Correlation between Socratic Questioning and Development of Critical Thinking Skills in Secondary Level Science Students

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Abstract

This study explores the nature of relationship between Socratic questioning and development of critical thinking skills in secondary level science students. Critical thinking skills are considered crucial for individual's survival in digital era of information processing. Social interaction in classroom is considered beneficial for development of critical thinking skills. It was a correlational research conducted in provincial public schools of Rawalpindi. Population constituted science teachers teaching at secondary school level and science students of secondary level. Sample of five interactive science teachers was drawn purposively from the population and their respective 125 students studying at grade 10^{th} were also selected to assess the developed skills. Data were collected using two instruments; observation sheet for teachers and observation sheet for students. Data were analyzed through SPSS calculating Pearson *r* correlation coefficient. Results have showed successive increase in development of students' reflective thinking and reasoning skills after engaging them in learning via Socratic questioning. It is concluded that Socratic questioning and development of critical thinking are strongly positively correlated. It is suggested to train teachers for better utilization of questioning while teaching science at secondary school level.

Keywords**:** *Socratic Questioning, Reflective Thinking Skills (RTS), Reasoning Skills (RS)*

1. Introduction

This study is rooted in social constructivism specifically Lev Vygotsky's Sociocultural theory. Which states that child development passes through two planes social plane; where he learns in interaction with people in his surroundings and then this socially learned knowledge is internalized by the children at individualized plane memorizing that information (Le et al., 2024; Kilag et al., 2024; Mahmud & Tryana, 2023). Social interaction between learners adds in their overall personality development. As human being it's impossible to avoid facing hurdles and crucial problems throughout the journey of life. To cope with such situations and wisely solve the encountered challenges everyone needs to think critically and logically (Adeyemi, 2012). A person with well-

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developed critical thinking skills can confidently believe their judgments catering such difficulties (Abdullah et al., 2022). It is the responsibility of educationists to dig into the ways of involving students in their personalized social learning within varying educational contexts.

Cultivation of critical thinking is crucial for individual survival and development in 21st century to solve the real world problems of complex nature (Jamil et al., 2024; Pitorini, 2024) and process information intelligently in upcoming digital era. Reflective thinking and reasoned decision making as elements of critical thinking are requirement of digital age youngsters to analyze information being provided by their surrounding world (Cottrell, 2017). Reasoning involves interpretation, analysis, evaluation, explanation, sequence, questioning and finally taking informed decisions (Tuzlukova & Usha, 2018). Students with well-developed critical thinking are supposed as better dynamic candidates fulfilling the demands of 21st century employers (Shaheen, 2024). Development of these skills is considered as lifelong transferable skills which prepare young learners for their future careers (Elder & Paul, 2020). With rapid technological development students have access to much more information than ever before; it is needed to make them skillful for extraction of valid, reliable, true and healthy information out of that junk (Jamil et al., 2024). Mahoney et al., (2023) endorsed that students can be developed into skillful individuals if we focus such developments not only at initial learning stages but throughout their schooling years. School years are critical for leaner's personality development.

Globally scholars and educationists are focusing on development of critical thinking skills; reflective thinking and reasoning as lifelong learning skills and fulfilling need of the students beyond school boundaries in their lives (Jamil et al., 2024; Shaheen et al., 2024). Development of critical thinking skills is demand of 21st century labor market (Karakoç, 2016). Despite various calls for development of reflective thinking and reasoning skills, it is still being considered difficult to be developed or taught at school level (Radulović & Stančić, 2017; Slameto, 2014; Tapung et al., 2018). Need of teacher's professional development for switching between teaching techniques for development of critical thinking skills is also highlighted (Firdaus & Darari, 2024). It is responsibility of the educational researchers and curriculum developers to dig into the appropriate teaching strategies.

Interactive pedagogies are stated beneficial for the development of critical thinking skills; reflective thinking and reasoning skills. Critically examining and understanding the need of development of desired skills at school level along demand of exploring teaching strategies helpful in this conception, specific study was designed with an objective to investigate the relationship

between Socratic Questioning and development of critical thinking skills in secondary school science students. Researcher classified critical thinking into reflective thinking and reasoning skills in this particular study.

1.1 Objectives of Study

Objective of this study included to;

1. Investigate the relationship between Socratic Questioning and development of critical thinking skills in secondary school science students.

1.2 Hypotheses of Study

Following hypotheses were designed to address the research objective;

H_{01}: There is no significant relationship between Socratic questioning and development of reflective thinking skills in secondary school science students.

H_{02}: There is no significant relationship between Socratic questioning and development of reasoning skills in secondary school science students.

1.3 Significance of Study

This study would be helpful for curriculum developers, educators and students to understand the significance of student's active participation in classroom for their holistic development. It will broaden professional development agencies and teacher's viewpoint for adoption of most suitable teaching approaches for development of student's critical thinking and make them adaptable to future endeavors.

2. Literature Review

National curriculum (2006) emphasizes the adoption of interactive teaching methods at higher level of schooling while teaching sciences for development of reflective thinking and reasoning in students (Shaheen, 2024).Curriculum seeks students to get involved in real world problems, engage actively in learning and extending their experiences and thinking abilities. It can be made possible by adopting interactive class talks in form of Socratic questioning at school level (Shaheen et al., 2024). Preconception or questioning in the hypothetical form is the main notion of the Socratic questioning (Sharma, 2022) that instigates the students thinking processes (Chang et al., 2024) and provides a broad view (Acim, 2022). Such kind of questioning allows students to think wisely, reflect back and strengthen their reasoning abilities. Questioning is useful for the improvement of higher-order thinking skills; like reflective thinking and reasoning skills (Suhadi, et al., 2014). Instigation is the process of stirring ones cognition to expand and think realistically about any question or situation. It is initiated by frequent and subsequent questioning. Kinney (2022)

stated that probing and asking for logic underlying any response are some techniques for development of reasoning and reflective thinking skills.

Several teaching methods have been approved beneficial for development of critical thinking skills among students; Socratic questioning is one of them being used by teachers at school and university level. It was introduced long ago by Greek philosopher, Socrates. Socratic questioning allows students and teacher's conversation around the topic being taught. Questions and answers between them makes classroom environment more proactive and interactive. In such an environment teacher pretends unawareness of the topic under discussion to fully involve students to come up to the needed understanding level. It also allows both participants to contemplate at equal level. It becomes source of close bonding between teacher and students. It develops logical argumentative classroom environment (Abdullah et al., 2022; Suhardiana, 2019). Being such a critical thinker is the highest stage of one's development, it also aligns with development of high quality competencies like reflective thinking and reasoning skills among students.

Merriam Webster Dictionary (2022) defines Socratic questioning as an inquiry approach popularized by Plato and characterized by Socrates usage of investigation to reach desired correct answer in all respects for every participant of the communication. In other words it revolves around logically reviewing and considering all possible situations and opinions and coming up to correct on the basis of reflective thinking and reasoning skills. According to Collins English Dictionary (2022) Socratic questioning is technique employed by Socrates to train his students to reach truth by questioning and answering within a socially interactive classroom. Where both teacher and students may converse at the end unit taught to pass through a practice to think logically out of multiple opinions and select best one. In other words it's simply a two way listening and response based training technique to communicate wisely, reflect logically and to reach reason based conclusion within classroom settings.

Socratic questioning owns growing recognition in current times for development of higher order thinking skills (Chang et al., 2024; Abidah, 2022) as this method is quite different from traditional teaching methods fostering reflevtive thinking and reasoning in an environment of intellectual exploration (Hu, 2023; Rahimdjanova, 2024; Chian, 2020). Exploration is the student's practice of searching for the correct responses to any question or set of questions raised by the teacher (Kinney, 2022). The most widely seen practice is that teachers leave the students with an assumption in question and let the students explore, second option that is not much widely used is that students explore at their own without the help of any relevant hypotheses while the last most

accepted way of exploring information is that teacher and students together explore the required phenomenon by considering counter examples put forward (Acim, 2022) by the teacher or students. The focus of the Socratic dialogue is to broaden the student's viewpoint (Montazeri, 2022) and let them explore their surroundings by instigating their reflective thinking and reasoning via hypothetical questioning (Sharma, 2022) and let them develop critical thinking; reflective thinking and reasoning skills (Mahoney et al., 2023).

Various studies have highlighted the need of integrating reflective thinking and reasoning skills with curriculum at school level specifically in Pakistani context. Shaheen (2024) in her dissertation found Socratic questioning positively correlated with development of reflective thinking skills at elementary school level. Jamil (2024) conducted content analysis of chemistry curriculum, Biology and Physics for fostering critical thinking with curriculum content (Jamil, et al., 2024; Jamil & Muhammad, 2024) and SNC of Social Studies (Jamil et al., 2024; Naseer et al., 2022) and further more a study found significance of social interactive teaching techniques in development of said skills by Shaheen et al. (2024). All these studies addressed the need for development of critical thinking skills at school level as first and foremost priority and looking for the pedagogical practices required for development of these skills. Research study conducted by Akhmedov et al. (2024) validated the significance of questioning in development of student's critical thinking. The potential of instigation, probing and exploration in triggering the student's critical thinking in variety of contexts is evident from literature. Based on evidences this study is planned in Pakistani context at secondary level to unwind the relationship of Socratic questioning and development of reflective thinking skills and reasoning skills.

3. Research Methodology

3.1 Research Design

This study is social constructivism based empirical research. It has followed quantitative research approach and designed with basic purpose to find nature or strength of relationship between two variables; Socratic questioning and development of critical thinking skills at secondary school level. It was conducted on 10^{th} grade Science students. Correlation research design is well-thought-out for investigating the relationship between various variables within short period of time without manipulating any of the variables (Creswell, 2019). Frist set of continuous data were collected from teachers through quantified observation checklist and second set of data were obtained from students through researcher developed observational checklist.

Correlational research design was adopted to explore the nature of relationship between Socratic questioning in the science classroom and development of critical thinking skills among participant students (Harefa, 2023). This design supports in exploring both strength and the direction of relationship.

3.2 Population and Sampling

Secondary level (10^{th} grade) fifteen science teachers adopting Socratic questioning during teaching and respective (450) students in their classrooms studying in provincial public schools of city Rawalpindi were taken as the population of study.

To reach up to desired sample for data collection purposive sampling technique was adopted. It is suitable type of non-probability sampling to select participants of interest for collection of data (Gay et al., 2012). Teachers involving their science students in Socratic questioning while teaching and their students were concern of the researcher. Desired sample of five teachers were purposefully selected along their respective students which were around 125 students of 10^{th} grade. Hence 5 teachers and 125 students were selected to be observed for the data collection.

3.2 Instrumentation

Two instruments were used by the researcher to dig into the phenomenon of interest. They were observation sheet for teachers and observation sheet for students.

3.2.1 Observation Sheet for Teachers

It was developed to rate the observation of teachers adoption of maximum interaction in form of Socratic questions with students. This checklist was finalized after extensive reading of literature, selection of common sub-constructs and indicators of interest extended up to validation pilot testing. Rigorous observation checklist was designed and utilized for recording teacher's classroom performance. Teachers were rated on 5 point Likert scale varying from 5: Always 4.Mostly, 3.Sometimes, 2.Rarely 1.Never adopted by Maren, et al. (2021). It was validated by five experts of the field and pilot tested on three teachers to get its reliability coefficient that was 0.80. Detail is being given,

	Indicators	No. of items	α
Socratic Questions	Questioning frequency & Flow	03	.78
	Probing & Logic	02	.79
	Information Provision & Exploration	02	.84
	Consideration of Counterexamples	02	.78
	Understanding of basic principles	02	.83

3.2.2 Observation Sheet for Students

Critical thinking based instrument used in the study was an observational checklist. It constituted 9 point rating scale developed by the researcher to rate the level of development of each skill in the student. Their level of development was categorized into low (1-3), medium (4-6) and high (7-9). Critical thinking was classified in reflective thinking and reasoning skills. Both constructs were again subdivided into sub-constructs and indicators. Reflective thinking was broken down into following common sub-constructs; thinking for action, considering properties of situation, analysis of reasons, comparison, giving reasons for choosing actions, and reconstructing situations. Reasoning was divided into these sub-constructs; ability to set goals and priorities, identification of suitable options, analysis of options, create logical links, selection of option, and rationale of selecting option. It was validated from five experts and pilot tested to calculate reliability coefficient that was 0.82.

Critical Thinking Skills	No. of items	α
Reflective Thinking	11	0.83
Reasoning Skills	09	0.82

3.3 Critical Thinking based Tasks for Students

Content free critical thinking based tasks were developed after extensive reading of literature and discussions with subject experts. Tasks were designed and executed within the classroom after specified time duration encompassing couple of activities for students to get involved. Tasks were comprised of predefined scoring criteria for each activity completed by students. Their skills were rated on observation checklist parallel to the task performance and written responses. In designing these tasks help was taken from the studies of Llopis-Albert and Rubio (2021) and Eadie et al. (2021). Validity of the tasks were ensured from five subject experts, these were amended, retained and discarded on the basis of experts' opinion.

	Assessment		
Task	Performance	Skills	Tool/s
Content Free	Group	Reflective thinking	Observation
Task	Discussion	Reasoning	Written Response

3.4 Data Collection

Data were collected by the researcher through teacher and student's observation sheets.

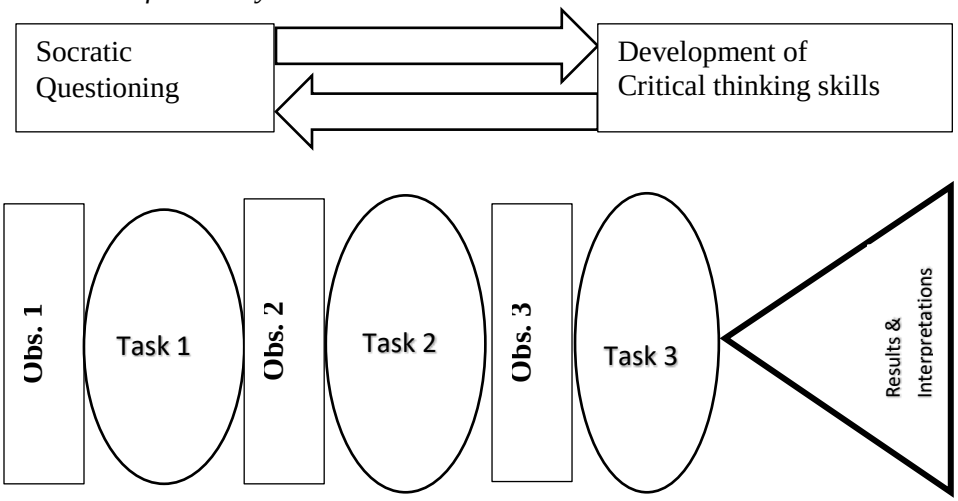
3.5 Procedure of the Study

Researcher was interested in the teacher's practice of instigating students while studying science subjects through Socratic questions. This was ensured by obtrusively observing five teacher using observation checklist for three months.

Student's data were collected at three time slots after first month, after second months and lastly after third month of teacher's observation on 9 point rating scale while being engaged in performing first, second and third tasks based on critical thinking skills. Nine points categorized into low (1-3), medium (4-5) and high (6-9) levels of skill's development. This data were utilized to measure the level of student's developed skills due to involvement in Socratic questioning.

Figure 1

Procedure of the Study



4. Data Analysis and Interpretation

Data collected through teacher and student's observation sheets were tabulated and presented using mean and standard deviation. Both paired data sets were correlated using Pearson *r* correlation.

Table 1

Descriptive of teacher's adoption of Socratic Questioning

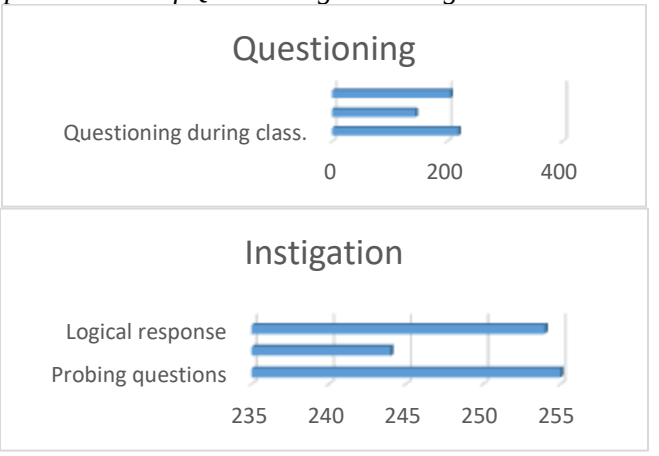
Sub-Construct	Statements	Scale 1 %	2 %	3 %	4 %	5 %	Ranking
Questioning	Questioning during class	--	16.7	--	83.3	--	220
	Subsequent questions	8.3	41.7	50.0	--	--	145
	Questioning flow	--	6.7	43.3	50.0	--	206
Instigation	Probing questions	--	--	16.7	41.7	41.7	255
	Student's reasoning	--	--	25.0	43.3	31.7	244
	Logical response	--	--	20.0	36.7	43.3	254

	Information provision	--	--	16.7	41.7	41.7	255
Exploration	Students explore	13.3	63.3	23.3	--	--	126
	Contextual examples	--	--	16.7	40.0	43.3	256
	Welcomes counterexamples	--	--	16.7	33.3	50.0	200
	Understanding of content	--	--	--	25.0	75.0	285
Focus	Understanding of concept	--	--	--	50.0	50.0	270

Table 1 is displaying data regarding the question sub-construct of the Socratic Method. Frequency percentages and ranking of statements are tabulated in it. Two statements against its indicator questioning frequency were developed. 83.3% of teachers were mostly focusing on questioning during class. While only half (50.0%) were raising succeeding questions while 41.7% were rarely asking successive questions and 8.3% never raised any subsequent question. Another point that was noticed during the observation was the direction of the flow of questions; half teachers were observed with the tendency of mostly asking questions and providing fewer chances of questioning to teachers during the whole session. 43.3% were sometimes flowing questions in the class while they were also providing students with an opportunity of asking questions. So the majority of teachers were asking systematic, contextual, and clear quality questions while few were allowing students to ask questions freely and fewer (6.7%) were rarely providing such opportunity to their students. Ranking data in figure 4.6 showed that the highest calculated score (220) of rating was allotted to the fact that the majority of teachers were questioning during class while the second highest ranking (206) was awarded to the flow of questions from teacher to students.

Figure 2

Graphical Representation of Questioning and Instigation

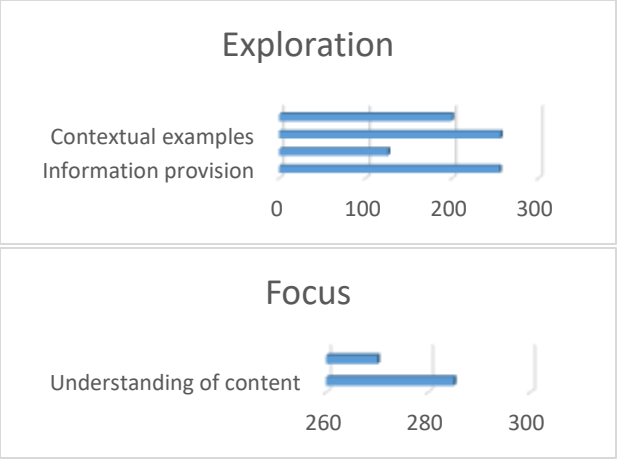


Instigation was expanded into probing and logic. Overall view of the data showed high ratings towards probing and asking logical questions from teachers' end. 43.3% of teachers were always encouraging students for giving logical responses and 36.7% of teachers most of the time used this technique. 41.7% of the teachers were always asking probing questions after receiving a bit confusing response from the student and the same (41.7%) was the percentage of teachers adopting this technique most of the time during their teaching. 43.3% of teachers were instigating their student's minds for most of the instances to find and place reasons of any happening to give in response to questions. 255 was the highest ranking received for the statement developed against probing questions based on students' responses. Nearly the same (254) ranking score was secured by the statement that teachers were encouraging logical responses. These ranking details have been portrayed in graphical form for clear understanding in Figure 2.

Most of the teachers were rarely allowing students to explore at their own. Half (50.0%) of the teachers were welcoming counterexamples from students and 43.3% of the teachers were always sharing contextual examples with students. Hence the majority of teachers were extending the conversation by providing clarification and contextual examples to the students. Such examples became grounds for students' thinking for the right example or right response for argument building. Such practices helped in building ethical arguments and became a source of production of solid and legitimate examples by students and teachers interaction. Ranking details are shown in figure 3. Which exhibited that a highly rated response got a 256 score for the provision of context-related examples.

Figure 3

Graphical representation of Exploration and focus of Socratic Questioning



Almost 75.0% of the teachers were always focusing on students' understanding of content while 25.0% were mostly looked at working for the same. Whereas student's attainment of conceptual understating of students using the interactive method was the focus of all the teachers half (50.0%) were always working on conceptual understanding of students while the remaining half (50.0%) were mostly portraying it as their focus of the teaching-learning process. By asking analytical, explanatory, probing, and instigating questions for extraction of comments and counterexamples from students referring to a specific part of the content /principle to be taught, teachers focused on students' conceptual understanding.

Table 2

Socratic questioning and development of critical thinking skills (RTS, RS) Task-I

Skills	Socratic Questioning	
	Pearson Correlation	Sig.
Reflective thinking skills	.570*	.014
Reasoning skills	.511*	.030

Table 2 is portraying data of students critical thinking skills observed after one month performance during task-I. Data showed a weak positive correlation (.570*) between reflective thinking and Socratic questioning and reasoning skills (.511*) and Socratic questioning at 0.05 level of significance.

Table 3

Socratic questioning and development of critical thinking skills (RTS, RS) Task-II

Skills	Socratic Questioning	
	Pearson Correlation	Sig.
Reflective thinking skills	.680**	.002
Reasoning skills	.605**	.008

Table 3 is showing data of student's second observation taken during task-III. It is showing a moderate positive correlation between reflective thinking (680**), reasoning skills (605**) and Socratic questioning at 0.05 level of significance.

Table 4

Socratic questioning and development of critical thinking skills (RTS,RS) Task-III

Skills	Socratic Questioning	
	Pearson Correlation	Sig.
Reflective Thinking Skills	.780**	.000
Reasoning Skills	.805**	.000

Table 4 is showing data regarding correlation among adoption of Socratic questioning and development of reflective thinking skills and reasoning skills. Development of reasoning skills among 10^{th} grade science students and adoption of Socratic questioning by Science teacher also produced highly

significant (.805**) with strong positive correlation (.000). Whereas development of reflective thinking skills also proved positively and significantly (.000) correlated (.780**) at 0.05 level.

It is shown if teacher adopts Socratic questioning while teaching Science subjects at secondary level (grade 10^{th}) it triggers the development of reflective thinking and reasoning among corresponding students. It may develop due to thinking process involved while responding to the hypothetical questions asked by the science teacher, mental processes involved while coming up to the correct response by students to the teacher may strengthen the student`s reflective thinking as it involves the recalling of past events or previously learned concepts and relate them to answer the questions. All this processing of mental and real world information to reach decisions helps development of student's reasoning abilities as well. Hence it is concluded that adoption of Socratic questioning at secondary level helps in the development of student's critical thinking which the demand of this digital age is.

5. Discussion and Conclusion

The researcher aimed to explore the role of Socratic questioning in development of critical thinking skills (reflective thinking and reasoning). It is found that if teacher adopts Socratic questioning while teaching Science subjects at secondary school level; it triggers the development of reflective thinking among corresponding students. Stated results are consistent with the study of Chang et al., (2024); Ho et al., (2023) and Mohamad and Tasir, (2023). It may develop due to thinking process involved while responding to the hypothetical questions asked by the teacher, mental processes involved while coming up to the correct response by students to the teacher may strengthen the student`s reflective thinking and reasoning as it involves the recalling past events, previously learned concepts and relating them to answer contextual questions. Thinking, investigation and raising questions enhance the student's higher order thinking skills (Saracoglu, 2022) and hence strengthen their critical thinking skill development. Rational thinking is the skill demanded for intelligent decision making self-organization and time management. Teachers adopted social interactive features of Socratic questioning for development of reflective thinking and reasoning among students. Vogelsang et al., (2022) expressed thinking process as important for effective planning and holistic development. Critical examination triggers an individual's reasoning and reflective thinking practices this fact is replicated by Mahoney et al. (2023) in their study designed to evaluate secondary vocational level lessons highlighting Socratic dialogue for thinking transforming strategy. Aydin et al. (2022) concluded in their reflective thinking based study that questioning enhances reasoning and evaluation skills. It is found

in this certain study that students' abilities to consider properties of contextual situations in detail were developed after getting involved in interactive learning experiences through Socratic questioning. These are consistent with the results of Aydin et al. (2022) study results; they suggested that involvement of students in questioning develops student's reflective thinking and reasoned decision making skills. Results are also replicating the findings of mixed method study conducted by Sulaiman and Ahmed (2020) in Omani post-basic school students. Development of critical thinking skills help students become self-reliant and enhance teacher and student's self-efficacy level (Saracoglu, 2022) for resilient survival in their professional careers.

It is also found by Manurung (2019) in study conducted at University of Muhammadiyah Sumatera Utara Medan, that Socratic questioning significantly improves student's self-confidence and reflective thinking and reasoned decision making a well. However to efficiently use it in educational settings it is requisite to understand thinking process and its evaluation patterns completely to get maximum benefits. Paul and Elder (2007) has also suggested questioning can also be utilized to get decent worth of reasoning among students. Lipman (1991) also stated significance of Socratic questioning in development of strong reasoning and confident, valuable reflective thinking skills.

Socratic questioning proved effective for development of student's reflective thinking skills. Results are aligned with Delic and Becirovic (2016) in their study "Socratic Method as an Approach to Teaching" mentioned that Socratic questioning improves student's logical reasoning. As this method provides a ground for informative and directional dialogue and questioning hence it provokes their cognitive abilities and they try to answer after practicing logical reasoning for deciding a right answer. A Widyatama University based study also demonstrated that Socratic questioning enhances critical thinking skills along deepest level of learner development like reflective thinking and reasoned decision making instead of focusing on surface level knowledge accumulation. Students need to be actively engaged in higher order questioning and analytical opportunities for development of strong reflective practices and to create logical links between multiple complex ideas and situations (Gunawan et al., 2024). Results of this particular secondary school based study are consistent with researches conducted in varied educational settings (Ibarra & Cadenas, 2022; Chang et al., 2024; Dhuha & Manik, 2023) Socratic questioning is also proven beneficial for development of critical thinking skills in nursing education (Mahmud & Tryana, 2023; Dinkins & Cangelosi, 2019; Makhene, 2019). However these results are contrary to the results of study conducted at Indonesian university (Abidah, 2022; Ismah & Muthmainnah, 2021; Dalim et al., 2022)

explaining limited scope of Socratic questioning in development of critical thinking skills. That may involve some cultural restrictions along allowing minimum social interaction within classrooms.

It is concluded on the basis of findings that adoption of Socratic questioning is positively correlated with development of reflective thinking among secondary level science students. Hence first research hypothesis is accepted and null hypothesis H_{01} is rejected. Second null hypothesis that Socratic questioning is negatively correlated with development of reasoning skills in secondary level science students is also rejected on the basis of findings and its alternate research hypothesis is accepted. Hence it is concluded that Socratic questioning has significant positive correlation with development of critical thinking; reflective thinking and reasoned decision making among school level students.

6. Recommendations

On the basis of contextual findings of the study following recommendations are being put forwarded;

1. Teachers may utilize hypothetical questioning for development of these skills at various educational levels.
2. It is needed to upgrade the national curriculum and provide supplementary content for secondary level to elaborate multidisciplinary concepts; to enhance relevance and authenticity of the contexts for students to apply and nurture their critical thinking skills across various disciplines.
3. Critical thinking skills can be developed in interactive class environment; teachers should be trained adequately for adoption of Socratic questioning in Science classrooms for achievement of objective.
4. Researches are needed to be planned and executed at various educational levels to better devise the mechanism of adopting Socratic questioning for development of critical thinking skills.

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