2016). Effective improvement requires aligning syllabus aims to instructional principles and assessments, nurturing authentic critical thinking rather than test performance alone, with empirical evaluation. Constructivist literature recommends explicit discovery-based lessons leveraging collaborative debates, argumentation tasks, project-based learning, and technology integration that mirror real-life interdisciplinary problem-solving requiring critical thinking (Kivunja, 2015a; Ten Dam & Volman, 2004). Assessments should also align standards to performance-based rubrics assessing multifaceted thought through writing, modeling, and extended responses. These evidence-based strategies need concerted efforts to transform policy ambitions into classroom realities, enriching critical faculties.

Critical thinking skills are essential for students to develop, yet research shows that opportunities to build these skills are lacking in many educational contexts. Different recent studies in the Pakistani context have explored critical thinking development in Pakistani secondary schools, specifically within science and social studies curricula and teaching practices (Jamil et al., 2023; Jamil & Muhammad, 2019; Jamil et al., 2021a, 2021b; Naseer et al., 2022). Key objectives across these studies included assessing teacher perspectives and observed practices related to critical thinking instruction (Jamil et al., 2023; Jamil et al., 2021b); analyzing the presence of critical thinking concepts in educational policies and curricula (Jamil & Muhammad, 2019); and evaluating 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).

3. Research Methodology

This study was based on qualitative content analysis (Kyngäs, 2020). Moreover, the purposive sampling technique was used to select the Physics curriculum (2006) since the study aimed to analyze the document to develop critical thinking skills (Patton, 2014). The current technique was used for an in-depth understanding of the curriculum document (Zikmund et al., 2013). Qualitative content analysis was used to analyze the data with the facilitation of NVivo 12 software. This software easily handles the many pages of the document for text (Bazeley & Jackson, 2019). Moreover, this software was the most suitable since having different tools for addressing the research objectives from different sources (Bazeley & Jackson, 2019). To do the analysis, four steps were used in NVivo, i.e., importing data, coding data, creating framework matrices, and reporting the findings (Bazeley & Jackson, 2019). The curriculum for Physics was imported in PDF format in NVivo. After this, the relevant text was coded, called nodes in NVivo. The relevant part of the text was coded as nodes and child nodes (Miles, 2020). Furthermore, the coding units had been condensed after summarizing for geting in-depth meanings of the text (Bazeley & Jackson, 2019).

4. Findings of the study

4.1 Critical Thinking

The curriculum emphasizes developing critical thinking skills in students through its learning outcomes and assessment objectives. Some examples of learning outcomes that promote critical thinking skills are as "explain that value of 'g' decreases with altitude from the surface of earth" (Unit 5 Gravitation); "differentiate with examples between distance and displacement, speed and velocity" (Unit 2 Kinematics); "explain the effect of friction on the motion of a vehicle in the context of tyre surface, road conditions including skidding, braking force" (Unit 3 Dynamics)

The assessment objectives state that students should "apply the knowledge and principles of Physics set out in the syllabus to explain simple phenomena or effects which are not already familiar to them" and "apply the knowledge and principles of Physics set out in the syllabus to solve problems involving familiar or unfamiliar situation." It requires critical thinking.

4.2 Importance of Critical Thinking

The preamble highlights the need to develop thinking abilities and problem-solving skills in students:

> *"The structure of the syllabus is based on logical sequencing of the subject matters kept by proper placement of the concepts, appropriate to the comprehension level of the students...Emphasis has been given to promote process-Investigation Skills/Laboratory work, problem-solving abilities and application of concepts, useful in real life situations for making Physics learning more relevant, meaningful and stimulating."*

The standards also emphasize higher-order thinking skills like reasoning, explaining, arriving at conclusions, etc. Developing critical thinking skills equips students to meet challenges in a complex, technological world.

4.3 Pedagogy for Critical Thinking

The teaching strategies section provides guidelines for interactive, student-centered methods that develop critical thinking like inquiry/investigation, demonstrations, discussions, concept mapping, etc. Each unit's investigations and practical work also promote critical thinking through experimentation, data analysis, and conclusion.

The teaching strategies section (p.90-96) provides guidelines for developing critical thinking.

4.4 Assessment for Critical Thinking

The assessment objectives require assessing critical thinking skills like explaining unfamiliar phenomena, solving unfamiliar problems, interpreting and analyzing scientific data, and drawing valid conclusions from investigations. The question paper is intended to "test the following range of abilities," including "applications and problem-solving." The practical test also assesses experimentation and investigation skills.

The assessment objectives on p.54-55 require assessing critical thinking skills. Testing abilities and skills are also mentioned on p.58. A practical test for assessing investigation skills is on p.59.

Finally, the curriculum emphasizes critical thinking as an important ability, uses interactive teaching methods to develop it, and assessments to evaluate whether students have achieved proficiency in critical thinking related to Physics concepts and applications. Relevant quotes are provided for each aspect.

4.5 Discussion

The current study analyzed the Physics curriculum for grades IX-X (2006) regarding developing critical thinking skills. The document found that it has clear directions for nurturing critical thinking, higher-order capabilities, and reasoning in science with suggested pedagogy like inquiry-based learning. Also, the assessment has been discussed to focus on developing critical thinking skills. The same has been reported for cognitive development through competencies in Physics (Saavedra & Opfer, 2012; Velmovská et al., 2019; Wenno et al., 2022). Moreover, for problem-solving, there is a need for conceptual understanding as per the global trends regarding science subjects. Since intellectual adaptability is vital for curriculum reforms, highlighting thinking skills development in an international context through creative reasoning has evidence for more progress mastery (Kurniawan et al., 2020; Trilling & Fadel, 2012). That is why there is a great need to prioritize Physics learning through inquiry, logical thinking, and conceptual understanding with application and observation. The previous literature also focuses on critical thinking with evidence evaluation, reasoning, explanation through mechanisms, and debates (Gestsdóttir et al., 2018; Ivanitskaya et al., 2002). The Physics curriculum aimed at analytical thinking abilities through the subject. Similar research on learning outcomes covering schools to higher education confirms vigorous gains in 21st-century competencies like flexible perspective-taking, multi-dimensional evaluation before conclusions, and metacognitive regulation of thinking processes through designed Physics instruction (Etkina et al., 2006; Thornhill-Miller et al., 2023). Consequently, realizing the curriculum desires regarding application, experiments, and reasoning capability transmits meaningful scope for impact.

Furthermore, as discovered in the findings, understanding such a vision needs connecting aspiring guidelines to application, given the tendency for high-stakes testing to continue the status quo in teacher-centric classrooms. Therefore, beyond curriculum content, focusing efforts on interpreting recommendations into learning environments and experiences systematically consolidating reflective judgment is necessary. Indication highlights key instructional essentials that can strongly foster critical thinking when structured around Physics concepts – case analysis, argument, role-plays, collaborative projects, and concept mapping tools, with inspired support and exposure to model scientific critique (Berry & Kowal, 2022; Bossér & Lindahl, 2020; Ten Dam & Volman, 2004). Assessment reform towards open-ended inquiries, illuminating model rubrics, and domain-general thinking skills tests can also catalyze changes. Consequently, continuously evaluating adopted instructions and learning analytics is vital, along with placing curriculum foundations and developing critical thinking through relevant assessment (I. Suastra et al., 2019).

5. Conclusions

This qualitative content analysis of the National Curriculum for Physics Grades IX-XII, 2006 in Pakistan provides insight into policy priorities and reforms towards enhancing critical thinking abilities, considered an essential learning goal for 21st-century education. It was found that critical thinking has been focused on the Physics curriculum. In the start, as from the preamble and vision statement, it has been discussed and to be focused on by the curriculum developers. The curriculum also emphasizes conceptual understanding, inquiry methods and skills, reasoning, experimentation, and investigation for higher-order thinking skills. Moreover, regarding the aim of the curriculum, critical thinking has also been focused on elaboration, instruction, and pedagogy, and to build competencies with suggested pedagogies like inquiry, questioning, observation, experimentation, debates, collaboration, and reasoning to reach critical thinking skills.

Moreover, regarding assessment, testing higher-order thinking is focused on relevant techniques. Moreover, the curriculum guidelines also explored active and constructive teaching-learning practices for developing critical thinking skills. Also, there are different pedagogies like open-ended questions, concept maps, and scientific debates specifically emphasizing critical thinking.

5.1 Recommendations

The following recommendations have been made based on the findings of the study:

- Research on instructional practices and learning outcomes regarding critical thinking skills among students is needed under the Physics curriculum.
- Teachers' training modules should be conducted that effectively nurture critical thinking abilities through Physics education, including case analysis, simulations, argumentation, inquiry projects, etc.
- Create supplementary content elaborating real-world interdisciplinary applications of Physics concepts, which enhance relevance and lend authentic contexts for students to apply critical faculties.
- Reform formative and summative Physics assessments to emphasize evaluating conceptual application, scientific reasoning, and multi-dimensional critical thinking skills over factual recall alone.
- There is need to update the curriculum in accordance with the need of the society.

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