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Pedagogical Practices for Critical Thinking Skills Development in Science Subjects: A Qualitative Study at Secondary Level

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Abstract

Critical thinking in science education has become a significant objective of the current global landscape. The current qualitative study explored pedagogical practices used by secondary school science teachers for the development of critical thinking among their students. The hermeneutic phenomenological approach was used to get the lived experiences of the twelve secondary school science teachers from public schools in the Sahiwal district of Punjab province. The sample was selected through a purposive sampling technique. Keeping in view the objective of the study, a semi-structured interview guide was developed based on the literature and experts' perspectives. Data were analyzed through the facilitation of Nvivo software. The findings of the study revealed a diverse range of pedagogical practices employed by secondary school science teachers including Socratic questioning through inquiry-based teaching, discussion methods, conversation, debates, cooperative learning like think-pair-share, activity-based methods, and problem-solving methods to develop critical thinking and face real-life challenges. Moreover, the study underscored the significance of these methods to engage the students and foster critical thinking among them in science subjects. The study also recommends professional development opportunities for secondary school science teachers, revising the curriculum and assessment methods, with resource allocation, optimizing student-teacher ratios, and establishing a culture of continuous improvement to increase the implementation of critical thinking-focused pedagogies in science education.

Keywords: *Critical Thinking Skills, Science Education, Pedagogical Practices, Qualitative Study, Hermeneutic Phenomenology.*

1. Introduction

Critical thinking has become a buzzword for the twenty-first century. In science education, globally, it has been focused on developing critical thinking among students. This approach equips students' ability to navigate different aspects of life offering critical thinking skills as an important skill for the twenty-first century (Bialik et al., 2015; Wagner, 2014; Yacoubian, 2020). It has been recognized as necessary for the development of reflective thinking (Akpur, 2020; Higgins, 2015) as it plays a significant role in different domains like technology, information, economics, and

science (Bailey & Mentz, 2015). In the contemporary era, CT has been focused on the evaluation of information for its effective utilization as it is emphasized by Zhang and Kim (2018).

In the scientific field, critical thinking has been defined differently as logical and autonomous thinking, with abilities of inferences, data interpretation, analysis, synthesis, evaluation, and decision-making. It also encompasses sound conclusions with the application of problem-solving techniques (Garner et al., 2016). The higher-order thinking skills also called critical thinking skills with the aspects of analysis, synthesis, and evaluation that are described in Bloom's taxonomy also classified as advanced thinking capabilities (Xiangjun et al., 2022).

The curriculum's advocacy on interactive and student-centered teaching strategy is congruent to the principles of constructivism and findings of several studies that underline the benefits of active learning in mathematics education (Asunka et al., 2018). By allowing scientific investigations, group projects, and encouraging creativity in students' work, a better learning environment for nurturing critical thinking skills is aimed at.

Some of the reasons that have led to international emphasis on this topic include its significant role in the education system. Critical thinking is considered one of the most important components of science teaching today (Qiang et al., 2020). This crucial line on how scientific knowledge gets to students is elucidated by Yacoubian (2020). To address the problem of rote learning, the Pakistani educational policy has recently changed, and as such, several strategies including CT have been proposed for achieving those objectives. This necessitates creating an appropriate socio-academic environment. Thus, the present study seeks to examine pedagogical techniques employed by secondary school teachers working in public schools only with a view to developing critical thinking abilities among their pupils. Such exploration helps in molding learners with relevant skills required to succeed in a fluid educational system. In international literature, critical thinking has been focused and highlighted. In the science education, critical thinking is an important aspect (Qiang et al., 2020) In the view of Yacoubian (2020), critical thinking has its important role in science education.

2. Objective of the study

1. To explore pedagogical practices used by secondary school teachers for the development of critical thinking in science subjects.

3. Research Question

1. Which pedagogical practices are utilized by secondary school teachers to develop critical thinking in students?

4. Review of the Literature

Critical thinking is an indispensable skill for the 21st century, and its significance in science education has been extensively acknowledged. According to scholars (Paul & Elder, 2019), critical thinking encompasses scientific observation, awareness of one's thinking process, active and organized engagement with subjects, and the application of acquired knowledge with effective communication. From a psychological perspective, critical thinking is intricately linked to behavior and decision-making processes, involving mental processes focused on problem-solving techniques (Verawati & Sarjan, 2023). Critical thinking is a logical process encompassing decision-making, problem-solving, openness, flexibility, analysis of arguments, counterarguments with supporting information, identification of misconceptions, drawing conclusions, and making suggestions (Hutasuhut, 2020).

The idea behind this research is that many researchers believe that critical thinking should be incorporated into science education programs globally. It is possible through critical thinking, which complements research and scientific methods used for generating valid knowledge bases

through observation and experiments. Inquiry based learning, team-work promotion, teaching critical thinking directly and problem solving, digital solutions as well as teacher influence towards attitudes of students are some ways we can approach this complex.

Other ways that CT skills building has been achieved include using cooperative learning method; while Marcos et al. (2020) and Warsah et al. (2021) aimed at fostering CT skills among field of study students particularly through practice-based approaches such as cooperative learning where student come together in small groups actively sharing ideas leading to development of CT skills. Consequently, apart from analyzing different issues it involves synthesis analysis and evaluation involving higher levels of cognitive thinking. To teach scientific subjects or inquiry based investigation group discussion has also been used effectively (Liou, 2021; Michael & Ephrem, 2022)

Questions and inquiry-based learning also contribute to the development of CT skills. The role of inquiry has been identified in several studies. Firstly, the discussion based on questions contributes positively to critical thinking development. The reason is that it provokes inquiry towards higher-order thinking, open-mindedness, analytical, inquiry, and evaluation-based questions. Different studies identified the association between the teaching method of questioning and the enhancement of critical thinking skills. Debates are a particular technique of helping the student in the development of critical thinking abilities has been used as well.

Problem-solving also involves a systematic approach to identifying and recognizing the problem situation, its definition, limitations, task analysis, collection of data, synthesis, evaluation, and recommendations with communications of results (Orlich et al., 2012). Moreover, critical thinking has been recommended with specific behaviors like the development of lesson plans focusing on thinking, thought-provoking questioning, awareness of students about their mental process, involvement in problem-solving, and provision of positive reinforcement.

In the Pakistani context, different studies have been conducted focusing on the development of critical thinking skills. In a study conducted by Buzdar and Ali (2013) about reflective thinking skills development through distance teacher education programs at Allama Iqbal Open University. The positive impact of AIOU teaching programs was explored to encourage critical reflection among students. In the same way, Khan (2017) conducted a study to explore the CT concept in the B.Ed/ADE degree programs of Pakistan. In the most recent era, different studies have been conducted in this perspective with different aspects like CT skills development in secondary school teachers with respect to teachers' perspective (Jamil et al., 2023); secondary school teachers' perspective about critical thinking skills development in English classroom (Jamil et al., 2024). In these studies, critical thinking has been focused on and admitted by the teachers to be developed in secondary school students. Different student-centered pedagogical practices like cooperative learning, group work, questioning, and discussion have been used for the development of CT in these studies (Jamil, 2021; Jamil & Muhammad, 2019; Jamil et al., 2021a, 2021b).

5. Research Methodology

This study adopted a qualitative research design to gain an in-depth understanding of the participants' real-life views regarding teaching science and fostering critical thinking skills (Astroth & Chung, 2018). Open-ended questions were employed in semi-structured interviews to explore teachers' perspectives on the topic within their teaching environment (Yazan, 2015). The current study used hermeneutical phenomenological approach due to getting lived experiences of the participants (Van Manen, 2023). For the selection of the sample, purposive sampling technique was employed. From four public schools of Sahiwal district, twelve secondary school teachers (one for physics, chemistry, and biology each) total three from each school were selected. During

selection procedures eligibility criteria outlined included teaching experience for at least one year within the same area where physics or chemistry or biology are taught. Primary data collection method used was semi-structured interviews which facilitated active exchange of views as well as thorough exploration of respondents' standpoints (Charmaz, 2017). An interview protocol was developed based on expert opinions and relevant literature that consisted broad open-ended questions as well as follow-up prompts for further information. The interviews were conducted in Urdu which is the national language then translated into English later for analysis. At the end of each interview debriefing sessions were held to summarize main ideas and elicit feedback ((Kvale, 1996). The interviews were audiotaped for transcription purposes and six of them are randomly selected to be checked by English language experts for translation accuracy. Data were analysed with NVivo software that facilitated a systematic rigorous analysis of qualitative data.

6. Findings of the study

The findings of the study are described as under keeping in view the objective. regarding the pedagogical practices employed by secondary school science teachers in fostering critical thinking skills among students.

7. Pedagogical Practices Employed:

7.1.Inquiry-Based Teaching:

Teachers emphasized the use of the Socratic questioning method as a key construct for developing critical thinking skills. They described starting classes by exploring students' existing thoughts on main topics, examining evidence, and revising mental models through questioning. One of the teachers explained it as: *"I start up by asking students of their opinions; we then challenge the information together toward strengthening or revising positions, examining critical plausibility" (Physics Teacher 1).*

7.2.Discussion-Based Pedagogy:

Classroom conversations and formats like debates over controversial issues were commonly used to compare perspectives, practice reasoning, and build collective knowledge. A teacher described this as: *"Working on real-world problems in groups helps students see grey areas…they become academically able to accommodate alternate legitimate perspectives" (Chemistry Teacher 1).*

7.3.Cooperative Learning Strategies:

Techniques such as think-pair-share, strategic pairing of students with differing abilities for peer tutoring and observational learning were emphasized to promote verbalization of thinking and collective cognition. One of the teacher narrated it as: *"When I put strong and weak students in groups and have them talk through problems, they both stretch their thinking, openly sharing reasoning" (Biology Teacher 2).*

7.4.Demonstration-Based Pedagogy:

Science teachers underscored the strong influence of demonstrations on secondary learners' cognitive growth, as experiential learning sharpens conceptual clarity and promotes problem-solving skills. A teacher described this technique as: *"Seeing theory manifest concretely imprints knowledge structurally…students intrinsically understand methodical investigation of natural phenomena" (Physics Teacher 3).*

7.5.-Based Methods:

Interactive and engaging activities such as live experiments, model construction, lab specimen analysis, and science project writing were cited as exercises generating procedural concept internalization and enhancing cognitive abilities. One of the participants described it as: *"Experimental demonstrations effectively solidify conceptual clarity which plain lecturing would not...active learning triggers analytical thinking" (Chemistry Teacher 2).*

7.6.Problem-Solving Approaches:

Linking critical thinking skills to real-life problems and current events fostered cognitive transformation through the integration of challenges and the use of ingenious resources in developing plausible analogies. A science teacher described this as: *"Once you apply computation to problems that can be seen and touched, it awful good, structured thinking...students get transferring their understanding for praxis, like in real life" (Biology Teacher 3).*

8. Conclusion

The study highlights the diverse range of pedagogical strategies employed by secondary school science teachers in fostering critical thinking skills among students. The teachers emphasize the significance of inquiry-based teaching through the Socratic questioning method, which encourages students to examine evidence, challenge existing notions, and revise mental models. Additionally, discussion-based pedagogy, such as classroom conversations and debates on controversial issues, is widely utilized to compare perspectives, practice reasoning, and build collective knowledge. Cooperative learning strategies, including think-pair-share and strategic pairing of students with differing abilities, are implemented to promote verbalization of thinking, peer tutoring, and observational learning, leading to collective cognition. What's more, demonstration-based teaching and activity-based strategies like live experiments, model construction, and lab specimens are used to improve conceptual understanding, internalize procedural concepts, and problem-solving skills. Findings also underscore the importance of critical thinking skills in real-life problems and current events, fostering cognitive transformation through challenges integration and development of plausible analogies.

9. Discussion

This study aimed to identify the pedagogical techniques that secondary school teachers use to develop critical thinking skills among students. It also sought to discover how effective these techniques were as well as any implementation issues teachers encountered. The study found that a wide range of teaching methods were utilized by participants in their classrooms including questioning, discussion, cooperative learning, demonstration, hands-on activities and problem-solving approaches (Wagner, 2014). These participatory methods are often very helpful in engaging students with content while also promoting critical thinking. The Socratic inquiry method was found to be the most highly regarded strategy for developing critical thinking abilities among participants. This approach involves encouraging students to express their initial viewpoints on key issues, followed by collaborative examination of evidence to support or modify those positions through active, critical evaluation (Wagner, 2014). However, the teachers cautioned that the potential of this method is often hindered by the prevalence of transmissionism paradigms and deference to authority, which can impede genuine, autonomous intellectual inquiry (Davies, 2015). Discussion-based pedagogy, such as classroom conversations and debates on societal problems, was also recognized as an effective instructional approach. These activities foster the comparison of diverse viewpoints, practice reasoning, and collective knowledge production (Wagner, 2014). One participant highlighted how group discussions on societal issues helped students understand the complexities and acknowledge intellectual "gray areas" (Davies, 2015). However, the effectiveness of these discussions was contingent upon establishing norms of constructive engagement within the peer environment (Wagner, 2014).

Cooperative learning strategies, such as think-pair-share discussions, were frequently employed by the teachers, as they promote verbalization of thought processes and problem-solving skills (Florea & Hurjui, 2015). Additionally, demonstration lessons and active learning activities involving group interaction and concept implementation were perceived as more effective than

lectures in reinforcing conceptual clarity and facilitating skills transfer and real-world problem-solving abilities (Wagner, 2014). Teachers observed that these kinesthetic learning experiences enhanced procedural knowledge, conceptual internalization, and cognitive abilities ranging from simple recall to evaluation and innovative thinking.

10. Recommendations

Based on the findings and conclusions, the following recommendations can be made:

1. Provide comprehensive professional development opportunities for teachers to enhance their skills in implementing inquiry-based, discussion-based, cooperative learning, and other interactive pedagogical strategies that foster critical thinking skills.
2. Revise curricula and assessment practices to align with the development of critical thinking skills, reducing the emphasis on content-heavy syllabi and rote memorization, and incorporating more open-ended, problem-solving, and higher-order thinking tasks.
3. Invest in classroom redesign and resource allocation to create learning environments conducive to interactive, student-centered activities, such as group work, hands-on experiments, and collaborative problem-solving sessions.
4. Implement measures to address overcrowded classrooms and optimize student-teacher ratios, ensuring that teachers have the capacity to effectively employ participatory and individualized approaches to nurture critical thinking abilities.
5. Establish a culture of continuous improvement and professional learning communities, where teachers can share best practices, reflect on their teaching strategies, and collaboratively develop innovative approaches to fostering critical thinking skills in their students.

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