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Critical Thinking Skills Development: An Analysis of Mathematics Curriculum 2006 (Grade-wise)

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Abstract

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Keywords: Critical Thinking, Mathematics Curriculum, Qualitative Content Analysis, Grade Levels, Logical Reasoning, Problem-Solving, Technology Integration

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Contents

Abstract

The current qualitative study was conducted to analyze the mathematics curriculum across grade levels for students' critical thinking skills development. Qualitative content analysis was used to analyze the document with the facilitation of NVivo software. As per the analysis, Grades I-III cover core math concepts at an introductory level using real-life examples presented concretely. Then grades IV-VIII revisit these same ideas with more depth and add logical reasoning. Finally (IX-X) and higher secondary (XI-XII) levels aim to build a rigorous conceptual understanding of complex mathematical topics like calculus, vectors, and complex numbers as well as non-routine problem-solving capacity utilizing proof techniques and technology tools like MAPLE software. The research results show that the curriculum is indeed effective for 21st-century skills development such as critical thinking, problem-solving, and technological literacy. Students who complete this systematic program will be prepared for advanced studies or careers that require mathematical proficiency.

Keywords: Critical Thinking, Mathematics Curriculum, Qualitative Content Analysis, Grade Levels, Logical Reasoning, Problem-Solving, Technology Integration

Introduction

Critical thinking is one of the main objectives in education today (Dwyer et al., 2014). It consists of many cognitive abilities such as analyzing information, evaluating evidence, making reasonable arguments, and solving complex

problems (Dwyer et al., 2014). These abilities are not only necessary for achieving success in school but also play a vital role in personal relationship building and professional environment navigation when knowledge plays a crucial role (Ananiadoui & Claro, 2009).

Different field experts in mathematics have focused on the development of critical thinking skills since it is used for logical and analytical reasoning which are basic aspects of critical thinking (Dolapcioglu & Doğanay, 2022; Hitchcock, 2018). Given this known connection between math and critical thinking, researchers have tried designing materials and instruction methods for it (Afriansyah et al., 2021; Setiana & Purwoko, 2021).

Different organizations related to mathematics have placed it as a core subject and integration of critical thinking in it. NCTN (2000) uses problem-solving and argumentation as its main tools to engage the students and focus on the significance of communication in it. In the same way, another organization, Common Core State Standards for Mathematics provides the standard for the incorporation of critical thinking through its practices that aim at argumentation that is used in mathematics (Reston, 2000).

With all this in mind, it is not surprising that there is a surplus of research on different teaching strategies and curriculums that have been found to help grow these skills. Some studies have shown that students work better in groups when trying to analyze information and find solutions (Warsah et al., 2021). Others found that having students argue or solve problems based on real-world issues grew their cognitive abilities over time (Giri & Paily, 2020; Razak et al., 2022).

In addition, the integration of technology in math lessons has been said to promote critical thinking skills (Yaniawati et al., 2020). The use of computer simulations, virtual elements, and software can help students visually explore concepts they may not understand otherwise. It gives them a chance to experiment and think outside the box (Leung, 2023).

With that being said, the study at hand aims to add to an ongoing discussion by putting a popular math curriculum taught in Pakistan through a comprehensive analysis. The program spans from first grade through twelfth. By doing this it hopes to find out if this curriculum could potentially foster critical thinking skills as much as they hope. Simply by analyzing the curriculum documents such as educational content and instructional approaches, does it pose any gaps or strengths? If so, how could these teaching practices be made more effective? These are all questions the study is going to answer for the development of critical thinking skills among students. The point of this research is for its findings to be used when making decisions about future curriculums. The old saying goes "If it's not broken don't fix it," but if this one is broken then we need to know how to build a better one. And not just that but also training programs for teachers and other methods for creating strong cognitive skills within our youth.

Objective of the Study

- To analyze the mathematics curriculum across grade levels about incorporating critical thinking skills development.

Literature Review

Critical thinking skills give students the ability to problem-solve in real-life situations (Diano Jr et al., 2023; Sitopu et al., 2024). This applies beyond academics too when you consider their future careers or their day-to-day lives as adults. Researchers suggest that CT skills need to be developed early on with problem-based learning because it's crucial Ahdhianto et al. (2020). Progress has been made in recent years with critical thinking components being added to curriculums, however, there needs to be more done in terms of making them explicit (Dolapcioglu & Doğanay, 2022). This same study has shown that many problem-solving skills need to be authentic to promote CT and problem-solving.

Analyzing the relationship between mathematics learning in school with these skills is highly important in enabling students to solve non-routine problems and navigate complex real-world situations (Diano Jr et al., 2023; Sitopu et al., 2024). In the view of Ahdhianto et al. (2020), critical thinking is significant for them regarding the application of knowledge to solve problems that can be developed using problem-solving learning techniques.

There are also different recent methods of teaching like inquiry-based teaching that is used to

encourage the students to question and make predictions regarding the subject that are understandable to them (Vlasenko et al., 2020). This type of method is used for problem-solving and conceptual understanding. On the other hand, problem-solving is used to encourage students with real-world problems (Suryawan et al., 2023). Cooperative learning and argumentation are great ways to get students to think critically. Students can evaluate other's reasoning and develop their own in a collaborative environment (Warsah et al., 2021). This approach is very important as it encourages students to articulate their thought processes, defend their arguments, and analyze the perspectives of others.

Technology has taken over education too in recent years, for the better. Chen and Chuang (2021)found that digital storytelling games help high school students think critically. Games give students the chance to problem-solve, make decisions, and try different scenarios.

In the local context of Pakistan, different studies have been conducted to investigate critical thinking through different aspects regarding their development and focus on the teaching-learning process as well as education policy documents. In the national context of Pakistan, different studies are focusing on CT skills development at different levels with diverse aspects. A recent qualitative study has been conducted to explore creative thinking in public schools in Pakistan as per teachers' perceptions and practices (Fazal et al., 2023). Creative thinking is an important aspect of the twenty-first century, but it is not being promoted effectively. In another experimental study, it was found that the integration of ICT enhanced students' reasoning skills. Moreover, ICT integration had a positive effect on student achievement in Physics (Ali et al., 2023). CT has been explored in the national context regarding science studies including Physics, Chemistry, and Biology curricula and teaching practices (Jamil, 2021; Jamil, Bokhari, et al., 2024; Jamil, Bookhari, et al., 2024; Jamil et al., 2023; Jamil & Muhammad, 2019; Jamil et al., 2021a, 2021b). Secondary school science teachers' perceptions and practices have been explored in different studies for the promotion of critical thinking (Jamil et al., 2023; Jamil et al., 2021b); analysis has been done for the policy documents regarding CT (Jamil & Muhammad, 2019); and assessing critical thinking skill development opportunities in textbooks. In another study effect of flipped science classrooms was explored on students' achievement in grade 7 (Saeed & Munir, 2023). It was found that students with flipped classroom experiences showed meaningful improvements in their CT capabilities.

Research Methodology

This study employed a qualitative content analysis approach to investigate the potential of a widely used Mathematics curriculum in fostering critical thinking skills among grade I-XII students. To analyze the data from this curriculum document, the technique used was qualitative content analysis (Kyngäs, 2020; Schreier, 2012). It gives us a good look at all the text data by identifying patterns, themes, and meanings (Mayring, 2014). A criterion was selected while choosing the math curriculum for analysis. The curriculum document is widely adopted with relevant to grades I-XII in Pakistan (Etikan & Bala, 2017). The document we chose allowed us to have an accurate representation of all typical instructional material used in the region. Using NVivo12 software all the finding was organized into codes and categories (Jackson et al., 2019). This process makes it easy for us to find patterns within large volumes of text data quickly and efficiently (Silver & Woolf, 2018).

Findings of the Study

Following is the analysis of the curriculum document in different grades.

Primary Level (Grades I-III):

Focus on Conceptual Understanding

The curriculum aims to build a strong foundation of mathematical concepts in the early grades. For example, in Grade I, students are expected to *"Recognize and represent unit fractions up to 1/12"* (page 4). In Grade III, they should "Define a fraction" and *"Identify unit, proper, improper and mixed fractions"* (page 26).

Emphasis on Skill Development

Along with conceptual understanding, the curriculum also focuses on developing key mathematical skills. For instance, in Grade II, students should be able *to "Add and subtract*

measures of distance, time and temperature" (page 4). In Grade III, they are expected to *"Add and subtract units of time with carrying/borrowing"* (page 28).

Introduction to Problem Solving

The curriculum introduces simple real-life problem-solving at the primary level. For example, in Grade I, students should *"Solve real-life problems involving addition"* (page 19). This is further extended in later grades.

Use of Manipulatives

The use of concrete objects and manipulatives is encouraged to make mathematical ideas more tangible. For instance, in Grade I, students *should "Match the numbers 0-9 with objects"* (page 8).

Middle Level (Grades IV-VIII):

Deepening Conceptual Understanding

The curriculum revisits and extends the concepts introduced in earlier grades. For example, in Grade IV, students learn about the *"Highest Common Factor (HCF)"* and *"Least Common Multiple (LCM)"* (page 25), building upon the idea of factors introduced earlier.

Emphasis on Skill Proficiency

The curriculum expects students to become proficient in mathematical skills. For instance, in Grade V, students should be able to *"Add and subtract decimals" and "Multiply and divide decimals by 10, 100 and 1000"* (pages 27).

Emphasis on Problem-Solving Strategies

The document has a strong focus on problem-solving, with students assumed to study and apply several problem-solving approaches. For example, in Grade VI, students should *"Solve real-life problems related to HCF and LCM"* (page 40).

Overview of Logical Reasoning

The curriculum document introduces the conception of rational reasoning and validation in the middle grades. For example, in Grade VIII, students are expected to think logically and present arguments in a clear, complete, concise, and correct way.

Incorporation of Technology

The curriculum document suggests the usage of calculators and computers in proper places. For instance, in Grade VIII, learners are expected to *"Use MAPLE graphic commands for the two-dimensional plot"* (page 114).

Secondary and Higher Secondary Level (Grades IX-XII):

Rigorous Conceptual Development

The curriculum expects students to develop a rigorous understanding of advanced mathematical concepts. For example, in Grade XI, students learn about *"Complex numbers and their properties"* (page 4).

Advanced Problem Solving

Students are expected to solve complex, non-routine problems. For example, in Grade X, students should be able to solve *"real-life problems leading to quadratic equations"* (page 79).

Emphasis on Mathematical Reasoning and Proof

The curriculum places a strong emphasis on mathematical reasoning and proof. For instance, in Grade IX, students are expected to *"Prove theorems along with corollaries and apply them to solve appropriate problems"* (page 67).

Preparation for Higher Mathematics

The higher secondary curriculum aims to prepare students for university-level mathematics. Topics like "Matrices and Determinants", "Vectors", "Continuity and Differentiation", "Applications of Derivatives" etc. are covered in depth (pages 69-116).

Integration of Technology

The curriculum incorporates the utilization of mathematical software like MAPLE at the higher secondary level. For example, in Grade XII, a complete unit is dedicated to *"Introduction to Symbolic Package: MAPLE"* (page 113).

Discussion

The curriculum's findings on critical thinking skills

seem to be positive from the feedback they have received from educational organizations across Pakistan. As for each grade towards higher secondary school, you can see learning shift from basic concepts into advanced logic techniques and more consistent technology integration which later becomes essential skills needed beyond school work. At the most basic level (Grades I-III), the curriculum starts with concrete, real-life problems. Bartolini and Martignone (2020) said that this was smart and that using real, tangible stuff is good for young learners. NCTM (2014) also agrees — it's important to build a deep understanding of math. In middle school (IV-VIII), the curriculum takes a second look at the concepts taught in previous years, going deeper into skill proficiency and structured problem-solving strategies. This works well and Firdaus and Darari (2024) recommend it because they found positive impacts of this math learning module on developing CT skills. The curriculum uses technology when it needs to help students develop their critical thinking skills. Leung (2023) supports this strategy, suggesting that software, simulations, and computer games can be effective tools for visualizing your problems. The curriculum also prepares students for university by emphasizing proof and argumentation as early as Grade IX. Campbell et al. (2020) say that proof is one of the best ways to get kids' brains working fast. Students will then have no problem when they need to analyze or evaluate things later. To boost technological literacy skills some more, technology use is encouraged at higher secondary levels through tools like MAPLE. Setting up computer simulations has been proven by Erbas et al. (2022) in 2022 to have positive effects on math-related critical thinking development. There's just one thing though: all of these ideas sound good but you know how teachers are. Alsaleh (2020) says a lot could go down between now and then so there should be programs designed to teach teachers how to get their plans off paper and into practice instead. And even if things do go according to plan there's still no guarantee that a student will take an interest in what's being taught. Facione et al. (2020) say that the things that excite one student won't always excite another. They think it's best to just give everyone a chance and let them work on what interests them the most.

Conclusion

The current study analyzed mathematics curriculum grades I-XII (2006) regarding the incorporation of critical thinking skills. There is a strong emphasis on critical thinking keeping in view conceptual understanding. From the primary level there is described basic conceptual understandings, skills development, and foundation of problem-solving, the curriculum moves gradually towards logical reasoning and integration of the technology through the higher secondary level. There is a focus on different aspects like problem-solving, real-context situations, analysis, synthesis, argumentation, and reasoning to equip twenty-first-century learners with higher-order thinking skills. Moreover, curriculum implementation is required which may involve teachers' preparation, alignment of pedagogical practices with critical thinking skills, and keeping in view the contextual aspects. Also, there is a need for a continuous assessment, and collaboration with the stakeholders to ensure the purpose of the curriculum regarding higher-order thinking skills in mathematics to make the students' problem solvers and decision-makers of the twenty-first century.

Recommendations

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

- Professional development programs for teachers should be arranged.
- Alignment of assessment practices with objectives of critical thinking should be outlined.
- There should be encouraged student-centred and active learning strategies.
- Integration of technology should be focused throughout the curriculum.
- Critical thinking culture should be promoted with inquiry and questioning-based classrooms.
- Conduct continuous evaluation and refinement of the curriculum, involving all stakeholders, to ensure that it remains relevant and effective in fostering critical thinking skills in the rapidly evolving educational landscape.

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