

EFFECTS OF QUESTION FORMULATION TECHNIQUE INSTRUCTION ON LOWER SECONDARY STUDENTS' CRITICAL THINKING SKILLS

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ABSTRACT

The objective of our study was to compare lower secondary students' critical thinking skills before and after being taught through the Question Formulation Technique instruction (QFT). The participants were lower secondary students (N = 29), which were selected by purposive sampling approach. Research design was the pre-experiment one group pretest-posttest design. Participants were taught the fundamental content of the Chemical reactions and Materials in everyday life from Thailand's Core Standard Curriculum (revised edition 2017). Over 15 sessions (750 minutes), students engaged in QFT-based activities aimed at fostering critical thinking skills. Critical thinking skills was assessed using five components: Interpretation, Evaluation, Inference, Explanation, and Analysis.

The results revealed a statistically significant improvement in overall critical thinking skills ($p < .05$), with notable gains in Analysis and Evaluation, but no significant changes in Interpretation, Inference, and Explanation.

Keywords: Question Formulation Technique, Critical Thinking Skills, Science Education

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INTRODUCTION

Over a decade, McDonough (2024) asserted that the world has entered in the Generative AI era, which plays a crucial role in students' science learning, in terms of improving knowledge, skills, attitudes, and/or competencies (Nagelhout, 2024). However, Technology (2024) highlighted that AI can feed biased and/or unsourced information to users through predictions. In this context, critical thinking skills defined as the set of skills for thinking carefully and reasoned judgments are indispensable for students (Facione, 1990).

Critical thinking skills originate from ability to ask questions as mentioned in one of Kelley-Mudie's (2016) research which stated questioning can broaden perspectives and enhance the analysis and evaluation of statements in depth, influencing individual concepts and beliefs.

Later, the Question Formulation Technique (QFT) was first introduced in the book "*Make Just One Change: Teach Students to Ask Their Own Questions*" by Rothstein (2011). He stated that QFT is an instruction that emphasizes helping students learn how to ask questions systematically through practicing question formulation, understanding different types of questions, prioritizing questions, and planning how to use those questions effectively.

Moreover, QFT has been continuously studied in the field of education. According to Torres Garibay's research (2020), more than 250,000 educators around the world have used QFT in their teaching, and it has been applied at all educational levels from preschool to higher education and across all disciplines. Similarly, Clark (2017, 2019) found that QFT can enhance students' curiosity, and studied by Cummings (2020) reported that QFT also promotes student engagement in learning.

Therefore, in this study, we investigate whether QFT instruction could affect critical thinking skills by comparing lower secondary students' critical thinking skills before and after being taught through QFT instruction.

LITERATURE REVIEWS

Definition of Critical Thinking Skills

Danczak (2018) synthesized previous studies and found that critical thinking has been defined differently depending on the context of each discipline namely philosophy, cognitive psychology, and education.

Philosophical perspective, according to the Delphi Report by Facione, which compiled opinions from 47 philosophers and experts, critical thinking skills are defined as "*purposeful judgment about information, evidence, concepts, methodologies, or criteria through the use of interpretation, analysis, evaluation, inference, and self-regulation skills.*"

Cognitive psychological perspective, cognitive psychologists define critical thinking as "*a set of cognitive skills, strategies, or behaviors that increase the likelihood of achieving a desired outcome*". Halpern further stated that this set of skills includes thinking necessary for problem-solving, making inferences, decision-making, reasoning, and analyzing arguments.

Educational perspective, research in the field of education defines critical thinking as "*a set of skills*". Dressel and Mayhew further explained that this set of skills include identifying key ideas, examining underlying assumptions, evaluating the credibility of evidence, and drawing reasoned conclusions.

Based on these definitions, the researcher concludes that critical thinking is a set of thinking skills that form part of reflective thinking, leading to rational decision-making regarding studied issues. It consists of interpretation, inference, analysis, evaluation, explanation, and self-regulation skills.

Components of Critical Thinking Skills

Facione (1990) proposed a standard framework for the development and assessment of critical thinking skills, consisting of six main components as follows:

Interpretation - Refers to identifying and understanding the meaning or significance of various experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria.

Inference - Refers to analyzing available data and facts by connecting relationships among pieces of information to draw reasonable conclusions.

Analysis - Refers to distinguishing or identifying relationships among information, questions, concepts, explanations, beliefs, judgments, experiences, reasons, or opinions.

Evaluation - Refers to examining and judging the credibility, logical strength, or weaknesses of statements, explanations, descriptions, perceptions, experiences, situations, decisions, beliefs, or opinions.

Explanation - Refers to presenting one's reasoning derived from thinking or analyzing statements, explanations, descriptions of perceptions, experiences, situations, decisions, or beliefs.

Self-Regulation - Refers to monitoring and evaluating one's own thinking processes in order to develop and improve them for greater effectiveness.

Question Formulation Technique (QFT) Instruction

Instruction using the Question Formulation Technique (QFT) refers to an instruction that centers on **questioning as the core of learning**, aiming to promote systematic question formulation among students (Cummings, 2020). Rothstein (2011) proposed the following steps:

1) The Question Focus (QFocus)

The teacher creates a scenario (QFocus) for question formulation. The QFocus may be a text, phrase, image, video, sound, experiment, situation, or any other material. It should be simple, clear, provide minimal additional information or explanation, and must not be a question.

2) Producing Questions

Students generate questions from the QFocus by following these rules:

Ask as many questions as possible.

Do not pause to discuss, judge, or answer any questions.

Write down every question that comes to mind.

Convert every sentence into a question.

3) Improving the Questions

The teacher teaches the definitions of open-ended and closed-ended questions so students can classify their own questions—marking open-ended questions with “O” and closed-ended questions with “C.” Then, the teacher and students discuss the advantages and disadvantages of each question type. Students select one interesting question of each type and then convert those questions into their opposite type.

4) Prioritizing the Questions

Students select the three questions they are most interested in and explain their reasoning. The selected questions must align with the QFocus. Minimal or no teacher interaction is allowed at this stage to avoid content bias influencing the students' selection.

5) Reflecting on Learning and Planning Next Steps

Students reflect on what they have learned, how they have learned it, and what has changed after engaging in the process of QFT. Then, the teacher and students collaboratively set goals for how to use the questions they have developed.

6) Using Questions to Discover

The teacher selects and organizes students' questions to design learning activities that align with the learning objectives, content context, and students' readiness levels.

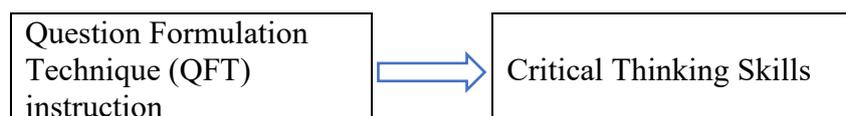
The Relationship between QFT Instruction and Critical Thinking Skills

We synthesized and analyzed the relationship between the steps of QFT instruction and critical thinking skills, as presented in Table 1:

Table 1: relationship between QFT instruction and critical thinking skills

Steps of QFT	Sub-skills of critical thinking
Presenting a QFocus which requires students identify the key points of QFocus as formulating questions.	Interpretation is the ability to identify main ideas or essential points from experiences, texts, or situations.
Posing questions have structure to prompts students connecting their prior knowledge with new information (QFocus) to form conclusions in questions.	Inference is defined as the ability to draw logical conclusions and form ideas based on evidence and prior knowledge.
Improving the Questions which requires students classify their own questions into open-ended and closed-ended types, then convert them into the opposite type and consider the advantages and disadvantages of each.	Analysis is the ability to identify relationships among data, questions, concepts, explanations, beliefs, judgments, experiences, reasons, or opinions.
Prioritizing the Questions which requires students select the three questions they are most interested in and explain their reasoning, which must align with the QFocus.	Explanation refers to the ability to present in a cogent and coherent way the results of one's reasoning Evaluation is the ability to examine and judge the credibility, reasonableness, or strengths and weaknesses of statements, explanations, descriptions of perceptions, experiences, situations, decisions, beliefs, or opinions.

From the literature review, the conceptual framework can be drawn as shown in Figure 1.

**Figure 1** Conceptual Framework

RESEARCH METHODOLOGY

Research design was the pre-experiment one group pretest-posttest design.

Participants and Sampling

The participants were lower secondary students (N = 29), which selected by purposive sampling approach.

Data Collection Procedures

- 1) Contacted the Grade 9 science teachers to explain the research objectives, expected benefits, and data collection timeline.
- 2) Prepared official letters requesting cooperation in data collection and the use of school facilities and equipment, one copy each.
- 3) Sent the letters to the science teachers to forward to the school principal's office.
- 4) Selected one classroom of 29 students who had been taught content on the "*Chemical Reactions and Everyday Materials*" align with the Basic Education Core Curriculum B.E. 2551 (Revised 2017), including:
 - 4.1) Rusting of iron
 - 4.2) Reactions of acids with metals
 - 4.3) Reactions of acids with bases
 - 4.4) Reactions of bases with metals
 - 4.5) Combustion reactions

This selection was based on Oyama's (2017) research, which indicated that students need prior content knowledge; without it, their questions were often limited to recall and comprehension levels according to Bloom's Cognitive Taxonomy. Similarly, Otero (2009) stated that teachers must ensure students have foundational knowledge, as lacking this results in basic factual questions (e.g., "What is...?"). In contrast, students with prior knowledge can generate questions that stimulate higher-order thinking. Similarly, Scardamalia (1992) compared student questions on two topics: "Fossil Fuels" (students lacked knowledge) and "Endangered Animals" (students were familiar with the content). The study found that lack of knowledge did not significantly affect the number of questions; however, unfamiliar content led to questions about basic facts, whereas familiar content prompted questions reflecting epistemic curiosity.

5) Collected pretest data on students' critical thinking skills assessment before implementing the QFT instruction.

6) Conducted QFT instruction over 15 class periods, each 50 minutes (Boonsathirakul, 2023; Surin, 2024) in the first semester of the 2025 academic year.

7) Collected posttest data on students' critical thinking skills assessment after completing the QFT instruction.

Research Instruments

Critical Thinking Skills Assessment consists of 30 items of multiple-choice, measuring each component of critical thinking skills as follows: Interpretation: 7 items, Evaluation: 6 items, Analysis: 7 items, Inference: 5 items, Explanation: 5 items (Danczak et al., 2017)

RESEARCH RESULTS

Comparison of Students' Critical Thinking Skills before and after Instruction Using QFT

This table presents the results of normality tests conducted on students' critical thinking skills scores before and after instruction using QFT. It indicates whether the distribution of the pretest and posttest scores meet the assumption of normality.

Table 2 Tests of Normality for Students' Critical Thinking Skills Scores

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Interpretation	.180	29	.017	.918	29	.028
Evaluation	.186	29	.012	.935	29	.072
Inference	.294	29	<.001	.850	29	<.001
Explanation	.232	29	<.001	.871	29	.002
Analysis	.138	29	.169	.952	29	.203

From Table 2, the normality test using Shapiro-Wilk (for $N < 50$) showed that the Evaluation component had a significance value of .072 and the Analysis component had a significance value of .203, both greater than .05 ($p > .05$). Therefore, the data are normally distributed, and a paired sample t-test was used for data analysis.

However, for Interpretation, Inference, and Explanation, the significance values were .028, <.001, and .002, respectively, which are less than .05 ($p < .05$). Therefore, the data did not meet the assumption of normality and the Wilcoxon signed-rank test was used for data analysis.

Table 3 Comparison of Mean Scores (\bar{X}), Standard Deviations (S.D.), and t-test Statistics for Students' Critical Thinking Skills Before and After Instruction in the Evaluation and Analysis Components Using Paired Sample t-test

Critical Thinking Skills		(N)	\bar{X}	S.D.	t-test	One-Sided p (Sig.)
Evaluation	Before	29	2.103	1.345	-2.156	.020*
	After	29	2.655	1.173		
Analysis	Before	29	3.069	1.580	-1.746	.046*
	After	29	3.586	1.701		

*p<.05

From Table 3, it was found \bar{X} of students' critical thinking skills after instruction were higher than before instruction using QFT, with statistically significant differences at the .05 level in the Evaluation and Analysis components.

Table 4 Comparison of Mean Scores (\bar{X}), Standard Deviations (S.D.), and Test Statistics for Students' Critical Thinking Skills before and after Instruction in the Interpretation, Inference, and Explanation Components Using the Wilcoxon Signed-Rank Test

	Interpretation	Inference	Explanation
Z	-1.501	-.214	-1.305
Asymp. Sig. (one-tailed)	.066	.415	.096

From Table 4, it was found that \bar{X} of students' critical thinking skills before and after instruction using QFT did not differ significantly at the .05 level in the Interpretation, Inference, and Explanation components.

Table 5 Comparison of Students' Critical Thinking Skills before and after Instruction Using QFT

		(N)	\bar{X}	S.D.	One-Sided p (Sig.)
Critical Thinking Skills	Before	29	13.310	3.083	.007*
	After	29	15.138	3.925	

From Table 5, it was found that \bar{X} of students' critical thinking skills after instruction were higher than before instruction using QFT, with the difference being statistically significant at the .05 level.

Based on the analysis of the effects of instruction using QFT on students' critical thinking skills, the researcher discusses the findings as follows:

1) Interpretation skill (*No significant changes after implemented by QFT*)

According to Facione (1990), interpretation is the ability to identify main ideas or essential points from experiences, texts, or situations. While the steps of QFT: Presenting a QFocus (e.g., a situation or chemical experiment related to "Chemical reactions and materials" content), which requires students identify the key points of QFocus as formulating questions.

However, the development of interpretation skills was not observed. The lack can be explained by the context of the research: the participants had already studied the content on "Chemical reactions and materials" before engaging in QFT activities. For instances, in Activity 1, "Rusting of Iron," students were supposed to know that "Rust is formed by a reaction between iron, water, and oxygen, producing a reddish-brown rust, and that it can be prevented by coating or painting". Therefore, in this activity, we aimed to expand this knowledge (by designing QFocus) to distinguish between wet rusting (electron transfer between Fe, H₂O, and O) and dry rusting (loss of electrons at high temperatures).

Nonetheless, during the key point identification step, many students **lacked foundational knowledge** about rusting, as shown in the question recording. Common questions included: “*What is rust?, What prevents rust?, Does iron rust because it gets wet?, Why does rust make iron thinner?*”

These findings align with research of Oyama (2017), Otero (2009), and Scardamalia (1992) found that sufficient prior knowledge is necessary to generate higher-order questions. Without this, students tend to produce factual questions (e.g., “*What is...?*”), whereas familiarity with the content encourages complex, curiosity-driven questions.

These basic-level questions appeared repeatedly across all activities of QFT. We, therefore, inferred that the lack of significant developing in “Interpretation skill” is a direct consequence of deficit foundational content due to students were unable to identify and comprehend the more complex, advanced concepts. They spent their time with thinking their missing foundational knowledge through questioning, rather than engaging the Interpretation skill to generate complex and/or higher-order questions. This finding is consistent with Facione (1990) framework, which defined that Critical thinking skills, including Interpretation constitute higher-order thinking skills.

2) Inference skill (*No significant changes after implemented by QFT*)

Inference is defined as the ability to draw logical conclusions and form ideas based on evidence and prior knowledge (Facione, 1990).

The research findings indicated no statistically significant change or difference in students’ Inference skills after QFT implementation. The activity of QFT have structure to prompts students connecting their prior knowledge with new information (QFocus) to form conclusions in questions.

However, this result may be from the insufficient foundational content knowledge (based on the research findings regarding Interpretation skills), which relate the process of linking prior knowledge with new data to drawing conclusion as questions. Furthermore, across all activities, we found that students consistently **posed questions with the factual/basic question structure-which was at the level of “Memory and Comprehension”**. For instance,

“*What is rust? (Activity 1), “(How did bubbles form after soaking metal in acid (Activity 2)” or “How did you know if this substance is an acid or a base? (Activity 3).”*

Those questions indicated that was unable to link prior knowledge with new information at the higher-order thinking level that resulted in difficulty of drawing inferential conclusions or questions. This is consistent with Facione (1990), which stated that Inference skill relies on a sufficient base of prior knowledge.

3) Explanation skill (*No significant changes after implemented by QFT*)

Explanation refers to the ability to present in a cogent and coherent way the results of one’s reasoning (Facione, 1990).

The research findings revealed no statistically significant change or difference in students’ Explanation skills after QFT implementation. The activities of QFT require students to articulate the rationale for their question prioritization (i.e., why their group selected these questions).

However, within the context of this study, the data showed that participants’ self-reflections were generally limited to just a few sentences. Examples of their reasoning included:

“*Because this is the question we think that is easiest to find the answer for.*”

“*We did choose this question because it is the best one able to extend our knowledge.*”

“*We are interested in this question because it is more important than the others; the other questions are least relevant to the situation.*”

Despite we allocated more than 20 minutes for students to think and write down their rationale for question prioritization, **the communication of reasons remained concise and lacked deep elaboration**. For instance, a statement as “We are interested in this question because it is more

important than the others; the other questions are least relevant to the situation” was not followed up with an explanation of how or why those other questions were considered less relevant compared to the chosen one. This lack of detail reflects a limited application of the core Explanation skill, which requires deeper justification.

4) Analysis skill (*Significant changes after implemented by QFT*)

The study found a significant improvement in students’ analysis skills, consistent with Rothstein and Santana (2011), who explained that **the improving questions step of QFT encourages students to classify their own questions into open-ended and closed-ended types, then convert them into the opposite type and consider the advantages and disadvantages of each.** This type of analytical practice aligns with Facione’s (1990) definition of analysis as the ability to identify relationships among data, questions, concepts, explanations, beliefs, judgments, experiences, reasons, or opinions.

For the assessment, we provided a set of factual and false information to them, each question (scientific scenario) required the selection of two information to best support/describe the scientific scenario.

5) Evaluation skill (*Significant changes after implemented by QFT*)

Research findings indicate that students’ evaluation skills demonstrated similarly significant development. This aligns with Rothstein and Santana (2011) stated that the prioritizing questions step of QFT focuses on having students **prioritize questions by analyzing, comparing, and evaluating all questions to ensure they are consistent with the objective.** This corresponds with Facione’s (1990) definition of evaluation as the ability to examine and judge the credibility, reasonableness, or strengths and weaknesses of statements, explanations, descriptions of perceptions, experiences, situations, decisions, beliefs, or opinions.

For the assessment, we presented students with a scientific scenario accompanied by a concluding statement. Students were required to reading critically the scientific scenario and evaluate concluding statement by selecting the most appropriate option from three choices: 1) this conclusion of the scientific scenario is correct; 2) this conclusion requires more information or is insufficient to conclude; or 3) the conclusion of the scientific scenario is incorrect.

REFERENCES

- Boonsathirakul, J., & Kerdsomboon, C. (2023). Synthesis of critical thinking research of basic education level students using meta-analysis in Thailand during 2010 to 2021. *Educational Research and Reviews*, 18(1), 1-8.
- Clark, S. (2017). *Cultivating classroom curiosity: A quasi-experimental, longitudinal study investigating the impact of the question formulation technique on adolescent intellectual curiosity*. Doctoral dissertation, Boston University. OpenBU.
- Clark, S., Harbaugh, A. G., & Seider, S. (2019). Fostering adolescent curiosity through a question brainstorming intervention. *Journal of Adolescence*, 75, 98-112.
- Cummings, K. M. (2020). *A mixed-method case study of the effects of question formulation technique on classroom engagement in a secondary earth science classroom and teachers’ perceptions of this shift*. Doctoral dissertation, St. John’s University.
- Danczak, S. M. (2018). *Development and validation of an instrument to measure undergraduate chemistry students’ critical thinking skills*. Doctoral dissertation, Monash University.
- Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. Research findings and recommendations. Retrieved from <https://eric.ed.gov/?id=ED315423>.
- Kelley-Mudie, S., & Phillips, J. (2016). A better question. *Journal of the American Association of School Librarians*, 44(5), 14-19.

- McDonough, M. (2024). *Large language model*. Encyclopedia Britannica. Retrieved from <https://www.britannica.com/topic/large-language-model>.
- Nagelhout, R. (2024). *Students are using AI already: Here's what they think adults should know*. Harvard Graduate School of Education. Retrieved from <https://www.gse.harvard.edu/ideas/usable-knowledge/24/09/students-are-using-ai-already-heres-what-they-think-adults-should-know>.
- Oyama, Y. (2017). Promoting learners' spontaneous use of effective questioning: Integrating research findings inside and outside of Japan. In *Promoting Spontaneous Use of Learning and Reasoning Strategies* (pp. 31-45). Routledge.
- Otero, J. (2009). *Question generation and anomaly detection in texts*. Routledge.
- Rothstein, D., & Santana, L. (2011). *Make just one change: Teach students to ask their own questions*. Harvard Education Press.
- Scardamalia, M., & Bereiter, C. (1992). Text-based and knowledge-based questioning by children. *Cognition and Instruction*, 9(2), 177-199.
- Surin, S., & Damrongpanit, S. (2024). Developing students' critical thinking: Examining the influence of learning management approaches through meta-analysis and propensity score matching. *European Journal of Educational Research*, 13(3), 1391-1409.
- Technology, M. I. of. (2024). *Critical thinking in the age of AI*. MIT Horizon. Retrieved from <https://horizon.mit.edu/insights/critical-thinking-in-the-age-of-ai>.
- Torres Garibay, C., Kerby, J., & Minigan, A. P. (2020). Implementation of the Question Formulation Technique as a teaching strategy in renewable energy engineering education. In *2020 ASEE Virtual Annual Conference Content Access*.

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