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An Analysis of Physics Textbook Grade X for Critical Thinking Skills Development

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Abstract

The purpose of this study was to qualitatively analyze the Physics textbook of Grade X published by the Punjab Textbook Board to examine critical thinking development. The document was selected using Purposive sampling techniques and analyzed by qualitative content analysis facilitated by NviVo 12 software. The results uncover that the textbook includes various strategies to develop the critical thinking of the students which includes providing the students hands-on experiences from activities and experiments, providing them the conceptual questions to apply their understanding in new situations, by relating scientific concepts to real-life applications, by providing the solved numerical to develop the problem-solving techniques, by delivering the historical background behind the scientific discoveries which illustrate the scientific process. The textbook has involved such strategies to develop critical thinking skills as well as it manifests that the development of the students' critical thinking can be increased through active learning, by creating brainstorming situations, making the situation for thinking flexibly, and showing the scientific investigation process. The current study yields meaningful implications for teachers that science education needs a variety of pedagogical approaches rather than traditional chalk and talk to develop the critical thinking.

Keywords: *Physics Textbook, Critical Thinking, Qualitative Content Analysis, NVivo 12*

1. Introduction

The significance of thinking critically has been recognized by educational research and practice. Thinking critically is a 21st-century vital skill consisting of the ability to analyze, synthesize, and evaluate information, which allows individuals to make informed decisions while solving complex problems (Dwyer et al., 2014). In today's complex, technology-driven, and rapidly changing world, critical thinking skills are increasingly important. Critical thinking (CT hereafter) involves a wide range of attitudes and dispositions as well as cognitive processes including inquisitiveness, intellectual humility, open-mindedness, metacognition, analysis, inference, deduction, induction, and evaluation (Facione et al., 2020).

Physics, as a field of study, lends itself to the cultivation of critical thinking abilities. Physics, as an academic discipline, requires students to engage in logical reasoning, problem-solving, and evidence-based decision-making. The discipline of Physics encourages students to question, investigate, and analyze the world around them. Therefore, Physics education aims to not only impart factual knowledge but also to develop students' scientific thinking skills, including critical thinking (Etkina et al., 2006).

Textbooks play important roles in nurturing students' learning experiences and cognitive growth (Khine, 2013). Due to their status as major teaching and learning resources, textbooks have been at the center of education. Consequently, textbooks can largely contribute to the improvement of students' critical thinking skills since the approach of textbooks in presenting contents, arranging activities, and suggesting questions can either favor or interfere with students' engagement in critical thinking (Fang & Wei, 2010).

Previous research has investigated textbooks' role in supporting critical thinking skills. Baviskar et al. (2009) found that students were highly concentrated on factual knowledge rather than the higher-order thinking that their learners need. Likewise, Tiruneh et al. (2017) studied to what degree Physics textbooks of Ethiopia promote critical thinking and found that most of the questions and activities in the textbooks are asked to develop only lower-order thinking skills. These findings show that textbooks need more thorough examination to be used effectively to develop critical thinking skills.

This research paper is targeted to expand the present understanding of critical thinking skills development in Physics. The specific objectives of the present study were to qualify the Grade X Physics textbook through qualitative content analysis and to identify the techniques utilized in the textbook to promulgate critical thinking skills.

The significance of the current study is that it could potentially be used to change the overall design that in turn changes the way that Physics is taught to grasp a better understanding of critical thinking and (hopefully) break down its meaning and its teaching styles outside the traditional classroom while also strengthening its worth in Physics itself. It will do this by providing new insights into the strengths and weaknesses of current textbooks that teachers, curriculum developers, and policymakers can use to make more informed decisions when revising and improving textbooks so that they can more effectively help students develop critical thinking in Physics (Smith, 2022).

2. Objective of the Study

1. To find out how the content, activities, and questions of the Grade X Physics textbook promote the development of critical thinking.
2. To identify how the Grade X Physics textbook engages students in critical thinking processes.
3. To give suggestions to improve the role of Grade X Physics textbook in developing critical thinking of the students.

3. Literature Review

For effective CT growth among students in Physics, it is important to consider the diverse strategies and instructional approaches that can be embraced. Textbooks, being a key component to learning, are indeed instrumental in growing this critical 21st-century skill. International literature contains numerous studies that have examined critical thinking skills in science education. For example, Vieira et al. (2011) conducted a study regarding conceptual clarification of critical thinking in science education. Physics education research reveals numerous strategies and instructional approaches in which to foster the development of critical thinking (CT) skills among students. Holmes et al. (2020) conducted a study to investigate the cognitive activities

students engaged in during a Physics undergraduate research program. The experience in research opened opportunities for students to delve into reflection, analysis, synthesis, evaluation of evidence, judgment, and argumentation.

Vaughn et al. (2020) conducted a study on group-level assessment as a methodological tool for the facilitation of science education. The literature focused on critical thinking in Physics education. Holmes et al. (2015) explored teaching critical thinking in their study. A correlational study was conducted regarding the science process and critical thinking skills for the Physics subject (Kurniawan et al., 2020). In the same way, regarding Physics, learning tools for the subject were developed for the development of critical thinking skills (Wenno et al., 2022).

There have been some recent studies conducted on the topic of critical thinking skill development of the students in the Pakistani context. A study by Ali et al. (2023) investigated the effect of ICT integration on students' reasoning skills development for Physics. Critical thinking skills development concerning Physic studies have been conducted as CT skills development of Physics curriculum (Jamil, Hafeez, et al., 2024); for Physics textbook grade IX (Jamil, Bokhari, & Ahmad, 2024). Moreover, in the Pakistani context, different studies have been conducted regarding CT skills development for Mathematics, Chemistry, and Biology curriculum (Jamil, Bokhari, & Iqbal, 2024; Jamil, Bokhari, & Rafiq, 2024; Jamil, Bokhari, & Zia, 2024), CT skills development regarding Physics, Chemistry, and Biology textbooks analysis (Jamil, Bokhari, & Ahmad, 2024; Jamil, Mehmood, et al., 2024; Jamil, 2024). In the same way, educational policy and curriculum documents are also analyzed (Jamil et al., 2020)

4. Research Methodology

The current study employed a qualitative content analysis approach to analyze the Physics textbook regarding the development of CT skills among secondary school science students. The current method is the most suitable one since it systematically interprets the large textual data to identify its themes, patterns, and meanings (Kyngäs, 2020). For textbook analysis, this approach is considered the most suitable in educational material like textbooks to get insights from the content and its learning outcomes (Mayring, 2014). The Physics textbook (downloaded from *https://pctb.punjab.gov.pk/E-Books*) for grade X was selected through a purposive sampling technique. This technique was used based on specific criteria and characteristics (Etkina et al., 2006). NVivo 12 software was used as a facilitator for qualitative content analysis (Jackson et al., 2019) since it is used for data organizing, analysis, and textual data efficiently (Silver & Woolf, 2018).

5. Findings of the Study

Based on the analysis of the Physics textbook for Class 10 published by the Punjab Textbook Board, the following are different aspects that can help develop critical thinking skills among students.

5.1 Thought-provoking questions and activities:

The textbook is filled with questions and activities designed to challenge students' thinking and encourage them to delve deeper into the subject matter. These questions go beyond simple recall and require students to analyze, evaluate, and synthesize information to formulate their responses. The following are the examples related to this aspect.

- *"Why do we always use metal wires for conduction of electricity?"* (Page 100)
- *"Do you think amount of positive charge on the glass rod after rubbing it with silk cloth will be equal to the amount of negative charge on the silk? Explain."* (Page 70)
- *"What would happen to the loudness of sound with increase in its frequency?"* (Page 24)

These types of questions prompt students to analyze, reason, and provide explanations, thus fostering critical thinking. To answer these questions effectively, students must critically examine the interaction between the glass rod and silk cloth, consider the transfer of electrons, and provide a reasoned explanation based on their understanding of electrostatics. By consistently engaging with such thought-provoking questions throughout the textbook, students develop the habit of critically examining information, considering multiple perspectives, and constructing well-reasoned arguments. These skills are essential for effective problem-solving and decision-making in Physics and beyond.

5.2.Real-world applications and connections:

The textbook attempts very hard to tie theoretical ideas back to their real-world applications. By constantly showing how Physics principles can be found in everyday life students will be able to easily understand how relevant their learning is. Some example prompts from the text include:

- *"Discussing the applications of ultrasound in medical and industrial fields"* (Page 31)
- *"Explaining the use of optical fibers in telecommunications and medical field"* (Pages 159-160)
- *"Describing the role of transformers in power transmission from power stations to houses"* (Pages 131-133)

The examples demonstrate the broad range of applications of ultrasound technology in diagnostic imaging, and therapy, as well as in non-destructive material testing. Understanding the underlying Physics principles, which are put to use in these application examples from everyday life, gives students the ability to critically evaluate the usefulness and limitations of these technologies in medical sciences, to evaluate the impact on society, and also to propose improvements, respectively developments. By exploiting Physics concepts during robot calisthenics students get the ability to critically examine already state-of-the-art robots of the mentioned kind regarding strengths and weaknesses, to evaluate consequences of use for robots of this kind in society, and also to propose developments. The topical reference of Physics to everyday life and application examples related to contents motivates the students to critically thinking concerning Physics basics, engineering problems, and also future developments in application fields, similarly. By understanding the Physics principles of power transmission at a theoretical level, students get, on the other hand, the ability to critically evaluate existing infrastructure in terms of advantages and disadvantages, to evaluate environmental and economic consequences, and also to propose problems regarding a sustainable energetic power supply of a country from Physics backed arguments.

5.3.Conceptual understanding over rote learning:

The textbook very much emphasizes the understanding of the topics rather than the memorization of facts and formulas and does so through uh sections like "Point to Ponder" and "Physics Insights" that introduce thought-provoking ideas, counterintuitive concepts, and common misconceptions, thereby challenging the students' existing notions and enhancing their understanding, like where-for example:

- *"Why leaves of charged electroscope collapse if we touch its disk with a metal rod but they do not collapse if we touch the disk with a rubber rod?"* (Page 74)
- *"Dispersion of light is due to the variation in refractive index with the colour."* (Page 43)

The textbook on many points in the chapter encourages critical thinking and deeper understanding by provoking the student to answer a question that may preconceive to not have thought of yet, or not aware of which can lead to a deeper understanding. For example, in the section on electrostatics, students are asked to compare the charge carriers in a metal and a rubber rod. To

answer this question the student must carefully analyze the detection and electrical flow of charge carriers and use his general electrostatics knowledge to generate a thorough out and well-founded answer, when conceptual teaching is used to teach anything we almost every time hear the teacher say what is the speed of an object at rest? This is an unanswerable answer because an object may not be moving at an instant in time, but we always know its speed a zero because if you are at rest your speed is always zero. This is what the Physics teacher would call an anomaly, so that requires them to know that means an exception. Another instance is when the student is asked why different colors of light bend at different angles in a prism. This question requires the students to analyze wavelength, frequency, and index of refraction and use his general concept of Physics to draw a well-formed and organized answer again analyzing the question. The textbook generates critical thinking and deeper understanding through presenting thought-provoking ideas, challenging their thinking and the involved concepts that lead them to actively engage with the material, question their understanding, and therefore gain a general deeper concept of the content of the text. Analysis, evaluation, and synthesis are grouped as critical thinking skills, and therefore when the textbook presents a thought-provoking Idea it must follow a certain process to critically analyze the material sync with what I have learned, internalize the information, and build it into a knowledge structure. What the skill analysis is doing is allowing me to check what I know according to what I have learned to see if the two relate. What the skill evaluation is doing is listing the facts found in the text and showing relationships and contradictions among them. What synthesis is doing is gathering relevant knowledge, and creating a well-referenced logical and coherent theory, concept, and ideas per the text Physics. The textbook is constantly presenting new concepts via many representations, like verbal, equation, illustration, or real-life concepts again just to get us to a similar question like before and they are using their conceptual Physics knowledge learned from the textbook to generate a similar deep well-formed answer or proposed a similar series of questions to that already answered but now with a different frame of reference.

5.4.Hands-on experiments and demonstrations:

The textbook includes many experiments that show students how to explore Physics by experience. Students will discover many things by experiencing themselves. To know how we think critically, textbooks include experiments, more examples, and exercises, so we practice a lot on it. For example,

- Activity 13.1 and 13.2 demonstrate the production and properties of electric charges (Pages 69-70)
- Experiment to demonstrate the magnetic effect of current using a compass needle (Page 119)
- *"Measuring the speed of sound by echo method".* (Page 28)

Opportunities for scientific inquiry and experimentation present opportunities for students to develop many critical thinking skills. For example, in the hands-on activities involving electrostatic charging and noticed and induction in this book, students are directly engaged with the phenomena, unlike in most books where the activities involve looking at pictures and diagrams or watching video clips. As students conduct these activities, they begin to develop skills in a variety of areas including making observations, formulating hypotheses, collecting, and analyzing data, and making inferences. They are forced to make careful observations of what happens during their investigations, develop testable hypotheses to explain their observations, make reasonably accurate, consistent measurements and observations, organize, and record their observations methodically so that others can replicate their experiments if they wish, and analyze the outcomes of their investigations to draw logical, well-supported conclusions.

5.5.Historical context and scientific discoveries:

The textbook does a great job of incorporating historical context with scientific discoveries in the chapters. It is helpful because it allows students to see the growth in the concepts of Physics as well as allows them to think critically before making a claim. History is important in Physics because knowing the progression of how discoveries were made allows a student to see how other great physicists have rigorously thought through a problem. Similarly, it shows how other scientists over the years have used creative ways to think about problems in a manner no one else thought of and were able to discover something revolutionary.

- *Discussing Rutherford's discovery of the atomic nucleus* (Page 175)
- *Describing Faraday's experiments on electromagnetic induction* (Pages 125-128)
- *Explaining Huygens' invention of the pendulum clock* (Page 4)

By learning about the scientific process and the critical thinking employed by renowned scientists, students are inspired to develop similar habits of mind. By understanding the critical thinking process behind Rutherford's work, students learn how scientists formulate hypotheses, design experiments to test their ideas, analyze data, and revise their models based on empirical evidence. This historical account demonstrates the importance of questioning existing theories, designing controlled experiments, and drawing logical conclusions based on observational evidence. It encourages students to think critically about the nature of scientific knowledge, the role of experimentation in validating or refuting hypotheses, and the ongoing process of refining scientific models based on new evidence. By understanding the critical thinking behind Faraday's discoveries, students appreciate the role of creativity, perseverance, and rigorous experimentation in advancing scientific knowledge. The study of Huygens' work helps students appreciate how scientists utilize their theoretical knowledge to solve practical problems, evaluate the limitations of current technologies, and propose innovative solutions. In these lessons students will gain a better understanding of these critical thinking skills, as they are, problem identification, solution generation, and iterative design.

6. Discussion

The findings of the current study indicate that the textbook employs a wide variety of strategies that aim to foster critical thinking among the students. These strategies include experimentation and hands-on learning, conceptual questions, their applications in the real world, solved numerical problems, and historical context. The strategies employed in the textbook emphasis on experimentation and hands-on learning are consistent with the findings of the prior research that featured inquiry-based learning as one of the strategies that contribute to critical thinking (Vieira et al., 2011). The textbook - through utilizing experiential learning - that promotes the students by allowing them to develop scientific reasoning, construction of hypotheses, and evidence-based conclusions, aligns with the constructivist learning theory that underscores the role of learners in making their knowledge through the introduction of the knowledge construction process that entails exploration and discovery (Baviskar et al., 2009).

The inclusion of conceptual questions and real-world applications in the text may contribute to the development of higher-order critical-thinking skills. Conceptual questions give the students a chance to apply their understanding of scientific concepts to new and novel scenarios invoking skills at higher levels of thinking such as analysis, evaluation, and synthesis (Dwyer et al., 2014). Real-world applications may allow the students to see the connection of Physics topics in their everyday lives and again may prompt them to think critically about the implications of scientific knowledge (Fang & Wei, 2010).

Another aspect of developing Critical Thinking Skills in Physics can be from combining solved numerical problems with historical context (Tiruneh et al., 2017). Solved Numerical problems are the model of problem-solving by demonstrating to the student how to approach problem-solving systematically, use the relevant Physics principles, and apply this known information to similar and number-based situations. The modeling of these examples educates learners about the inquiry processes needed to tackle more complex problems thus it contributes to two types of critical thinking skills in Physics Analytical and Evaluative. Equally important, incorporating the historical context of Physics, the key experiments, and the findings helps students to appreciate the nature of science, and the evidence-based nature of scientific knowledge thus, promoting a critical approach to Physics. Students learned to think critically and ask and evaluate ideas with evidence from empirical.

The study also identified areas where the textbook might be improved to further develop critical thinking skills. The analysis showed that the textbook could use more emphasis on open-ended questions and inquiry-based activities that encourage students to develop their experiments and explore scientific phenomena (Ali et al., 2023). The textbook could also include more direct instruction on strategies for critical thinking, the researchers said, since previous studies have shown that directly teaching critical thinking skills improves science education (Vieira et al., 2011).

7. Conclusion

Experimentation and hands-on learning in the Physics grade X textbook promote scientific reasoning through the application of reasoning. The textbook encourages the student to have a hypothesis, test the hypothesis by experimentation, analyze the data collected, and formulate a conclusion. Conceptual questions and real-world application problems also promote scientific reasoning because they test whether a student understands the concept and why. Questions within the conceptual and real-world application problems also target higher order thinking skills. For example, does the student realize that a particular force is acting on them even though they cannot see it? Consequently, the student would realize that the same force acts on everything and not by as tough or not at all, just because they are not touching. Rather an object can feel a force or torque being applied to it and not feeling it because they are touching is already something they have an experience within everyday life. More numerical problems and held this vector problem is solved (both non-conceptual type problems) and historical context. Numerous problems and historical contexts are problems, application of critical thinking skills, and the scientific method, or any other significant.

8. Recommendations

The following recommendations are made based on the findings of the current study:

- Provide more questions that have more than one answer and more activities that involve exploring topics the book does not specifically cover to challenge students to come up with their investigations and experiments to improve their learning and critical thinking.
- Include prompts with examples of specific critical thinking strategies in the textbook. Describe why each strategy is used and demonstrate how the student can use that strategy to solve Physics problems or understand Physics concepts.
- Connect Physics to the real world more and explain where these Physics concepts are encountered day to day—to encourage higher-level thinking to analyze and evaluate the effects on their daily lives.

References

Ali, H., Rafique, M., & Hussain, B. (2023). Effect of ICT Integration on Secondary School Students' Physics Achievement and Reasoning Skills. *Voyage Journal of Educational Studies, 3*(2), 383-398.

Baviskar, S. N., Hartle, R. T., & Whitney, T. (2009). Essential criteria to characterize constructivist teaching: Derived from a review of the literature and applied to five constructivist-teaching method articles. *International Journal of Science Education, 31*(4), 541-550.

Dwyer, C. P., Hogan, M. J., & Stewart, I. (2014). An integrated critical thinking framework for the 21st century. *Thinking Skills and Creativity, 12*, 43-52.

Etkina, E., Murthy, S., & Zou, X. (2006). Using introductory labs to engage students in experimental design. *American Journal of Physics, 74*(11), 979-986.

Facione, P. A., Facione, N. C., & Gittens, C. A. (2020). What the data tell us about human reasoning. In *Critical Thinking and Reasoning* (pp. 272-297). Brill.

Fang, Z., & Wei, Y. (2010). Improving middle school students' science literacy through reading infusion. *The Journal of Educational Research, 103*(4), 262-273.

Holmes, N., Keep, B., & Wieman, C. E. (2020). Developing scientific decision making by structuring and supporting student agency. *Physical Review Physics Education Research, 16*(1), 010109.

Holmes, N. G., Wieman, C. E., & Bonn, D. (2015). Teaching critical thinking. *Proceedings of the National Academy of Sciences, 112*(36), 11199-11204.

Jamil, M., Bokhari, T. B., & Ahmad, D. (2024). Evaluation of Critical Thinking Elements: A Qualitative Content Analysis of Physics Textbook Grade IX. *Qlantic Journal of Social Sciences, 5*(1), 344-350.

Jamil, M., Bokhari, T. B., & Iqbal, J. (2024). Incorporation of critical thinking skills development: A case of mathematics curriculum for grades I-XII. *Journal of Asian Development Studies, 13*(1), 375-382.

Jamil, M., Bokhari, T. B., & Rafiq, M. (2024). Critical thinking skills development for 21st century: An analysis of Biology curriculum (2006). *Voyage Journal of Educational Studies, 4*(1), 127-138.

Jamil, M., Bokhari, T. B., & Zia, Q. (2024). Qualitative Content Analysis for Critical Thinking and Skill Development: A Case of Chemistry Curriculum. *Journal of Asian Development Studies, 13*(1), 147-155.

Jamil, M., Hafeez, F., Abdul, & Muhammad, N. (2024). Critical thinking development for 21st century: Analysis of Physics curriculum. *Journal of Social & Organizational Matters, 3*(1), 1-10.

Jamil, M., Mehmood, W., & Shah, F. u. H. (2024). Development of critical thinking skills among secondary school science students: An analysis of Chemistry textbook grade IX (2020). *Global Educational Studies Review, 9*(1), 13-20.

Jamil, M., Muhammad, Y., Masood, S., & Habib, Z. (2020). Critical thinking: A qualitative content analysis of education policy and secondary school science curriculum documents. *Journal of Research and Reflections in Education, 14*(2), 249-258.

Saleem, A. (2024). Biology textbook grade X (2020): Analysis for the development of higher order thinking skills among secondary school science students. *Global Regional Review (GRR), 9*(1), 29-35.

Khine, M. S. (2013). Analysis of science textbooks for instructional effectiveness. In *Critical analysis of science textbooks: Evaluating instructional effectiveness* (pp. 303-310). Springer.

Kurniawan, W., Pathoni, H., Muliawati, L., Kurniawan, D. A., Romadona, D. D., Ningsi, A. P., & Dari, R. W. (2020). Relationship of science process skills and critical thinking of students in Physics subject. *Universal Journal of Educational Research*, *8*(11), 5581-5588.

Kyngäs, H. (2020). Qualitative research and content analysis. In *The application of content analysis in nursing science research* (pp. 3-11). https://doi.org/10.1007/978-3-030-30199-6_1.

Mayring, P. (2014). Qualitative content analysis: Theoretical foundation, basic procedures and software solution. In *Approaches to qualitative research in mathematics education* (pp. 365–380). Springer. http://nbn-resolving.de/urn:nbn:de:0168-ssoar-395173

Silver, C., & Woolf, N. H. (2018). From guided-instruction to facilitation of learning: the development of Five-level QDA as a CAQDAS pedagogy that explicates the practices of expert users. In *The Teaching and Learning of Social Research Methods* (pp. 83-100). Routledge.

Tiruneh, D. T., De Cock, M., Weldeslassie, A. G., Elen, J., & Janssen, R. (2017). Measuring critical thinking in Physics: Development and validation of a critical thinking test in electricity and magnetism. *International Journal of Science and Mathematics Education, 15*, 663-682.

Vaughn, L. M., Jacquez, F., Deters, A., & Boards, A. (2020). Group-Level Assessment (GLA) as a methodological tool to facilitate science education. *Research in Science Education*, 1-13.

Vieira, R. M., Tenreiro-Vieira, C., & Martins, I. P. (2011). Critical thinking: Conceptual clarification and its importance in science education. *Science Education International*, *22*(1), 43-54.

Wenno, I. H., Limba, A., & Silahoy, Y. G. M. (2022). The development of Physics learning tools to improve critical thinking skills. *International Journal of Evaluation and Research in Education (IJERE)*, *11*(2), 863-869.